WRD RESOURCE ROOM

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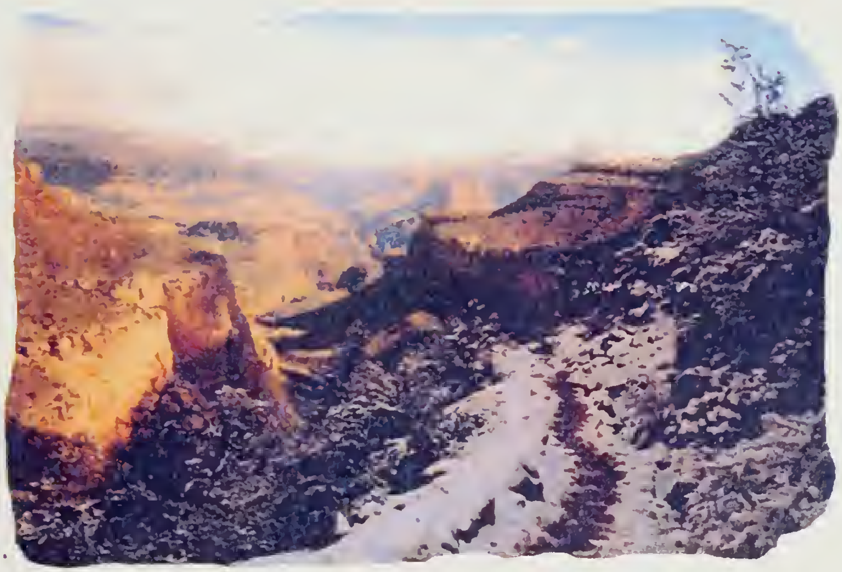
Grand Canyon National Park Water Supply Appraisal Study

Coconino, Mohave, and Yavapai Counties, Arizona



Prepared for

National Park Service
Grand Canyon National Park
Grand Canyon, Arizona

Prepared by

Bureau of Reclamation
Phoenix Area Office, Phoenix, Arizona
Technical Service Center, Denver, Colorado

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Executive Summary

Study Purpose

The Bureau of Reclamation (Reclamation) conducted this appraisal study to develop potentially viable options (alternatives) that would provide a treated water supply to the North and South Rims of Grand Canyon National Park (Park) through the year 2050. The alternatives could be further investigated at a feasibility level of study, with the intent of developing a preferred plan.

Study Need

Estimated water use at the Park in 1999 was 194.1 million gallons, or 596 acre-feet (af) a year. Based on National Park Service (NPS) projections, increased visitor growth would about double this water use by the year 2050 to 1,255 af per year.

Currently, the 12.5-mile-long transcanyon pipeline (TCP) delivers water from Roaring Springs (located about 3,000 feet below the North Rim) to the North Rim by pumping and by gravity flow to Indian Garden, located about 3,000 feet below the South Rim. Water is then pumped from Indian Garden to water storage tanks on the South Rim before it is delivered to developed areas along the South Rim. The South Rim receives about 90 percent of the Park's 5 million annual visitors.

The TCP frequently experiences two types of failures: (1) failures at bends in the pipeline and (2) failures due to washouts during high flow events. The reach of the TCP most sensitive and vulnerable to washouts is located in the "Box" area, a long narrow section of Bright Angel Canyon upstream of Phantom Ranch. About 10 to 12 minor failures occur throughout the TCP each year, mostly in the Box area, and mostly during the spring. Each failure costs about $15,000 and requires 1-4 days to repair. A catastrophic event occurs every 5 to 8 years that temporarily stops the flow of water to Park facilities on the South Rim.

These frequent failures of the TCP make it imperative for the Park to acquire a reliable, long-term water supply to meet existing and future visitor needs.

Study Constraints

The viability of any of the proposed alternatives is contingent on the many constraints that would apply to any opportunity to meet the study need. The Park would need to consider statutory and institutional constraints on any ground-disturbing activities that could affect the natural resources within the study area, including: South Rim seeps and springs; wetlands; caves; Wilderness areas; wildlife habitat and movement; species listed as threatened, endangered, or sensitive; historic buildings, districts, or landscapes; archeological sites; traditional cultural properties.

Alternatives

Reclamation evaluated 11 alternatives. Alternatives 1 through 8 were evaluated at an appraisal-level of detail. Alternatives 9 through 11 were evaluated in concept only, and costs were not estimated.

1. No Action
2. Repair or Replace Portions of the TCP
3. Replace the TCP from Roaring Springs to the Colorado River
4. Construct an Infiltration Gallery and Pumping Plant on Bright Angel Creek to Supply the South Rim and Phantom Ranch
5. Drill a Well from the North Rim to Roaring Springs

6. Use the Colorado River to Supply the South Rim and Continue to Use Roaring Springs to Supply the North Rim
7. Construct a Wellfield Inside the Park
8. Construct a Wellfield Outside the Park
9. Obtain a Dependable Water Supply From Water Providers or Companies
10. Truck or Train Water Into Park
11. Develop Water Conservation Measures

Alternative 1, the No Action Alternative, serves as the basis for comparing the effects of the alternatives. Under alternative 1, the Park would maintain the TCP and continue to use Roaring Springs as the primary water source for the Park. Failing TCP sections would continue to be replaced, as needed.

Under alternative 2, reaches of the TCP on the north side of the Colorado River (in the Box area) would be replaced.

Under alternative 3, a new TCP would be constructed along the existing alignment from Roaring Springs to the Colorado River. Roaring Springs would continue as the primary water source for the North and South Rims.

Under alternative 4, an infiltration gallery would be constructed at Bright Angel Creek, and the water would be conveyed to a pumping plant near the existing sewage treatment plant. The existing TCP from Roaring Springs to Phantom Ranch would be abandoned, but the remainder of the TCP would still supply water to the South Rim. Roaring Springs would continue to supply the North Rim, and a small package water treatment plant would be constructed near the new pumping plant to supply water to Phantom Ranch.

Alternative 5 consists of two sub-alternatives: Well Field (alternative 5A) and Directional Drill Hole (alternative 5B). Under alternative 5A, a well from the North Rim would be constructed to tap the groundwater system feeding Roaring Springs. The existing pump station would no longer be used to pump water up to the North Rim. Roaring Springs would continue to supply Phantom Ranch and the South Rim via the TCP.

Under alternative 5B, a directional drill hole (but not a well) would replace the exposed TCP reach from the Roaring Springs pump station to the North Rim. Alternative 5B includes two options: one option would use the existing overland power line for power (5B1), while the second option would replace the existing overland power line with two power cables placed in the directional drill hole (5B2).

Under alternative 6, another water supply system, such as a pumping plant on the mainstem of the Colorado River, and a pipeline routed through Tanner Canyon (alternative 6A), Cardenas Creek (alternative 6B), or the Comanche site (alternative 6C) would deliver water to the South Rim. Roaring Springs would continue to supply the North Rim. Phantom Ranch would still use the existing TCP to deliver its water and would require a storage tank if TCP failures occur in the future.

Under alternative 7, water would be supplied to the South Rim by constructing a well field and associated conveyance system within the Park boundaries. Water piped from the well field could be stored and used directly (depending on its quality) or treated.

Under alternative 8, NPS would acquire land to the south of the Canyon and construct a well field and associated conveyance system to supply water to the South Rim. Water piped from the wellfield could be stored and used directly (depending on its quality) or treated.

Table 1 summarizes project costs for these eight alternatives.

Table 1—Project costs,
Grand Canyon Water Supply Study

Alternative No.	Construction Cost	Nonconstruction Cost	Total Project Cost	Annual Operation and Maintenance Cost
1	$1,350,000	$351,000	$1,701,001	$189,220
2	$21,000,000	$5,460,000	$26,460,000	$142,944
3	$24,000,000	$6,240,000	$30,240,000	$142.944
4	$14,000,000	$3,640,000	$17,640,000	$1,057,451
5A	$10,500,000	$2,730,000	$13,230,000	$112,467
5B1	$5,200,000	$1,352,000	$6,552,000	$112,467
5B2	$9,400,000	$2,444,000	$11,844,000	$112,467
6A	$23,000,000	$5,980,000	$28,980,000	$1,028,768
6B	$39,000,000	$10,140,000	$49,140,000	$1,002,926
6C	$33,000,000	$8,580,000	$41,580,000	$1,002,926
7	$38,000,000	$9,880,000	$47,880,000	$345,363
8	$50,000,000	$13,000,000	$63,000,000	$537,570

Reclamation evaluated alternatives 9, 10, and 11 in concept only.

Under alternative 9, Roaring Springs would continue as the water source for the North Rim, and water companies or larger communities (Flagstaff, Williams, etc.) located within 100 miles of the Park would supply water to the South Rim. Water would have to be transported to the South Rim by pipeline, truck, or rail.

Under alternative 10, Roaring Springs would continue as the water source for the North Rim, and water would be transported by rail or truck to the South Rim.

Under alternative 11, the Park would implement water conservation measures and maximize reuse of treated effluent for irrigation and the potable water supply at the Park.

Table 2 ranks the 11 alternatives according to eight factors for alternatives that would affect the South Rim and according to six factors for alternatives that would affect the

North Rim only. Each factor was weighted according to its relative importance. Reclamation evaluated each alternative on the basis of how well it met the criteria. As shown in the table, alternative 4, with a score of 195 out of a maximum of 225, had the highest ranking.

Table 3 summarizes the effects of the alternatives on various resources within the study area, including water, wilderness and wildlife, geology, air quality, geology, economics, social environment/environmental justice, cultural resources, Indian trust assets, aesthetics, noise, and transportation.

Consultation and Coordination

Before any of the alternatives could be implemented, the Park would likely be required to conduct consultation under the Endangered Species Act, the Fish and Wildlife Coordination Act, and the Federal Clean Water Act. The Park would also consult with the State Historic Preservation Officer and affected tribes to determine cultural resource survey needs, effects, and mitigation in accordance with Section 106 of National Historic Preservation Act.

Conclusions and Recommendations

In conclusion, alternatives 1 through 5 appear to be viable alternatives, but a number of environmental issues for each would need to be resolved. Alternative 6 would have a significant effect on a designated Wilderness area. Alternatives 7 and 8 could significantly affect springs and seeps both inside and outside the Park.

Based on the potentially viable alternatives identified in this appraisal study, it is recommended to proceed to feasibility study. The focus of the feasibility study would be to investigate the potentially viable alternatives in detail and to develop a preferred plan that would meet the water supply needs of the Grand Canyon National Park through the year 2050. National Environmental Policy Act compliance would be completed in conjunction with the feasibility study.

Table 2.—Ranking of alternatives that affect the South Rim, Grand Canyon National Park Water Supply Study

Factor	Weight	% Weight	Alterna-tive 1	Alterna-tive 2	Alterna-tive 3	Alterna-tive 4	Alterna-tive 6A	Alterna-tive 6B	Alterna-tive 6C	Alterna-tive 7	Alterna-tive 8	Alterna-tive 9	Alterna-ative 10	Alterna tive 11
Restore flow to Bright Angel Creek	3	6.7%	NO 0	NO 0	NO 0	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5
Reduce or eliminate flow augmentation of Garden Creek	3	6.7%	NO 0	NO 0	NO 0	MAYBE 2	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5
Protect prehistoric and historical cultural resources	6	13.3%	YES 5	YES 5	YES 5	YES 5	NO 0	NO 0	NO 0	YES 4	YES 4	YES 5	YES 5	YES 5
Deliver water to Tusayan	2	4.5%	NO 0	NO 0	NO 0	MAYBE 2	MAYBE 2	MAYBE 2	MAYBE 2	MAYBE 2	MAYBE 2	MAYBE 2	MAYBE 2	MAYBE 2
Keep development in TCP corridor and out of proposed wilderness areas	6	13.3%	YES 5	YES 5	YES 5	YES 5	NO 0	NO 0	NO 0	YES 5	YES 5	YES 5	YES 5	YES 5
Protect South Rim aquifer, seeps, and springs	5	11.1%	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	NO 0	MAYBE 3	YES 5	YES 5	YES 5
Capital cost	15	33.3%	$1,701,000 5	$26,460,000 3	$30,240,000 3	$17,640,000 4	$28,980,000 3	$49,140,000 1	$41,580,000 2	$47,880,000 1	$63,000,000 1	$0 1	$0 1	$0 5
Maintenance	5	11.1%	HIGH 1	Moderate 3	LOW 5	LOW 5	LOW 5	LOW 5	LOW 5	LOW 5	LOW 5	LOW 5	LOW 5	LOW 5
Totals (maximum = 225)	45	100.0 %	165	145	155	195	129	99	114	128	143	159	159	159

Table 2.—Ranking criterial for alternatives that affect the North Rim, Grand Canyon National Park Water Supply Study

Factor	Weight	% Weight	Alternative 5A	Alternative 5B1	Alternative 5B2
Capital cost	10	34.4%	$10,500,000 1	$5,200,000 5	$9,400,000 2
Maintenance	7	24.1%	LOW 5	MODERATE 3	LOW 4
Aesthetics	5	17.2%	No Pumping Plant or Pipeline 5	No Pipeline 2	No Power Lines or Pipeline 4
Complexity of system operation	2	7.0%	SIMPLE 5	MODERATE 3	MODERATE 3
Water source reliability	3	10.3%	MODERATE 3	HIGH 5	HIGH 5
Construction difficulty	2	7.0%	HIGH 3	MODERATE 5	HIGH 3
Totals (maximum = 145)	29	100.0%	95	112	95

Table 3.—Potential effects of alternatives on resources, Grand Canyon National Park Water Supply Study

Alternative	Water Resources	Wilderness and wildlife (See table 3A)	Geology	Air Quality	Recreation	Economics	Social Environment/ Environmental Justice	Cultural Resources	ITAs	Aesthetics	Noise	Transportation
No Action Alternative (Alternative 1)	No effect.		No effect.	Federal and State standards would not be exceeded.	Potential significant effect on recreation because water availability constraints would limit recreation activities.	No significant effect.	No effect.	No effect.	No effect.	Minor effect.	No significant effect.	Minor effect.
Repair or Replace Certain Portions of the TCP (Alternative 2)	No effect on water quantity or quality.		No effect.	Air quality would degraded during construction.	Substantial effect because of major construction activity.	No significant effect.	No effect.	Consultation with the SHPO and affected Tribes would occur early in the planning process to determine survey needs, effects, and mitigation in accordance with Section 106 of NHPA.	No effect.	Slightly greater effects than alternative 1.	Possible significant effect.	Moderate effect.
Replace the TCP from Roaring Springs to the Colorado River (Alternative 3)	No effect on water quantity or quality.		No effect.	Air quality would degraded during construction.	Substantial effect because of major construction activity.	Minor beneficial effect.	No effect.	Same as alternative 2.	No effect.	Greatest effect.	Possible significant effect.	Moderate effect.
Construct an Infiltration Gallery and Pumping Plant on Bright Angel Creek to Supply the South Rim and Phantom Ranch (Alternative 4)	Would eliminate current excess unused flows (overflow) at Garden Creek		No effect.	Air quality would degraded during construction.	Minimal effect.	Minor beneficial effect.	No effect.	Same as alternative 2.	No effect.	Long-term beneficial effect.	Significant effect.	Moderate effect.
Drill a Well from the North Rim to Roaring Springs (Alternative 5)	No effect on water quantity or quality.		No effect.	Federal and State standards would not be exceeded.	Minimal effect.	No significant effect.	No effect.	Same as alternative 2.	No effect.	Minor effect.	No significant effect.	Moderate effect.
Use the Colorado River to Supply the South Rim and Continue to Use Roaring Springs to Supply the North Rim (Alternative 6)	No effect on water quantity. Water treatment would be required.		No effect.	Air quality would degraded during construction.	Minimal effect.	Minor beneficial effect.	No effect.	Same as alternative 2.	No effect.	Greatest effect.	Significant effect.	Greatest effect.

Table 3.—Potential effects of alternatives on resources, Grand Canyon National Park Water Supply Study (continued)

Alternative	Water Resources	Biological Resources (See table 3A)	Geology	Air Quality	Recreation	Economics	Social Environment/ Environmental Justice	Cultural Resources	ITAs	Aesthetics	Noise	Transportation
Construct a Wellfield Inside the Park (Alternative 7)	Would affect water quality and quantity at the Park. Could significantly affect springs and seeps inside and outside Park.		No effect.	Air quality would degraded during construction.	Minimal effect.	Minor beneficial effect.	No effect.	Same as alternative 2.	No effect.	Minor effect.	Would generate noise inside Park.	Moderate-to-significant effects.
Construct a Wellfield Outside the Park (Alternative 8)	Same as alternative 8.		No effect.	Air quality would degraded during construction.	Minimal effect.	Minor beneficial effect.	No effect.	Same as alternative 2.	No effect.	Minor effect.	Would generate noise inside and outside Park.	Moderate-to-significant effects.
Obtain a Dependable Water Supply from Water Providers or Companies (Alternative 9)	No effect on water quantity or quality.		No effect.	Federal and State standards would not be exceeded	Minimal effect.	No effect.	No effect.	Same as alternative 2.	No effect.	No effect.	Minimal effect.	No significant effect
Truck or Train Water into Park (Alternative 10)	No effect on water quantity or quality.		No effect.	Federal and State standards would not be exceeded	No effect.	No effect.	No effect.	Same as alternative 2.	No effect.	No effect.	Minimal effect.	No significant effect.
Develop Water Conservation Measures (Alternative 11)	No effect on water quantity or quality.		No effect.	**Federal and State standards would not be exceeded.**	No effect.	No effect.	No effect.	Same as alternative 2.	No effect.	No effect.	Minimal effect.	

Table 3A.—Potential effects of alternatives on wilderness and wildlife, Grand Canyon National Park Water Supply Study

Alternative No.	Wilderness	Section 7	Critical habitat	MSO surveys	SWF surveys	T&E Fish	T&E Plant surveys	Springs and seeps	Sensitive species	Historic buildings, districts, landscapes	Archeological sites	Traditional Cultural Properties	Caves	Wetlands	Habitat loss
1		/													
2		/		/		/									
3		X		X		X	X								
4		X	X		/	X									X
5		X	X	/	/	X			/						X
6	X	X	X	X	X	X	X		X						X
7	/	/		X				X	/						
8		/		/				X	/						
9															
10															
11															

/ = possible X = likely
Sensitive species = desert bighorn sheep, peregrin falcon, bats, goshawk, etc.
MSO = Mexican spotted owl
SWF = Southwestern willow flycatcher
TE - Threatened or endangered species

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CHAPTER 1

Introduction

1.1 Study Purpose, Scope, and Objectives

The Bureau of Reclamation (Reclamation) conducted this appraisal study to develop potentially viable options (alternatives) that would provide a treated water supply to the North and South Rims of Grand Canyon National Park (Park) through the year 2050. The alternatives could be further investigated at a feasibility level of study, with the intent of developing a preferred plan.

An appraisal study is a brief, preliminary investigation to determine the desirability of proceeding to a feasibility study. An appraisal study primarily uses existing data and information to identify plans to meet current and projected needs and problems of the planning area. An appraisal study identifies at least one potential solution that requires Federal involvement or identifies an array of options that have been screened and evaluated to substantiate potential Federal involvement.

A feasibility study is a detailed investigation, specifically authorized by law, to determine the desirability of seeking congressional authority for implementation. A feasibility study requires acquisition of primary data and the participation of public agencies and entities and the general public to develop a preferred plan from a range of alternatives. A feasibility study is usually integrated with compliance under the National Environmental Policy Act (NEPA), Fish and Wildlife Coordination Act, Endangered Species Act, National Historic Preservation Act, and other related environmental and cultural resources laws.

1.2 Study Authority

The Economy Act of 1932 gives Reclamation authority to provide services. The National Park Service's (NPS) authority to manage natural resources in Grand Canyon National Park comes from general authorities in the Organic Act of 1916 (Public Law [P.L.] 64-235), Grand Canyon National Park Establishment Act of 1919 (40 Statute 1175), Grand Canyon National Park General Management Plan (1995), and NPS Management Policies (2001).

The National Park Service Organic Act of 1916, P.L. 64-235, directs the National Park Service to:

> *Conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.*

Grand Canyon National Park was established on February 26, 1919, as a public park for the "benefit and enjoyment of the people" (Grand Canyon National Park Establishment Act, 40 Statute 1175). Grand Canyon National General Management Plan, Park (August 1995) recognizes that the Grand Canyon (Canyon) is a place of national and global significance and states that the Park is to be managed to:

> *Preserve and protect its natural and cultural resources and ecological processes, as well as its scenic, aesthetic, and scientific values. And to provide opportunities for visitors to experience and understand the environmental interrelationships, resources, and values of the Grand Canyon without impairing the resources.*

NPS Management Policies (2001) address aquatic resource policy:

> *The Service will perpetuate surface waters and groundwaters as integral components of park aquatic and terrestrial ecosystems. . .. The Service*

will. . .[t]ake all necessary actions to maintain or restore the quality of surface waters and ground waters within the parks consistent with the Clean Water Act [33 United States Code (USC) 1251 et seq.] and other applicable federal, state, and local laws and regulations.

1.3 Study Area

The study area is generally within the Park, although some alternatives contain components that may lie outside the Park boundaries. See figure 1-1. The Park is within the Colorado Plateau in northwestern Arizona and encompasses 1,218,376 acres. It is bounded on the north by the Kaibab National Forest and the Arizona Strip District of the Bureau of Land Management (BLM), on the east by the Navajo Reservation, on the south by the Kaibab National Forest and Hualapai and Havasupai Reservations, and on the west by the upper reaches of Lake Mead National Recreation Area.

1.4 Public Involvement and Scoping

General public involvement activities were not conducted at this level of planning, but will be conducted during the feasibility study.

1.5 Previous Studies of the Study Area

Previous studies in the study area include the following:

- Final Environmental Impact Statement for Tusayan Growth, Kaibab National Forest

Other water and related resources activities include:

- North Central Arizona Regional Water Study
- Western Navajo pipleline
- Coal Slurry/Mohave Pipeline lease renewal

- Coconino hydrological research
- Glen Canyon Environmental Study and Grand Canyon Research and Monitoring

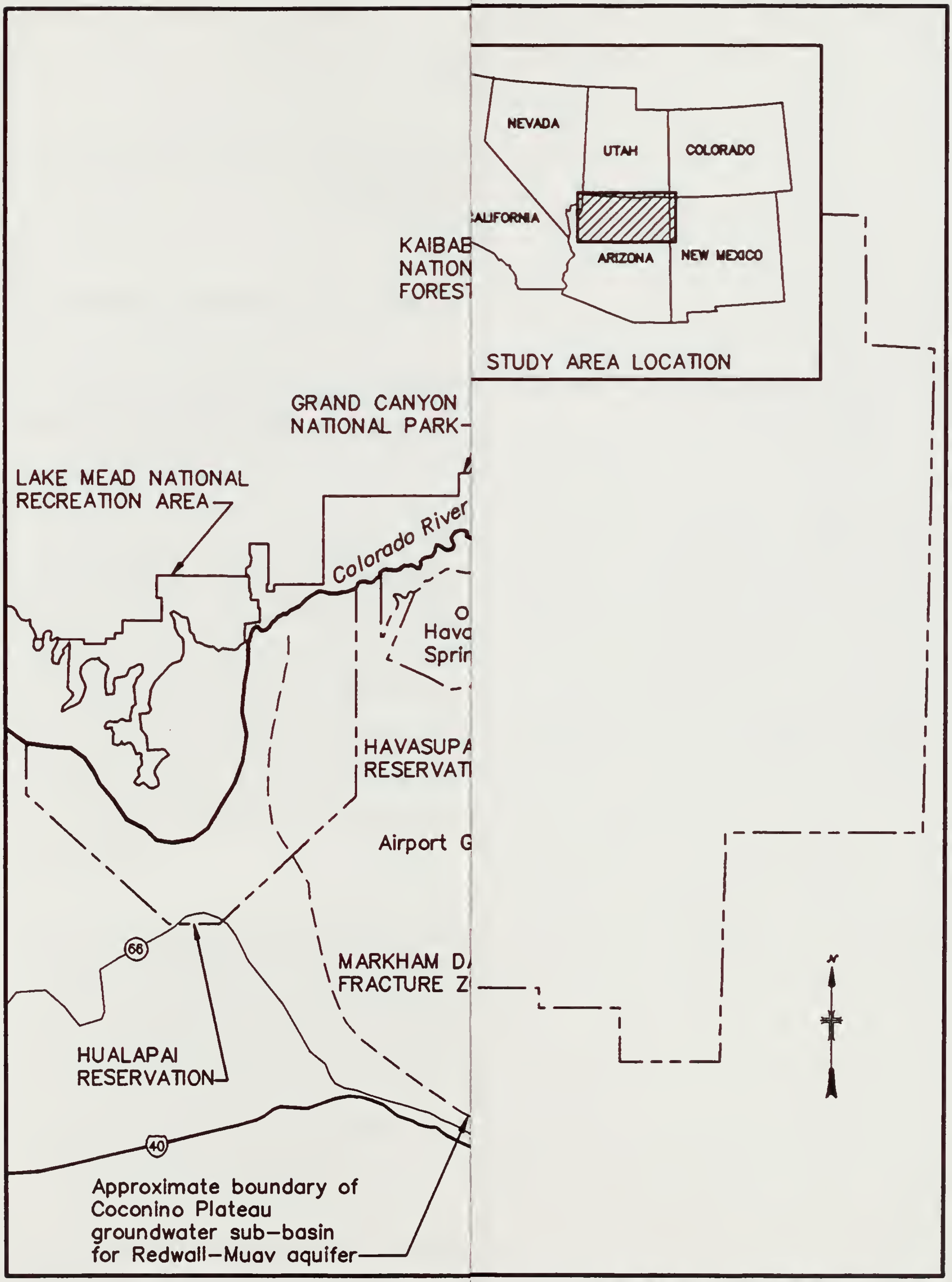

Figure 1-1.- General location map.

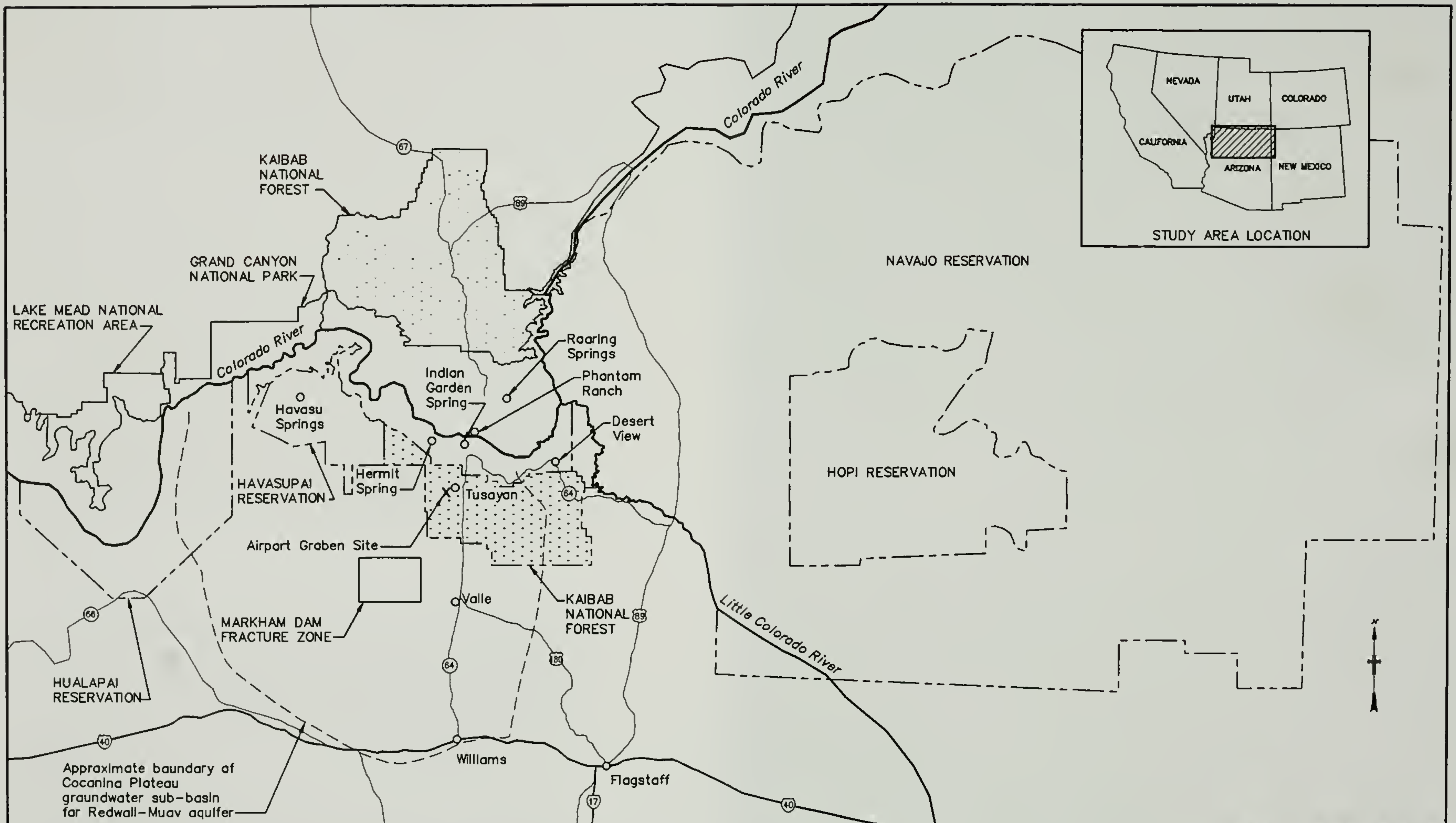

Figure 1-1.- General location map.

CHAPTER 2

Need for Action

This chapter describes the Park's need for a reliable water supply through the year 2050.

Estimated water use at the Park in 1999 was 194.1 million gallons, or 596 acre-feet (af) a year. Based on NPS projections, increased visitor growth would about double this water use by the year 2050 to 1,255 af per year (NPS, 2000).

Currently, the 12.5-mile-long transcanyon pipeline (TCP) delivers water by gravity flow from Roaring Springs, located approximately 3,000 feet below the North Rim in Bright Angel Canyon, to Indian Garden. Indian Garden, a NPS camping area with a pump station, is located along the Bright Angel Trail on the south side of the Colorado River, about 3,000 feet below the South Rim. Water is then pumped from the Indian Garden pump station through a directional bore hole to water storage tanks on the South Rim before it is delivered to developed areas along the South Rim. Nearly 90 percent of the Park's 5 million annual visitors enter at the South Rim; the remaining visitors enter at the North Rim.

The TCP frequently experiences two types of failures: (1) failures at bends in the pipeline and (2) failures due to washouts during high flow events. The reach of the TCP most sensitive and vulnerable to washouts is located in the "Box" area, a long narrow section of Bright Angel Canyon upstream of Phantom Ranch. Here, the TCP is buried beneath the trail carved out of the cliff wall. (Phantom Ranch is a camping area located on the north side of the Colorado River, near the confluence of Bright Angel Creek and the mainstem Colorado River.)

About 10 to 12 minor failures occur throughout the TCP each year, mostly in the Box area during the spring. Each failure costs about $15,000 and requires 1-4 days to repair. A catastrophic event occurs every 5 to 8 years that temporarily stops the flow of water to

Park facilities on the South Rim. Washouts require more than $100,000 to repair. A maintenance plan is being developed now that will probably add about $250,000 to the cost for a full maintenance program, including the replacement of air valves.

These frequent failures of the TCP make it imperative for the Park to acquire a reliable, long-term water supply to meet existing and future visitor needs.

This study examines several alternatives intended to meet these needs, including use of groundwater. Many studies have been commissioned, some controversial, to evaluate the effects of continued development and existing use of groundwater on seeps and springs. The Havasupai Tribe has confidential studies that suggest the continued pumping of the regional aquifer has affected, and will continue to affect, base flow of the Havasupai Spring. Studies are underway (2001 Grand Canyon Park and Arizona Water Protection Fund) to determine the effects on springs in the south wall of the Grand Canyon. Early indications are that groundwater use will adversely affect the seeps and springs emanating from the regional aquifer.

CHAPTER 3

Constraints

This chapter discusses the physical, statutory, social, institutional, and environmental constraints that could limit the capability of the resources to provide a treated water supply to the North and South Rims of the Park through the year 2050.

The viability of any of the alternatives described in chapter 4 is contingent on the many constraints that would apply to any opportunity to meet the study need. NPS would need to consider statutory and institutional constraints on any ground-disturbing activities that could affect the natural resources within the study area, including the following:

South Rim seeps and springs. Participants in the North Central Arizona Water Supply Study, including NPS, have expressed concerns that continued development of groundwater will have long-term adverse effects on seeps and springs in the region.

Wetlands.

Caves.

Wilderness area. In 1993, the NPS called for the immediate designation of 1,109,257 acres and the potential designation of 29,820 acres as Wilderness, for a total of 1,139,077 acres. While not designated, Park policy states that all categories of Wilderness (e.g., potential, proposed study) will be considered and managed as though they were designated Wilderness until legislative action occurs.

Wildlife habitat and movement.

Eight species listed as threatened or endangered.

Species listed as sensitive (including desert bighorn sheep, peregrine falcon, bats, goshawk)

Historic buildings, districts, landscapes; archeological sites; traditional cultural properties. In assessing the potential effects of the alternatives on cultural resources, NPS would coordinate with the nine tribal governments that have cultural and historical affiliations with the Grand Canyon. Each of these tribes maintains a government-to-government relationship with the Park.

CHAPTER 4

Alternatives

This chapter describes alternatives that could provide a treated water supply to the North and South Rims of the Park through the year 2050. Section 4.1 provides background information for the alternatives; section 4.2 describes alternative formulation and engineering methods of analysis. Section 4.3 describes alternatives 1 through 8—the construction alternatives—in detail and alternatives 9, 10, and 11 in concept only. Section 4.4 summarizes cost estimates for alternatives 1 through 8. Table 4-12 (at the end of the chapter) compares the effects of the alternatives on resources in the study area. Appendix 1 includes cost estimate worksheets for alternatives 1 through 8; appendix 2 contains the field report and cathodic protection requirements; and appendix 3 contains the hydraulic design notes.

4.1 Background

This section describes the study area setting, geology, and the Park's existing water supply system.

4.1.1 Setting

The study area is Grand Canyon National Park, located in northern Arizona. See figure 4-1, location map. The Grand Canyon divides the Park into the North Rim and South Rim areas. The South Rim has two entrances: the south entrance at the unincorporated community of Tusayan and the east entrance at Desert View. Other communities in the area include Valle, Williams, and Flagstaff. Phantom Ranch, located in the inner Grand Canyon, is a camping area that includes a NPS housing area and wastewater treatment plant.

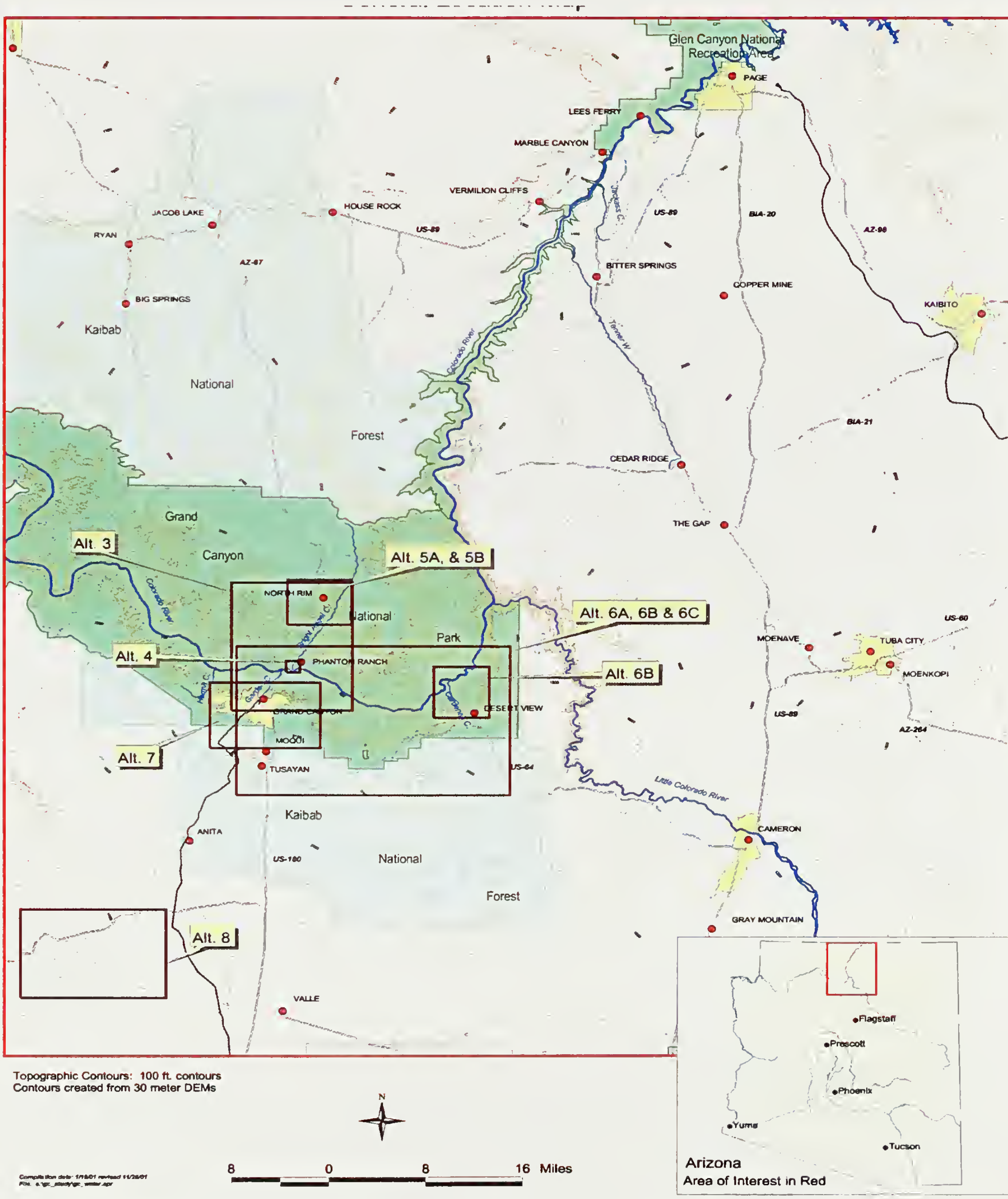

Figure 4-1.—Location of alternatives.

The two primary highways to the South Rim are U.S. 180 and State Route 64. U.S. Highway 180 connects Flagstaff to Valle, where it joins State Route 64 heading north from Williams. From Valle to Tusayan, the highway is jointly named U.S. Highway 180/State Route 64. Access to the North Rim is via State Route 67. See figure 1-1.

4.1.2 Geology

The Grand Canyon lies within the physiographic region known as the Colorado Plateau or Plateau Province. The Canyon's South Rim is considered a part of the Coconino Plateau, and the North Rim is a part of the Kaibab Plateau.

The Canyon consists of 11 Paleozoic Era-aged layers that from top to bottom (youngest to oldest) include the following: Kaibab Formation, Toroweap Formation, Coconino Sandstone, Hermit Shale, Supai Group, Surprise Canyon Formation, Redwall Limestone, Temple Butte Formation, Muav Limestone, Bright Angel Shale, and Tapeats Sandstone. Below the Tapeats Sandstone, Precambrian Era rocks are represented by two groups—one group composed of crystalline metamorphics (such as the Vishnu Schist) and the other of mostly unmetamorphosed sedimentary rocks.

4.1.2.1 Redwall-Muav Aquifer.—The primary water-bearing unit of the Coconino Plateau is the Redwall-Muav aquifer, found in the Redwall, Temple Butte, and Muav Limestones about 3,000 feet below the ground surface. The Redwall-Muav Limestone, which overlies the Bright Angel Shale and underlies the Supai Group, ranges from about 500 to 750 feet thick. The top of the Redwall-Muav Limestone formation is at a lower elevation than the water table, except as it approaches the South Rim, where only the lower half or so of the Redwall-Muav aquifer is saturated.

The Redwall-Muav aquifer is the only regional Coconino Plateau aquifer capable of yielding useable quantities of good quality water to wells. Most water supply wells in the Coconino Plateau tap this aquifer. Deep wells in Williams and Tusayan, for example, are completed in the Redwall-Muav aquifer. The largest South Rim springs, Havasu, Hermit, and Indian Garden Springs, (figure 1-1) also derive their flow from this aquifer. Springs along the lower South Rim support diverse flora and fauna and some known sensitive species.

4.1.2.1.1 Groundwater Recharge and Discharge.—Most of the recharge to the Redwall-Muav aquifer in the Coconino Plateau is via faults that propagate from the ground surface down through the strata. Spring discharge points on the South Rim of the Grand Canyon tend to be found where faults intersect the rim, indicating that the faults act as conduits. For example, the Havasu downwarp leads directly to Havasu Spring, the Hermit Fault leads to Hermit Spring and its associated springs, and the Bright Angel Fault leads to Indian Garden Spring.

Some investigators (Montgomery and Associates, 1996) report that about 98 percent of the reported discharge occurs at Havasu, Hermit, and Indian Garden Springs. The greatest discharge from the aquifer in the Coconino Plateau is thought to be 29,000 gallons per minute (gpm) at Havasu Spring. Groundwater discharge at Hermit Spring and Indian Garden Spring occurs along faults and related fracture systems. The base rate of discharge at each of these springs is 300 gpm.

Sections 4.3.7 and 4.3.8 discuss whether and to what extent new wellfields could affect South Rim springs and seeps.

4.1.2.1.2 Other Seeps and Springs.—A number of other seeps and small springs issue from the Redwall-Muav aquifer within the Grand Canyon. The seasonal nature and unsteady base flow of many of these seeps and small springs—compared to the steady flow of Havasu, Hermit, and Indian Garden Springs—suggest that discharge from these seeps and small springs may result mainly or solely from local near-rim recharge.

Perched water[1] is known to occur at the base of the Coconino Sandstone and throughout the Supai Group in the Coconino Plateau region. From these units, perched water is the source of small springs and seeps which discharge from the south Canyon walls. These small water-bearing zones respond to seasonal droughts and probably would not yield

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[1]Groundwater that occurs in a saturated zone that is higher than the general body of groundwater (in this case, the regional Redwall-Mauv aquifer) and separated from it by an unsaturated zone.

source of small springs and seeps which discharge from the south Canyon walls. These small water-bearing zones respond to seasonal droughts and probably would not yield enough good quality water from wells drilled in any site near the South Rim. Drilling many moderately deep wells is not worthy of consideration as a reliable supply of water.

4.1.2.2 Depth to Water.—Some of the alternatives under consideration consider drilling wells, both inside and outside the Park. To fully penetrate the Redwall-Muav aquifer near the Canyon, wells inside the Park would need to be about 3,000 to 3,400 feet deep because the water table surface drops in elevation from about Tusayan north as the South Rim is approached. Wells outside the Park would need to be about 2,500 feet deep.

Table 4-1 shows that the depth to water in seven existing wells, which fully penetrate the Redwall-Muav aquifer, ranges from about 2,350 to 2,600 feet below ground surface (bgs). Land surface elevations vary from about 6000 feet above mean sea level (amsl) at Valle, about 5500 in the Markham Dam Fracture Zone (MDFZ) area, to 6500 feet amsl at Tusayan and 7000 feet amsl at the South Rim. Montgomery (1996) used static water level readings from these wells to calibrate its steady-state groundwater model.

Table 4-1.—Characteristics of existing wells in the Coconino Plateau that penetrate the Redwall-Muav aquifer

Cadastral location	Located by	Reported yield (gpm), casing diameter (inches)	Water level elevation (feet amsl)	Depth to water (feet bgs)
(A-25-2) 27 aba	Quivero	28, 7	3327, poor quality	2838
(A-26-2) 01 cdd	Valle	41, 8	3550	2500
(A-26-2) 11 ddc	Valle	89, 8	3450	2550
(A-29-3) 20 bcd	Canyon Mine	5, 5½	3971	2534
(A-30-2) 24 bac	Tusayan	65, 8	4200	2400
(A-30-2) 24 caa	Tusayan	80, (as built), 8	4155	2420
(B-32-4) 24 cd	Supai	50, 5½	3310	2370

Note: Modified from table 3 in Tusayan Growth Environmental Impact Statement appendix (USDA, 1999).

Although one or several wells possibly could supply the entire amount of water that the Park needs in the future (for example, if the well screen were to tap a good water-bearing, cave feature), as many as 15 new wells, each 3,000 to 3,400 feet deep, may be required to produce the needed amount. This premise is based on data from deep wells completed in the Redwall-Muav aquifer and assumes that sustained yields of 50 gpm are available from any given new well, while assuming minimal drawdown interference in a wellfield setting.

4.1.2.3 Groundwater Conditions for the North Rim.—As discussed previously, Roaring Springs, located about 3,000 feet below the North Rim, is the primary source of water for both rims. Roaring Springs is a perennial spring that emanates from a solution opening (cave in the hillside) in the Muav Limestone at about elevation 5270. See figure 4-2. The spring occurs above the apex of the intersection of the Roaring Springs and Bright Angel faults (the two canyons are the eroded expressions of these faults). The Roaring Springs cave discharges an average of 3,500 gpm of water but can discharge up to 20,000 gpm during flood events. (However, Huntoon (2000) reports the normal discharge as 9 cubic feet per second (cfs) or 4,039 gpm, or 6,516 af per year.)

4.1.3 Transcanyon Pipeline

Indian Garden Spring, located 3,000 feet below the South Rim, was the original water source for the Canyon's South Rim. However, because this spring could not meet visitor growth needs in the 1960s, the NPS in 1970 completed a 12.5 mile-long transcanyon pipeline from Roaring Springs to the North Rim (figure 4-3).

The TCP delivers water from Roaring Springs to the North Rim by pumping (Roaring Springs pump station) and by gravity flow to Indian Garden, below the South Rim. Water is then pumped from the Indian Garden pump station through a directional bore hole to water storage tanks on the South Rim before it is delivered to developed areas along the South Rim. (A small amount of the flow between Roaring Springs and Indian Garden is siphoned off the TCP to supply Cottonwood and Phantom Ranch.

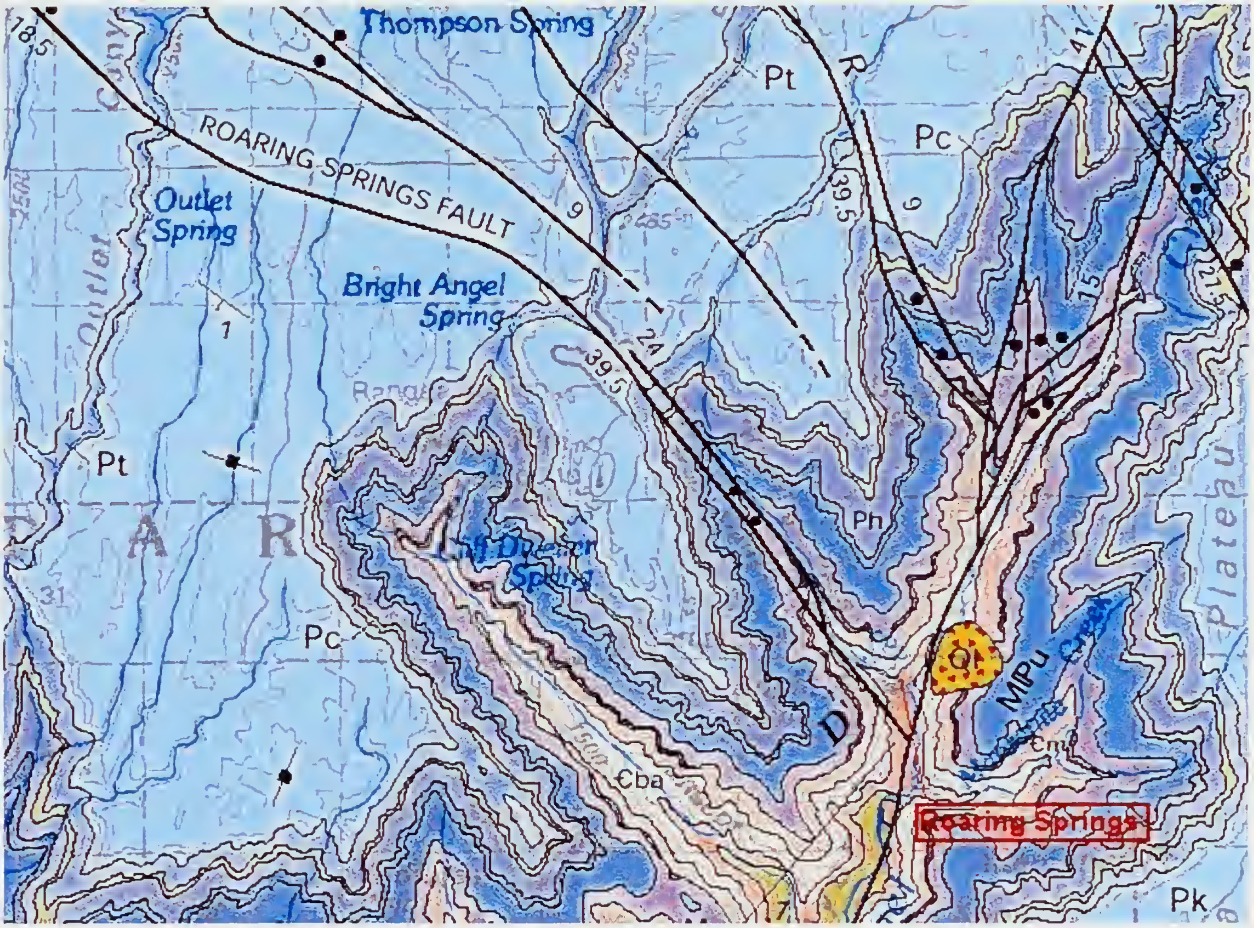


Figure 4-2.–Geologic map of North Rim and Roaring Springs (after Billingsly, 2000).

Cottonwood is a primitive camp area located 2 miles north of Phantom Ranch along the TCP alignment towards the Roaring Spring pump station.)

The TCP delivers 117 gpm to the North Rim when the pump is operating. The TCP delivers 650 to 700 gpm continually (24 hours per day, 7 days a week) between Roaring Springs and Indian Garden, or approximately 360 million gallons per year. The Indian Garden pump station can deliver a minimum flow of 530 gpm and a maximum flow of 640 gpm. The pump runs about 70 percent of the time (off-peak hours) and pumps approximately 200 million gallons to the South Rim annually. The remaining 160 million gallons is diverted to a riparian area (Garden Creek) at Indian Garden when the pump is not operating.

Figure 4-3.—Alternative 1.

The water storage tanks on the South Rim have a capacity of 13 million gallons, a 2-week water supply for the South Rim. The bottom 6 million gallons is held in reserve for fire protection, and the top 7 million gallons is used for the potable water supply. The water is treated (chlorinated) at the springs, North Rim, and South Rim storage tanks. Turbidity and mineral matter are also extracted from the water at the springs, pump sites, and storage tanks, but removal of these particulates is not a major problem.

4.2 Alternative Formulation and Engineering Methods of Analysis

Reclamation held a 2-day brainstorming session with NPS on July 19-21, 2000, at the Park to develop or consider alternatives that would provide a water supply to the Park.

Reclamation evaluated 11 alternatives. Alternatives 1 through 8 were evaluated at an appraisal-level of detail. Alternatives 9 through 11 are discussed in concept only, and costs were not estimated. (See chapter 1 for a definition of appraisal study.)

1. No Action
2. Repair or Replace Portions of the TCP
3. Replace the TCP from Roaring Springs to the Colorado River
4. Construct an Infiltration Gallery and Pumping Plant on Bright Angel Creek to Supply the South Rim and Phantom Ranch
5. Drill a Well from the North Rim to Roaring Springs
6. Use the Colorado River to Supply the South Rim and Continue to Use Roaring Springs to Supply the North Rim
7. Construct a Wellfield Inside the Park
8. Construct a Wellfield Outside the Park
9. Obtain a Dependable Water Supply from Water Providers or Companies
10. Truck or Train Water into Park
11. Develop Water Conservation Measures

11. Develop Water Conservation Measures

To develop the alternatives, Reclamation first examined the following:

- Flow demand (for all alternatives)
- Hydraulics (for all alternatives except 9, 10, and 11)
- Diverting Colorado River water (alternative 6)
- Directional drilling (alternatives 5A, 5B, 6B, and 6C)

4.2.1 Flow Demand

The Park's current water demand is 596 af a year (NPS, 2000). Reclamation used a peaking factor of 1.3 to derive the maximum day volume of 3.41 af. The peaking factor is based on information derived from *Water Delivery System Analysis, Appraisal Level Peer Review Study of the ADWR Phase 1, North Central Arizona Water Supply Study* (Reclamation, 2000a). Assuming pumping occurs 20 out of 24 hours on the maximum day, the required design flow is 1.72 cfs. Current maximum flow rate for the South Rim is 1.56 cfs. The remaining 0.16 cfs of the flow, or 10 percent, goes to the North Rim.

The Park's 2050 water demand was assumed to be 1,255 af a year (NPS, 2000). Using the same factors applied to the current demand, this demand equals a maximum day volume of 5.36 af and maximum flow rate of 2.70 cfs. The amount of flow required at the North Rim was increased from 10 percent to 20 percent of the total flow required in the Park. Therefore, for the South Rim, the maximum day volume is 4.29 af and the maximum flow rate is 2.16 cfs. For the North Rim, the maximum day volume is 1.07 af and the maximum flow rate is 0.54 cfs.

The flow demand of Phantom Ranch was based on information from John Beshears, Park Engineer (Beshears, 2001).

Average day = 10,000 gallons
Peak day = 14,000 gallons

4.2.2 Hydraulics

For alternatives 1, 2, 3, 4, 5, 6, and 8, Reclamation examined the existing TCP to determine the flow characteristics. Appendix 3 includes spreadsheets that show detailed hydraulic analyses. Park personnel provided data indicating that, in the past, the TCP supplied a maximum flow rate of 1.56 cfs to the South Rim. Reclamation determined losses using this flow rate and existing pipeline sizes. Reclamation used a "C" value of 143 as the frictional co-efficient to design a new, larger TCP (alternative 3) and the other pipeline alternatives (alternatives 2, 4, 5, and 6).

Reclamation derived all data for lengths and sizes of pipeline for the existing TCP from the Richard P. Arber Associates Inc. report, *Corrosion Assessment of Transcanyon Pipeline, Grand Canyon National Park* (Arber, 1993).

4.2.3 Colorado River Diversions

This section discusses diverting water from the Colorado River, which is a component of alternative 6.

4.2.3.1 Options for Diverting Colorado River Water.—Three possible options exist for diverting water out of the Colorado River to a pumping plant site: (1) infiltration gallery, (2) river intake, and (3) canal diversion.

4.2.3.1.1 Infiltration Gallery.—An infiltration gallery is essentially a horizontal well or subsurface drain that intercepts underflow in permeable materials or infiltration of surface water. Infiltration galleries are usually constructed to discharge water into a pump sump. The gallery can be placed below or adjacent to the river. The collector pipelines should always be packed with gravel. An infiltration gallery site requires permeable soils. Following are the advantages and disadvantages of an infiltration gallery.

Advantages

1. Intake facility would be buried.
2. No sediment disposal required.
3. Could be installed outside of the river bed.
4. Works with large river elevation fluctuations.

Disadvantages

1. Sands and gravels of sufficient stability to prevent movement of fines may be difficult to locate in the Canyon.
2. May have to construct a gallery with three times capacity to provide required reliability.

4.2.3.1.2 River Intake.—A river intake would consist of a pipeline that extends into the river and has a screening system at the end. The water would then be pumped into a settling basin or clarifier. The screens would be exposed to the elements in the river. Following are the advantages and disadvantages of a river intake.

Advantages

1. Can be installed in rocky areas.
2. Works with large fluctuations in river elevation.
3. Intake facility would be buried or below water line in river.
4. Less sediment to dispose of than with a canal diversion.

Disadvantages

1. Intake is exposed in the river.
2. Requires sediment trap.
3. Settling basin or clarifier is exposed.

4.2.3.1.3 Canal Diversion.—To divert water out of the Colorado River, a canal could be constructed that would divert water from the river into a settling basin, where the water would be pumped after the sediment has dropped out. This method normally requires a diversion dam in areas where the river fluctuates widely to provide a constant head into the canal diversion. Following are the advantages and disadvantages of a canal diversion.

Advantages

1. Simple system that provides reliable water delivery.

Disadvantages

1. Requires sediment disposal or sluicing back to the river.
2. Facilities are exposed.
3. Requires diversion dam.
4. Possibly high costs to removal of sediment may be high.

After evaluating these three options, Reclamation concluded that an infiltration gallery is the best option for use in the Canyon. All sites investigated for Colorado River diversions were evaluated based on an infiltration gallery design.

4.2.3.2 Treating Diverted Colorado River Water.—Under alternative 6, a peak day demand of 4.29 af or 1.4 million gallons per day (MGD) would be diverted from the mainstem of the Colorado River and treated to meet the requirements of the Surface Water Treatment Rule (SWTR) under the Safe Drinking Water Act (SDWA).

The appraisal level design for treating Colorado River water was based on unit capital and operation costs developed for the city of Espanola, New Mexico, in 2000 to evaluate using the Rio Grande River as an alternative water supply (Reclamation, 2000a).

Table 4-2 characterizes the water quality at two locations on the Colorado River: Lees Ferry and Glen Canyon Dam. With total dissolved solids (TDS) and sulfates below or at the secondary maximum contaminant levels of 500 parts per million (ppm) and 250 ppm respectively, water of this quality could be treated using either a ultrafiltration or a conventional system to meet the requirements of the SWTR. To reduce the effects of this turbid water on the treatment system, a streambed infiltration system would be used.

Table 4-2.—Colorado River water quality

Water quality parameter (mg/L)	Colorado River at Lees Ferry	Colorado River at Glen Canyon Dam	SMCL[1]
Average TDS concentration	489	512	500
Average sulfates concentration	205	228	250
Chlorides	41	45	250
Average total suspended solids - TDS	4.1	3.7	None
Maximum TDS	19	17	None
Average alkalinity	128	129	None

[1] Secondary maximum contaminant limits. These levels relate to aesthetic qualities only.
Source: 1990's U.S. Geological Survey data base.

The appraisal level design includes the cost and land requirements for two complete water treatment systems: hollow fiber ultrafiltration and conventional treatment. The estimated appraisal level capital cost of the state-of-the-art, hollow fiber ultrafiltration system with ultraviolet (UV) disinfection, clearwell, residual chlorination, controls, settling ponds, and building is $3.70 per gallon per day capacity, or $5,200,000. The estimated appraisal level annual operation and maintenance (O&M) cost is approximately $0.38 per million gallons per day capacity, or $532,000. Annual O&M costs include chemical usage, power, cost for operators, and annualized costs to replace membranes and pumps every 10 years. Costs to clean and dispose of material collected in the evaporation ponds are not included.

The estimated appraisal level capital cost of the conventional treatment system with UV disinfection, clearwell, residual chlorination, controls, evaporation ponds, sludge storage ponds, and building is $2.60 per gallon per day capacity, or $3,640,000. The estimated annual appraisal level O&M cost is $0.43 per million gallons per day capacity, or $602,000. Annual O&M costs include chemical usage, power, cost for operators, and annualized costs to replace pumps every 10 years. Costs to clean and dispose of material collected in the evaporation ponds and sludge storage ponds are not included.

In both systems, the wastewater generated during membrane cleaning, without citric acid, and sand filter backwash water would be routed to the settling ponds for settling and reuse.

Both systems would treat the water diverted from the Colorado River to a quality that meets current and future SWTR regulations. The main difference between the systems is that the conventional system would produce large amounts of chemical sludge that would need to be stored on site and eventually disposed of as waste. It would also require a larger "footprint."

Following are additional advantages and disadvantages of both systems.

Advantages of the Hollow Fiber Ultrafiltration System

1. Physically removes suspended solids greater than 0.1 microns in diameter, which includes Giardia (5-15 microns), Cryptosporidium (4-6 microns), large virus and large organic molecules, and requires no or minimal chemical addition for coagulation. The system has been demonstrated to remove up to 6 log reduction in Giardia/Cryptosporidium and 2 log reduction in viruses.

2. Is fully automated and easy to operate, and most of the wastewater can be recycled back into the treatment plant.

3. Annual O&M costs are lower than a conventional system because it uses fewer chemicals and requires no or little management of generated sludge.

4. Requires less land above the 100-year flood elevation.

Advantages of a Conventional Treatment System

1. Has lower capital costs and has been demonstrated to physically remove 2.5 logs (99.5%) of Giardia, 2.0 logs (99%) of Cryptosporidium and 2.0 logs (99%) of viruses.

Disadvantages of a Hollow Fiber Ultrafiltration System

1. Has a higher capital cost than a conventional treatment system.
2. Uses more water for continual cleaning or back washing than a conventional system and requires routine cleaning with citric acid. Although the citric acid is naturalized, it requires further treatment and disposal.
3. Hollow fiber modules typically need to be replaced every 10 years.

Disadvantages of a Conventional Treatment System

1. Requires highly skilled operators.
2. Requires the injection of a chemical coagulant.
3. Produces large quantities of sludge.

Table 4-3 provides an overview of the estimated land requirements and per gallon costs for each treatment system. Figures 4-4 and 4-5 show the approximate site layout for each system.

If alternative 6 were selected, additional data, including maps of the potential sites, would be needed to further refine surface water treatment costs and land requirements.

Bench scale testing and pilot testing of each treatment system would be required to verify the ability of each proposed treatment systems to meet the requirements of SWTR and to analyze the production of disinfection byproducts during the conveyance of treated water to various service points within the Grand Canyon.

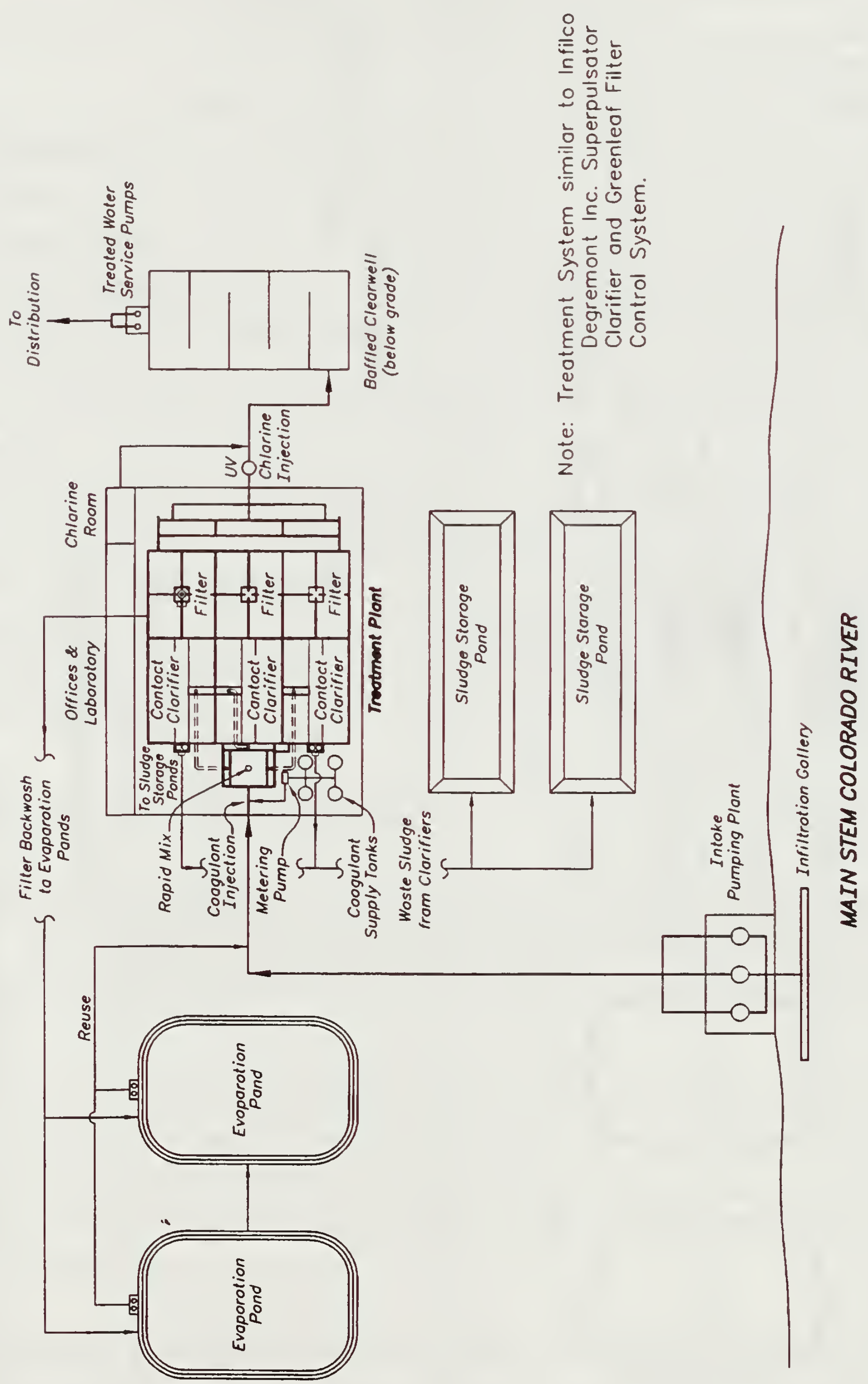


Figure 4-4.—Site layout – conventional treatment plant.

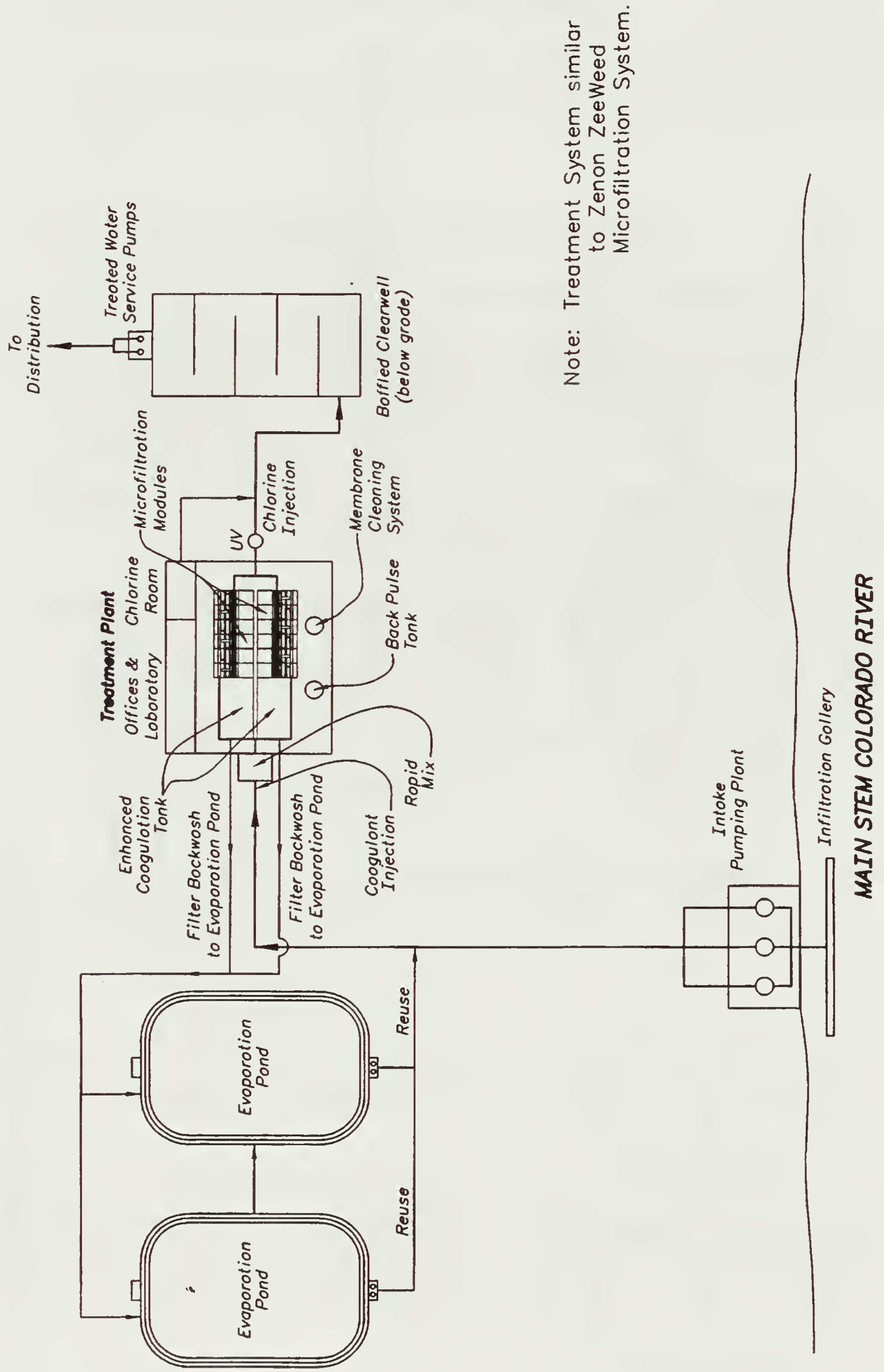


Figure 4-5.—Site layout – microfiltration treatment system.

Table 4-3.—Estimated land requirements for each treatment system (treatment rate of 1.4 MGD)

Feature	Conventional system (acres)	Ultrafiltration system (acres)
Treatment plant	0.11	0.1
Clearwell	0.03	0.03
Evaporation ponds	2.0	2.0
Sludge storage ponds	2.0	not required
Miscellaneous area for roadways, intake structure, etc.	0.5	0.5
Land requirement (acres) above 100-year flood elevation	4.64 say 5	2.63 say 3
Capital cost per gallon of water treated per day	$2.60	$3.70
Annual operations and maintenance costs per gallon of water treated water per day	$0.43	$0.38
Appraisal-level capital cost	$3,640,000	$5,200,000
Appraisal-level annual O&M cost	$602,000	$532,000

Source: Reclamation, 2000a.

4.2.4 Directional Drilling Technology

Reclamation examined directional drilling technology for alternatives 5A, 5B, 6B, and 6C. Current technology for drilling holes up to 12¾ inches in diameter suggests that it may be feasible to drill up to 12,000 feet using technology acquired from drilling oil wells.

However, based on the previous directional drilling at the Park, it seems likely that the hole may have to be drilled using air instead of a fluid because of leakage into the rock. Based on telephone conversations with Jerry Cerkovnik of Baker-Hughes, a horizontal directional drilling contractor, this would limit the practical length of air drilling to around 6,000 feet.

A directional drilled hole at the Park in the 1980s missed the final exit point by 200 feet, but technology advancements should significantly improve the accuracy. Baker-Hughes gave cost guidelines but stated that, without more information, uncertainties still exist. The construction cost estimates assume 200 feet per day could be drilled and assume mobilization/demobilization costs of $100,000 and drilling costs of $30,000 per day. Final design would require the construction records for the hole drilled in the1980s and possibly some exploratory drilling on the North Rim.

4.3 Description of Alternatives

This section describes alternatives 1 through 8 in detail and provides a general description of alternatives 9, 10, and 11.

4.3.1 No Action Alternative (Alternative 1)

The No Action Alternative serves as the basis for comparing the effects of the alternatives. Under the No Action Alternative, NPS would maintain the TCP and continue to use Roaring Springs as the Park's main water source.

The existing TCP could not meet the flow requirements for the year 2050. The 6-inch sections of the pipeline would have to be replaced with 8-inch pipeline to meet this demand.

As discussed in chapter 2, the existing aluminum TCP experiences periodic failures that result in short-term outages that can lead to water restrictions in the Park. The failures are usually of two types: (1) failures at bends in the pipeline and (2) failures due to washouts during high flow events. The reach of the TCP most sensitive and vulnerable to washouts is located in the "Box" area, a long narrow section of Bright Angel Canyon upstream of Phantom Ranch.

About 10 to 12 minor failures occur in the TCP each year, mostly in the Box area during the spring. Each failure costs about $15,000 and requires 1-4 days to repair. A catastrophic event occurs every 5 to 8 years that temporarily stops the flow of water to Park facilities on the South Rim. Washouts require more than $100,000 to repair. A maintenance plan is being developed now that will probably add about $250,000 to the cost for a full maintenance program, including the replacement of air valves.

Under the No Action Alternative, pipeline sections that fail would continue to be replaced as needed.

Reclamation conducted a survey in the early 1990s to determine the past performance of buried water pipelines, which culminated in the report, *Historical Performance of Buried Water Pipelines*, dated September 1994. This report compiled the failure rates for 12 different pipeline types from Reclamation and American Water Works Association (AWWA) water users. Failure rates were calculated using a weighted average age of pipeline to account for older pipelines that were more likely to have experienced more failures. Age for a pipeline was weighted by the feet of pipeline for a given pipeline type. The number of failures was then divided by the weighted average age and length of pipeline to yield failures per mile-year, as shown in the following tabulation:

Pipeline type	Failure rate
Asbestos cement	2.63
Cast iron	5.97
Ductile iron	1.75
Embedded cylinder prestressed concrete	[1]4.9
Lined cylinder prestressed concrete	0.3
Non-cylinder prestressed concrete	[1]48
Polyethylene	15.8
Pretensioned concrete cylinder	0.84
Polyvinyl chloride	2.14
Reinforced concrete	5.3
Reinforced concrete cylinder	0.0
Reinforced plastic mortar	5.82
Steel	3.4
Combined average	4.40

[1] Rates were determined based on projected repairs for Reclamation siphons on the Central Arizona Project.

While the report did not address aluminum pipeline, Reclamation derived a general sense of its expected reliability. Assuming that the 30-year-old TCP has experienced 10 breaks a year for the last 10 years, its failure rate per mile-year is 30.9, or nearly 10 times the combined average for the different pipeline types shown in the tabulation. From this failure analysis, Reclamation concluded that the reach of the TCP on the north side of the Colorado River should be replaced.

Future pipeline breaks and washouts will keep the TCP from being a reliable water source; therefore, sufficient water storage for Phantom Ranch must be addressed. A small storage tank could be constructed to supply water during outages due to line breaks. The tank should be designed for a 5-day supply and should also provide adequate fire protection. The tank could be sized on the maximum day usage of 13,000 gallons, which equates to a 65,000-gallon tank. The tank would be approximately 22 feet high and 22 feet in diameter. Figure 4-6 shows the piping and pumping plant associated with the storage tank.

Reclamation did not complete surveys to determine if the TCP is actively corroding. Appendix 2 includes recommendations for future study of the cathodic protection system.

4.3.1.1 Estimated Costs.—Estimate sheet No. 1 in appendix 1 summarizes the estimated quantities and costs of alternative 1.

4.3.1.2 Conclusions.—Alternative 1 is the least expensive of all alternatives under consideration, but it does not solve the problem of TCP breaks and washouts. The addition of a storage tank at Phantom Ranch would provide some flexibility for future TCP outages. Additionally, alternative 1 is not viable because the 6-inch pipeline would not meet the future water needs, which require an 8-inch pipeline.

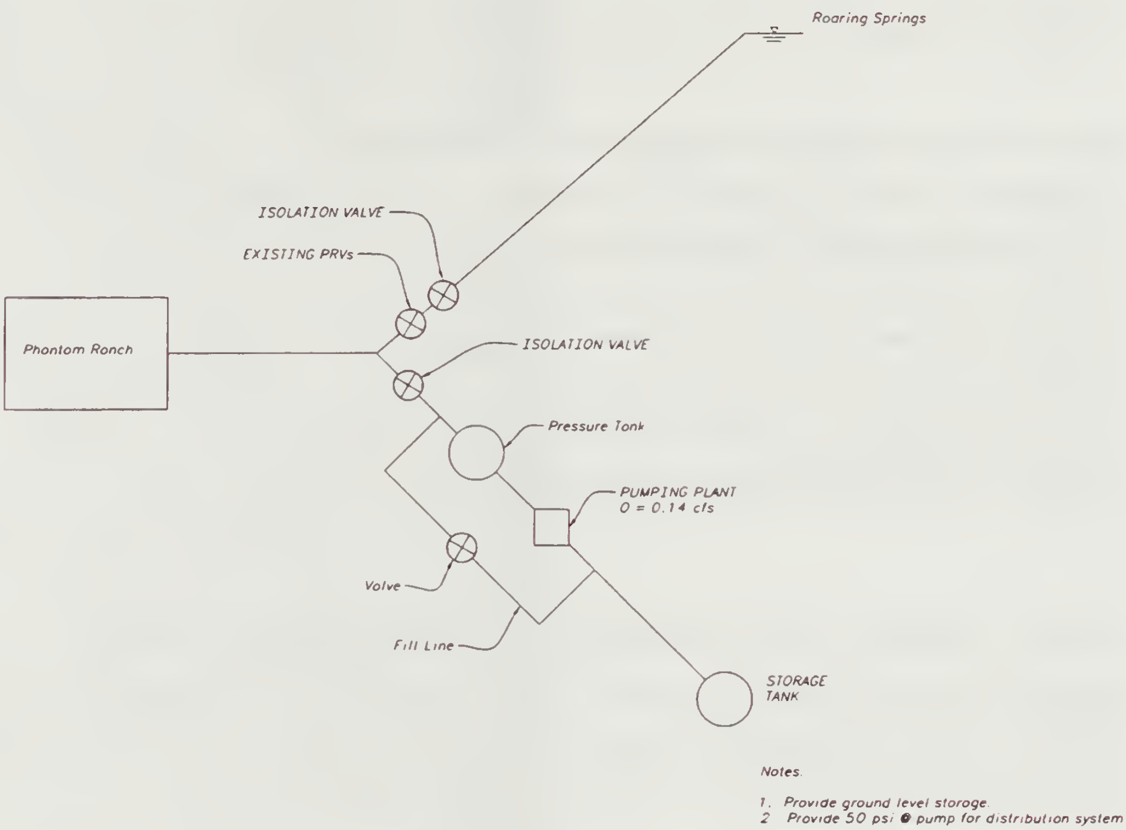


Figure 4-6.—Phantom Ranch schematic.

4.3.2 Repair or Replace Portions of the TCP (Alternative 2)

Under alternative 2, the reach of the TCP on the north side of the Colorado River (in the Box area) would be replaced. This reach can be further broken down into areas where problems actively occur.

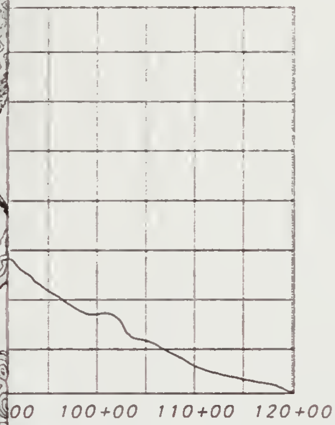
A total of 36,000 feet of existing 6-inch pipeline would be replaced with an 8-inch pipeline to increase capacity. The objective would be to remove sections of the TCP in the Box area first (reach 1), where pipeline breaks are common. The Box area has approximately 10,000 feet of 6-inch pipeline that would need to be replaced with 8-inch pipeline to provide the required flow rate in 2050. At a replacement rate of 1,000 feet a year, a crew would need 10 years to replace this portion of the pipeline. The remainder of the 6-inch pipeline lies in a reach where washouts occur (reach 2). Assuming a 2,000-foot-per-year replacement, this portion could be completed in 13 years. This estimate assumes one crew would replace one section at a time. This alternative is shown in figure 4-7. Section 4.4.1.1 lists durations and construction times.

The TCP would be drained; original pipeline would be removed and replaced with new sections of pipeline, and then the TCP would be refilled. This work would require a 2-week (or more) shutdown and would have to be performed during times of low demand. It would also require an intensive field survey of the trail to determine as close as possible the horizontal and vertical alignment required for the pipeline. The contractor would then manufacture bends to fit the surveyed alignment, which should minimize the amount of field changes required. Excavation and removal of the previous pipeline would be relatively easy because minimal rock excavation would be required.

4.3.2.1 Pipelines.—To develop pipeline cost estimates, Reclamation divided the pipeline pressure classes into five zones: 1,000 feet, 2,000 feet, 3,000 feet, 4,000 feet, and 5,000 feet. Pipeline pressure class equals elevation of the design gradient (static plus 10 percent) minus the centerline elevation of the pipeline.

In-line sectionalizing valves (valves located in the line of the pipe) would be spaced every 3 miles along the pipeline alignment. They would be housed in a corrugated metal pipeline vault-type structure. Blowoff valves would be located at several low points along the alignment to allow a 3-mile reach to be drained and filled in 72 hours. They would be designed for buried service. Air valves would be located at all high points, at either side of the sectionalizing valves, and where required for filling and draining of the pipeline. They also would be designed for buried service.

4.3.2.2 Excavation and Backfill.—The cost estimate for excavation was based on 100-percent rock trenching and a minimum trail width of 3 feet. The trench excavation for a pipeline was based on a depth equal to the pipeline diameter plus 2 feet, vertical sidewalls, and a trench width of 2 feet. See drawing 4-1. A track-mounted vehicle, such as the Vermeer T455, may be required for rock excavation.



L	SELECT MATERIAL
Y./ft.	0.076 C.Y./ft.

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
GRAND CANYON NATIONAL PARK – ARIZONA

PIPELINE

PIPELINE AND DIRECTIONAL DRILL ALIGNMENTS
TANNER (6A), CARDENAS (6B), AND
COMANCHE (6C) ALTERNATIVES
PLAN AND PROFILES

DRAWING 4 – 1

CADD SYSTEM	CADD FILENAME	DATE AND TIME PLOTTED
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SHEET 1 OF 2

PLAN

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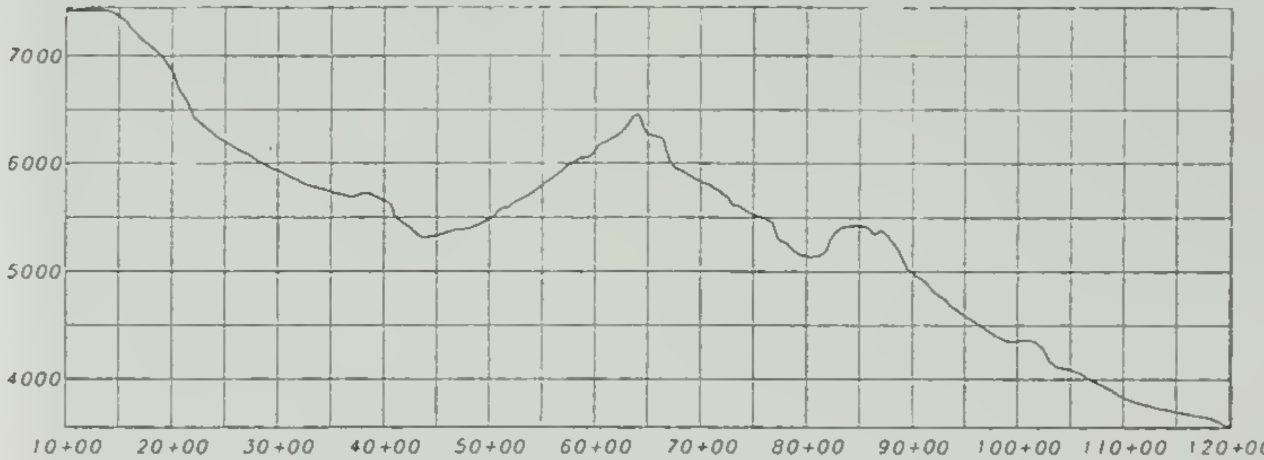
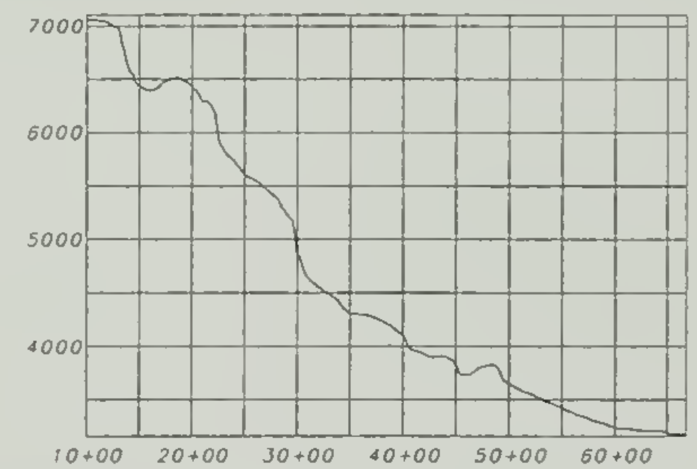


PROFILE
DIRECTIONAL DRILLING ALIGNMENT #1



PROFILE
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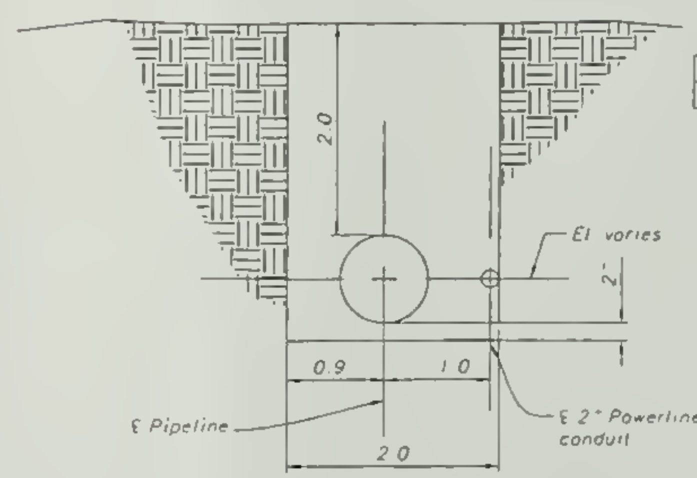

PIPE TRENCH SECTION
(TYPICAL)

PIPE SIZE	EXCAVATION	BACKFILL	SELECT MATERIAL
8" Dia	0.216 C.Y./ft.	0.124 C.Y./ft.	0.076 C.Y./ft.

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PIPELINE
PIPELINE AND DIRECTIONAL DRILL ALIGNMENTS
TANNER (6A), CARDENAS (6B), AND
COMANCHE (6C) ALTERNATIVES
PLAN AND PROFILES

DRAWING 4-1

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DENVER, COLORADO | APRIL 23, 2001 | SHEET 1 OF 2

Figure 4-7.—Alternative 2.

Backfilling the pipeline trenches would require placing a select material around the pipeline to a depth of 3 inches over the top of the pipeline. Reclamation assumed that this material would have to be imported and flown to the site. The remainder of the fill over the top of the pipeline could be trench excavation material.

The appraisal-level cost estimate for the excavation and backfill are as follows:

Pipeline trenching costs

Pipeline installation item	Unit cost ($ per cubic yard)
Excavation (rock trenching)	40
Pipeline bedding (select material)	20
Backfill	5

Washouts would also need to be addressed for areas that are not replaced. A more permanent solution should be considered, and designs completed, for areas where washouts are expected to occur in the future.

4.3.2.3 Estimated Costs.—Estimate sheet No. 2 in appendix 1 summarizes the estimated quantities and costs of alternative 2. The total cost for 13 years of construction is not presented as present worth dollars. Cathodic protection costs were not included. Appendix 2 includes recommendations for future study of the cathodic protection system.

4.3.2.4 Conclusions.—This alternative is feasible but expensive. This alternative would require 10-20 years to complete and could not guarantee that future washouts would not occur.

4.3.3 Replace the TCP from Roaring Springs to Colorado River (Alternative 3)

Under alternative 3, a new TCP would be constructed along the existing alignment from Roaring Springs to the Colorado River (figure 4-8). Roaring Springs would continue to supply the North and South Rims.

Figure 4-8.—Alternative 3.

Replacing this reach of the TCP would require difficult construction in the Box area in Bright Angel Canyon or a possible realignment to higher ground around the Box. Reclamation did not evaluate an exact alignment because it had insufficient information about the topography of the area and what alignments would be satisfactory to the Park. Even with a new alignment, flow from Roaring Springs may still need to be shut off for significant periods of time, which would require the Park to find other water sources during these outages.

Hydrologic studies should be conducted for locations where side creeks flow into Bright Angel Creek. The studies would provide information about permanently solving erosion problems in these areas. The same assumptions for alternative 2 about rock excavation and pipeline design apply to this alternative.

4.3.3.1 Estimated Costs.—Estimate sheet No. 3 in appendix 1 summarizes the estimated quantities and costs for alternative 3. Cathodic protection costs were not included. Appendix 2 includes recommendations for future study of the cathodic protection system.

4.3.3.2 Conclusions.—This alternative would require another water source for the Park during construction. The Bright Angel trail cannot support construction of a parallel pipeline in the narrow canyons without shutting down the original TCP for periods exceeding the 2-week storage capacity at the South Rim.

4.3.4 Construct an Infiltration Gallery and Pumping Plant on Bright Angel Creek to Supply the South Rim and Phantom Ranch (Alternative 4)

Under alternative 4, an infiltration gallery would be constructed at Bright Angel Creek, and the water would be conveyed to a pumping plant near the existing sewage treatment plant. The existing TCP from Roaring Springs to Phantom Ranch would be abandoned, but the remainder of the TCP would still supply water to the South Rim. Roaring Springs would continue to supply the North Rim, and a small package water treatment plant would be constructed near the new pumping plant to supply water to Phantom Ranch. See figure 4-9.

4.3.4.1 Diversion Site.—The diversion site for the infiltration gallery would be located at Bright Angel Creek. The site is in a rocky area with a undetermined depth of alluvium. Reclamation attempted to determine the alluvial thickness, distribution, and lithologic characteristics of the alluvium on which Phantom Ranch and campground are built to determine the feasibility of an infiltration gallery or vertical well in this area. However, a reasonable search effort via telephone contacts and the Internet did not locate any geologic/ geotechnical data, studies, or boring data that might exist in the Phantom Ranch/Bright Angel Canyon and delta bar areas. Specifically, Reclamation accessed NPS records but determined there were no construction or foundation data records available for the Phantom Ranch treatment plant. A staff member from the USGS Flagstaff, Arizona, office has not responded back at the time of this report. The Arizona Geological Survey office in Tucson, Arizona, responded that to their knowledge, no boring data is available for the area, and that there are no borings in their repository.

The required diversion rate of 2 cfs is small in comparison to flow in the creek. The site may be ideal to construct an infiltration gallery without substantial excavation. (Section 4.2.3.1 describes infiltration galleries.) A vertical well may also be an option to the infiltration gallery. Either method would require extensive testing to determine its suitability.

4.3.4.2 Hydraulics.—The advantage of the Bright Angel Creek site is that the original TCP could be used to deliver water to Indian Garden. This reach of the TCP has not experienced many maintenance problems since the addition of a new section of steel pipeline. Between Pipe Creek and Indian Garden, 6- and 8-inch pipeline exists. A storage tank may be required upstream of the Indian Garden pump station. Further study may show that the Indian Garden pumping plant can be eliminated when the new pumping plant is constructed at the bottom of the Canyon.

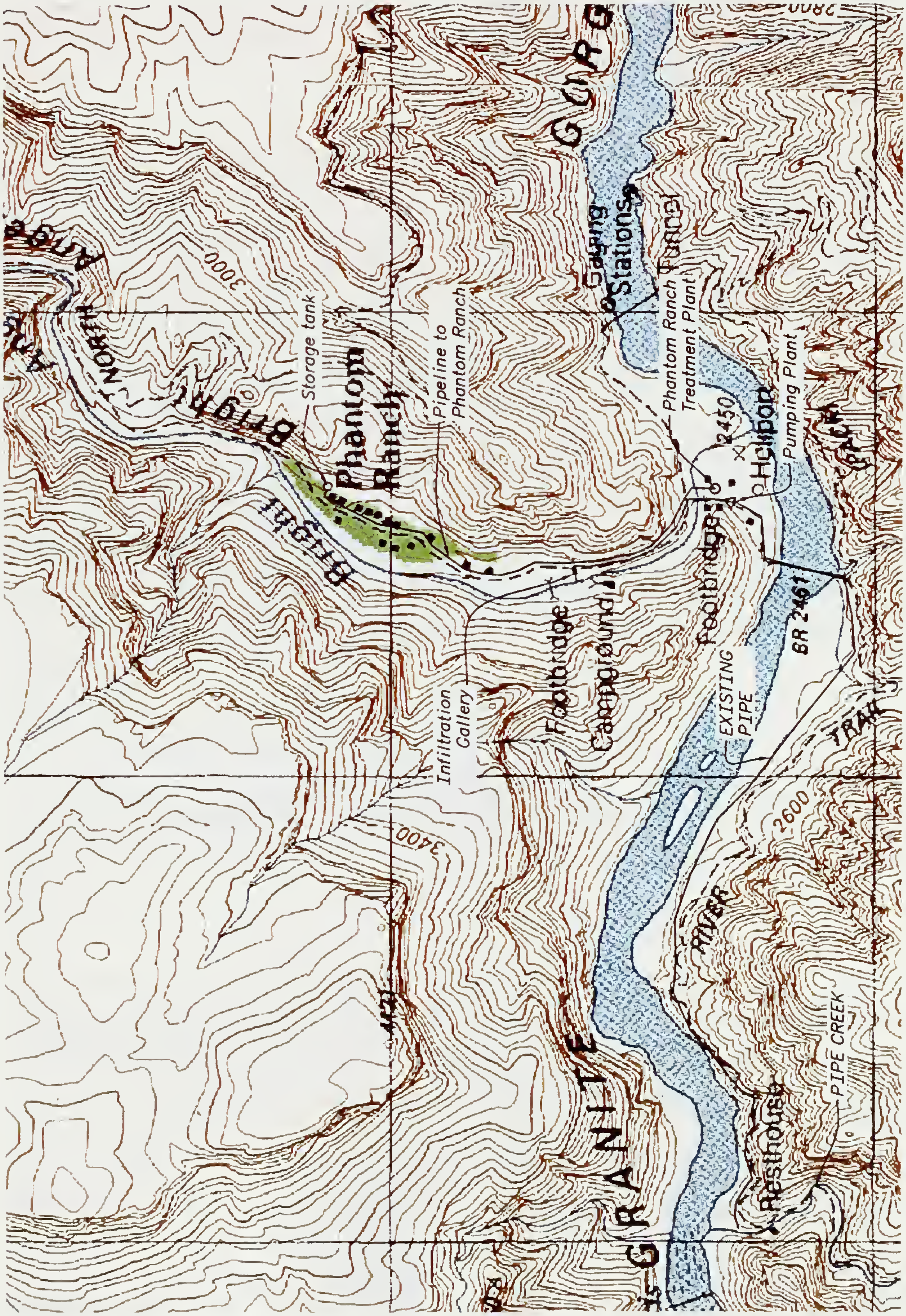

Figure 4-9.—Alternative 4.
January 2002

4.3.4.3 Pumping Plant.—The pump system would be designed as a one pump unit system (Q = 2.16 cfs and H = 1662 feet)[2] with a backup pump. This alternative would require a pump building (about 20 X 20 10 feet) to house the pumps, check valve, isolation valve and electrical cabinets.

4.3.4.4 Surge Control.—Reclamation conducted preliminary water hammer computer runs to determine the effects of pressure upsurges and downsurges on the system during a power failure. On the basis of these runs, an air chamber or other surge control devices would not be needed if a check valve were used.

4.3.4.5 Power.—Reclamation assumed that a power cable could be extended underground from Indian Garden to the Phantom Ranch pumping plant site with 5 kilovolts (kV) of power.

4.3.4.6 Water Treatment.—Water quality and sediment data for the Bright Angel Creek are unavailable. Section 4.2.3.2 provides general information about water treatment costs.

4.3.4.7 Estimated Costs.—Estimate sheet No. 4 in appendix 1 summarizes the estimated quantities and costs of alternative 4. Cathodic protection costs were not included. Appendix 2 includes recommendations for future study of the cathodic protection system.

4.3.4.8 Conclusions.—Alternative 4 is the least costly of all alternatives under consideration and, except for alternative 1, would have the least effect on the environment. As noted above, this alternative would require water treatment. The reliability of the infiltration gallery would still need to be addressed. Infiltration galleries have been successfully used in locations where large amounts of sands and gravels are

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[2]Q = flow in cfs; H = pump head in feet.

available in sufficient depths to provide a natural filtration system without plugging. The Ranney Corporation, which constructs Ranney collectors, has installations around the country that have performed satisfactorily for many years. The site at Phantom Ranch visually appears to have the necessary soils to construct a successful gallery. This alternative warrants further investigation. A vertical well also could possibly be used to obtain the water from this area.

4.3.5 Drill a Well from the North Rim to Roaring Springs (Alternative 5)

This alternative consists of two subalternatives: Well Field (alternative 5A) and Directional Drill Hole (alternative 5B).

4.3.5.1 Well Field (Alternative 5A).—Under alternative 5A, a well and associated conveyance and storage facilities would be constructed to supply water to the North Rim. A well from the North Rim would tap the groundwater system feeding Roaring Springs. Water pumped from the well to the North Rim could then be piped west to the existing storage tanks and used as it has been traditionally, from the existing Roaring Springs north TCP reach. The existing pump station (photo 4-1) would no longer be used to pump water up to the North Rim. A reported 117 gpm, (0.26 cfs or 188 af per year) is delivered to the North Rim. Demand by year 2050 is projected to be about double this amount, or 0.54 cfs, based on the projected demand for the South Rim.

The Park would continue to use Roaring Springs water via gravity flow through the TCP to Phantom Ranch and the pumped portion of Roaring Springs supply (at Indian Garden) to the South Rim.

Reclamation considered one or more vertical wells at the North Rim but eliminated them from consideration for the following reasons:

Photo 4-1.—Roaring Springs pump station.

- No vertical wells exist within the Park's North Rim limits, especially none that extend the more than 3,000 feet needed to tap the Redwall-Muav aquifer. Thus, no existing North Rim wells can provide insight (hard data) about where to drill such a vertical well, while providing a reasonable certainty of encountering sufficient fracture flow volumes of groundwater. Drilling such a deep "dry well" is just too risky. Existing deep wells south of the Canyon provide that type of information and help locate new wells with less uncertainty (e.g., using the Tusayan wells as representative of hydrologic conditions and potential well yields expected from any new wells completed in the Coconino Plateau region).

- Targeting the groundwater flow system that feeds Roaring Springs using directional drilling technology was thought to be much less risky: the location of groundwater is fairly well known in the vicinity of the North Rim (near and at the springs), but the groundwater system farther from the North Rim is less well known. Therefore, more uncertainty exists with a vertical well.

4.3.5.1.1 Potential Well Sites.—Reclamation identified three potential well sites at the North Rim: the Uncle Jim Point, visitor, and water tank sites. Figure 4-10, a plan map of the North Rim well sites, shows the locations of the three site profiles: Uncle Jim Point site profile (figure 4-11), visitor site profile (figure 4-12), and water tank site profile (figure 4-13). (The colored layering in the profiles is inherent in the software and does not represent geologic stratification.) These profiles (at natural scale) show that directional wells are feasible at the Uncle Jim Point and water tank sites but may not be feasible at the visitor site.

From the Uncle Jim Point site, a well could be 1.6 miles long (about 8,500 feet at a 23-degree angle from horizontal) to tap into the Roaring Springs cave (figure 4-11).

A well at the visitor site (figure 4-12) may be 1.3 miles long (about 6,850 feet at a 35- to 40-degree angle from horizontal), or 1,650 feet shorter than a well at Uncle Jim Point, but it may not reach its target because the bore could "daylight" near the bottom of Roaring

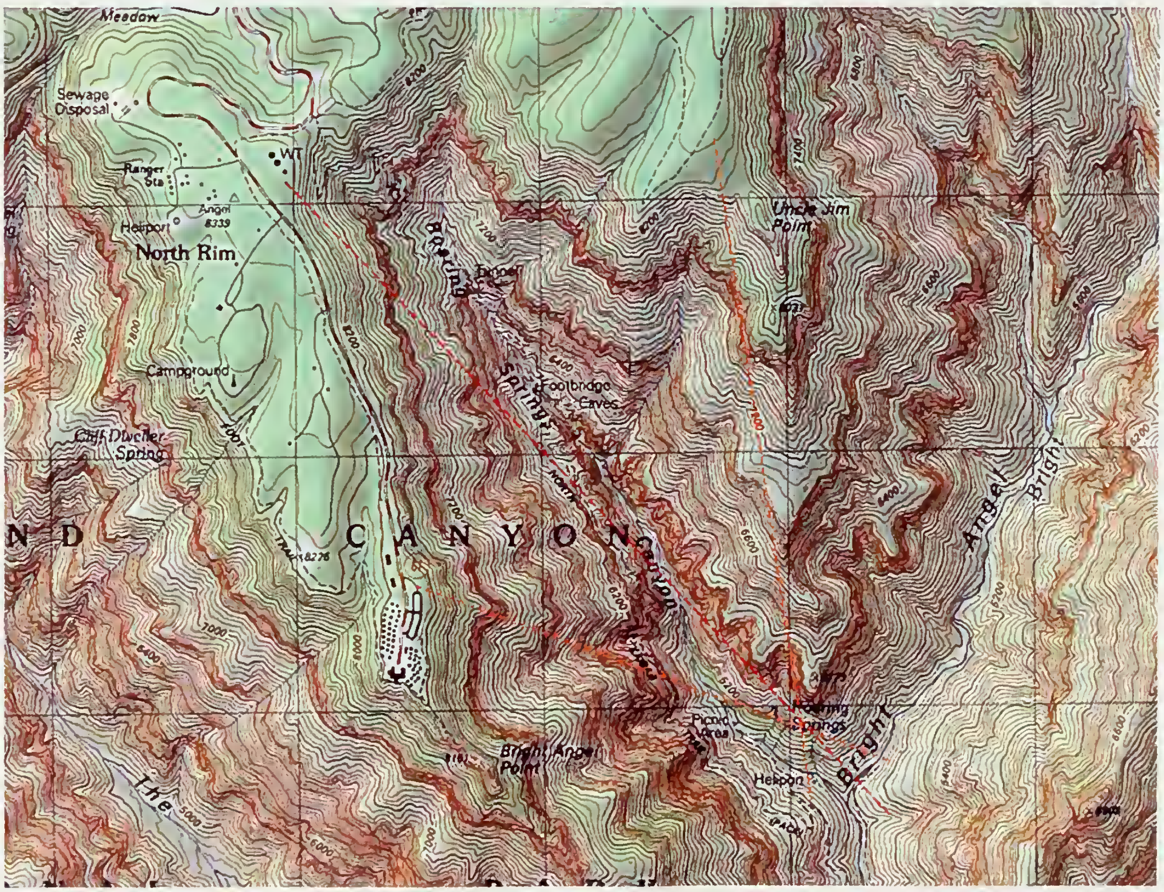


Figure 4-10.—North Rim well locations for profiles.

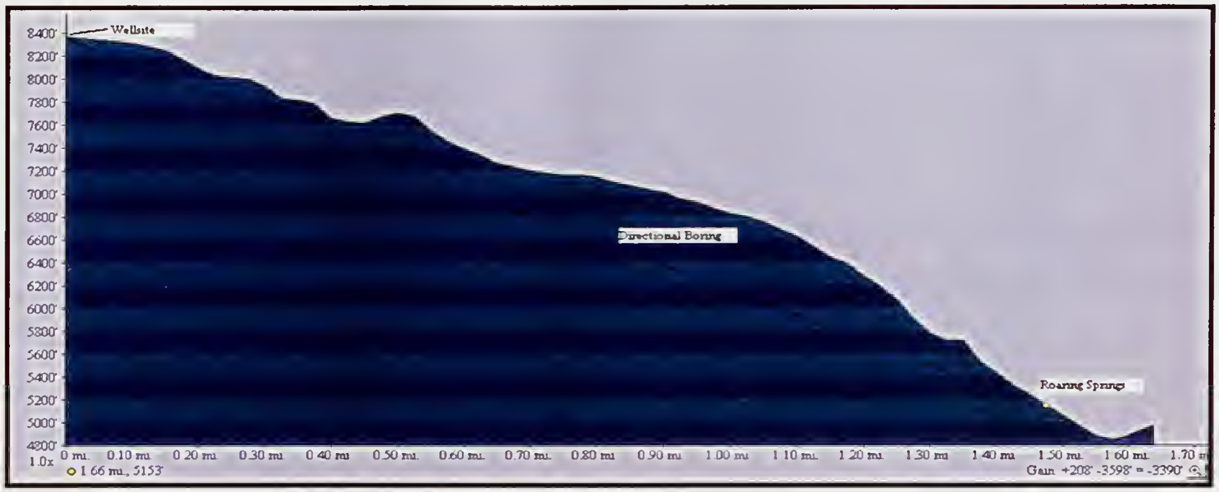


Figure 4-11.—Uncle Jim site profile.

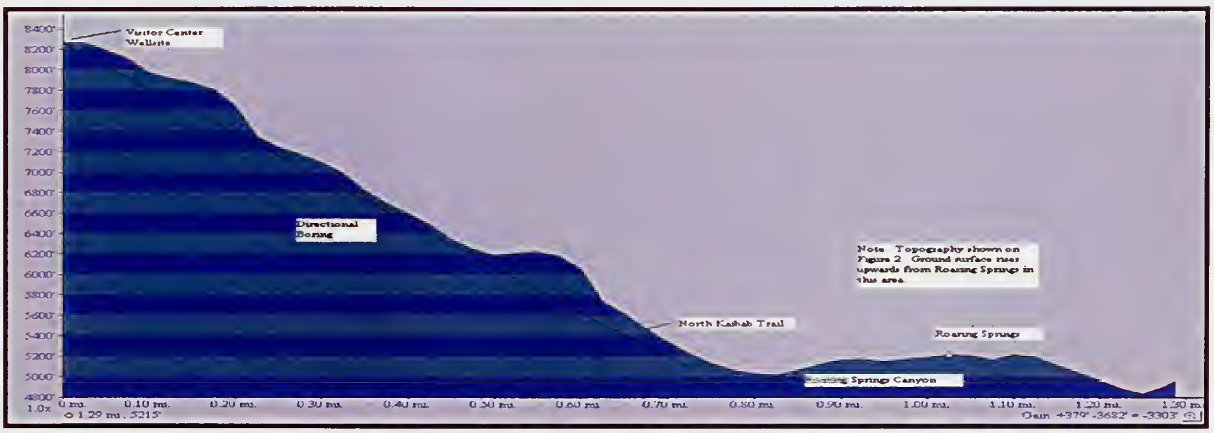


Figure 4-12.—Visitor site profile (lodge above Bright Angel Point).

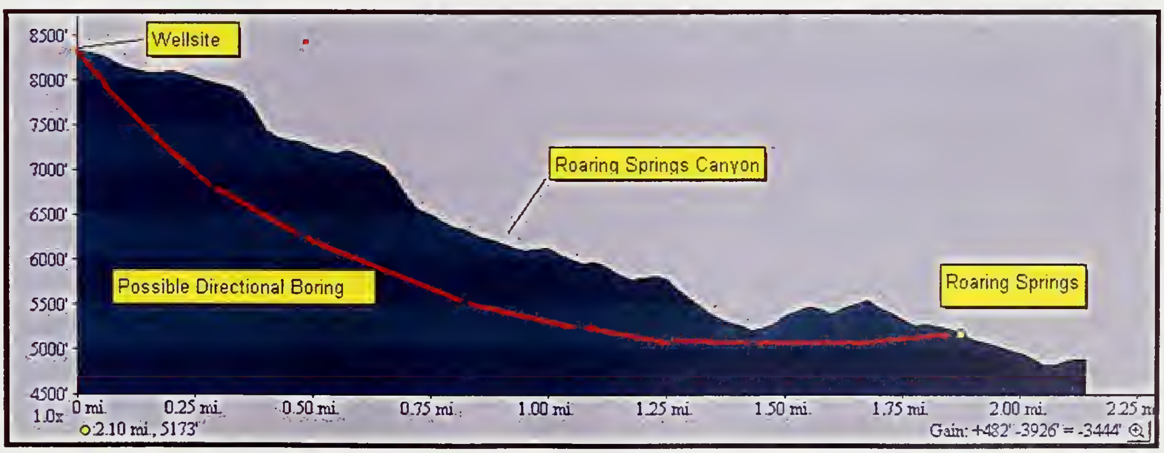


Figure 4-13.—Water tank site profile.

Springs Canyon about 100 feet farther below the spring, and the drillstring bend radius may be too extreme to reach the saturated zone of Roaring Springs, as shown on figure 4-12. Also, as interpreted from figure 4-2 (geologic map), no springs or seeps exist at the same elevation as Roaring Springs on the west side of Roaring Springs Fault, so it is uncertain if groundwater is available on the west side of Roaring Springs Canyon. This may be because the Muav Limestone has been downdropped and placed in fault contact with the Bright Angel Shale, resulting in a barrier to fracture flow from groundwater east of the fault, and the reason for the location of Roaring Springs. Because Roaring Springs emanates from a solution fracture, little or no fracture connection may exist in the Muav Limestone west of the fault. In this case, the fault may exert little, if any, control on groundwater flow. Because of these uncertainties, Reclamation dropped the well at the visitor site from further consideration.

The Uncle Jim Point site is in a remote area of the Park, would require construction of a new road, installation of power cable to the site, and construction of pipeline to the existing water storage tanks. Because of these difficulties, Reclamation eliminated the Uncle Jim Point well site from consideration and completed an estimate only for the water tank site.

The water tank site would have the least effect on the environment. The area (near the ranger station building) is already disturbed, and no pipeline or road building would be required, as it would be for the remote Uncle Jim Point area. One disadvantage of drilling a well at the water tank site is that it would require the longest bore (about 11,300 feet), so drilling costs would be significant. However, no pipeline would be needed, thus saving those costs. Additionally, winter access to the water tank site is much better than for the Uncle Jim Point area.

Regardless of the well site location, any well that taps the water-bearing feeder fractures to Roaring Springs would probably have a relatively short wellscreen, about 100 feet long or less. During pullback installation (in a curvilinear directional hole), the bottom side of the screen would contact the hole wall and, assuming that a smeared zone would remain even after development, some loss of efficiency will result. If the quantity and quality of water-bearing zones (perched zones) delineated while drilling through the Supai Group sediments are adequate, screened sections could be placed to collect that water.

4.3.5.2 Directional Drill Hole (Alternative 5B).—Alternative 5B includes two options: one option would use the existing overland powerline for power (5B1), while the second option would replace the existing overland powerline with two power cables placed in the directional drill hole (5B2). See figure 4-14.

Under alternative 5B, a directional drill hole (but not a well) would replace the exposed TCP segment from the Roaring Springs pump station to the North Rim. (Also see section 4.2.4, "Directional Drilling Technology.") As discussed previously, the current flow of 0.26 cfs requires a 4-inch-diameter pipe. The 2050 demand of 0.54 cfs would require a 4-inch-diameter pipe.

The drill rig site would be located near the observation overlook parking lot at Bright Angel Point. The drilling would extend from elevation 8200 amsl to about 5030 amsl; the hole would be approximately 4,000 feet long. Possible concerns would be changing of the hydrogeology by creating a shorter path for groundwater to an outlet. Roaring Springs and Cliff Dweller Springs are the closest springs. However, Roaring Springs is on the opposite canyon wall from the proposed directional drilling site.

Slurry drilling easily could be used for required drilling from the North Rim to the Roaring Springs pumping plant site. The existing powerline could possibly be included in the borehole for the directional drilling, but, for purposes of this report, the powerline and pumping plant would be unchanged. A short distance of overland pipe would be required to connect to the existing pumping plant.

4.3.5.3 Estimated Costs.—Estimate sheets Nos. 6 and 7 in appendix 1 summarize the estimated quantities and costs for alternatives 5A and 5B. Drilling costs were based on the horizontal directional drilling (HDD) rotary drilling method and costs incurred on the hole drilled on the South Rim in the 1980s.

4.3.5.4 Conclusions.—Alternatives 5A and 5B1 would eliminate the visual effect of the existing exposed steel pipeline. Alternative 5B2 would eliminate the visual effect of

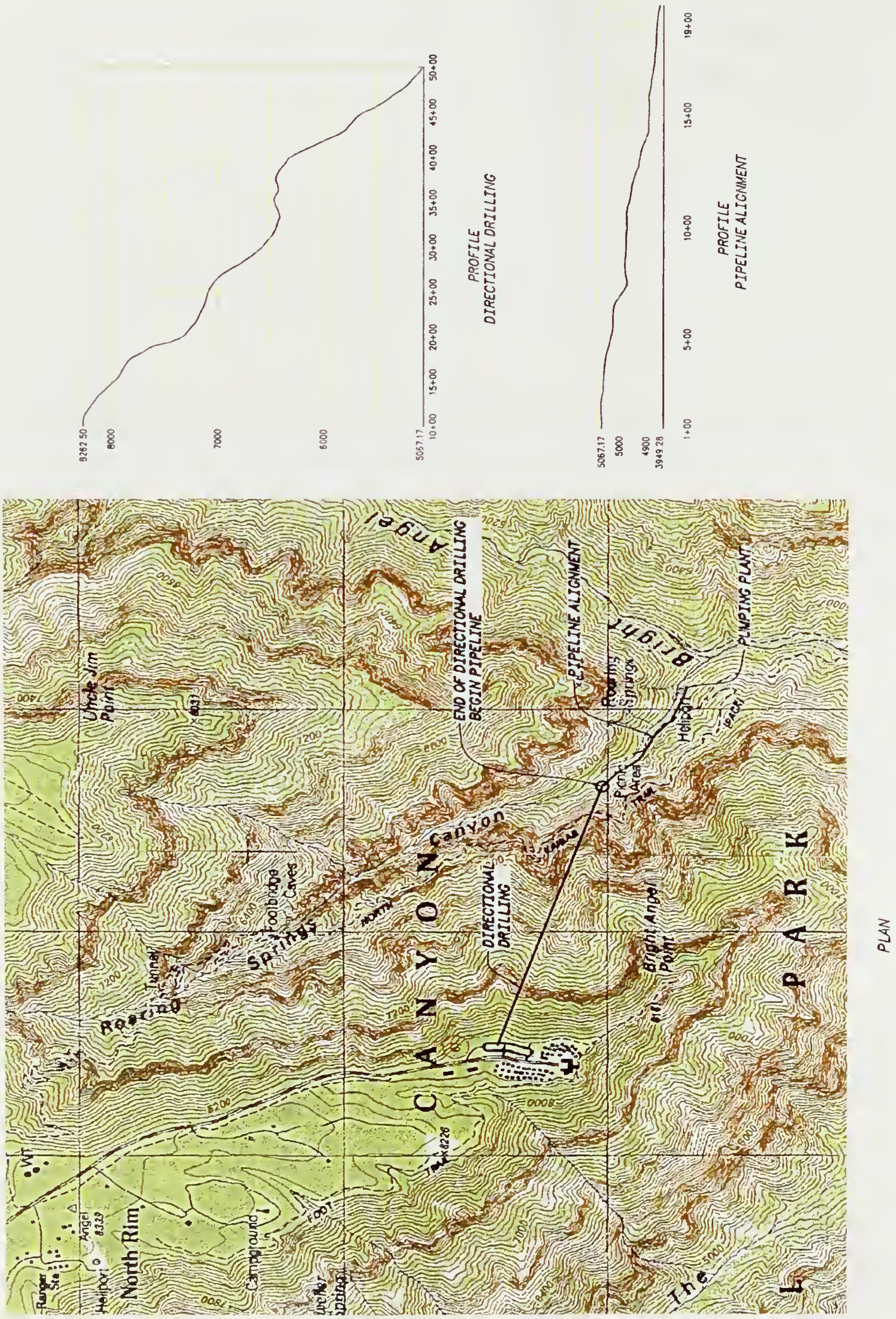


Figure 4-14.—Alternative 5B.

the overhead powerlines as well. Placing the power cable in the directional drilled hole would eliminate cable maintenance in the future, but installing a second backup cable would reduce the chances of a catastrophic failure.

4.3.6 Use the Colorado River to Supply the South Rim and Continue to Use Roaring Springs to Supply the North Rim (Alternative 6)

Under alternative 6, another water supply system, such as a pumping plant on the mainstem of the Colorado River, and a pipeline routed through Tanner Canyon (alternative 6A), Cardenas Creek (alternative 6B), or the Comanche site (alternative 6C) would deliver water to the South Rim. Roaring Springs would continue to supply the North Rim. Phantom Ranch would still use the existing TCP to deliver its water and would require a storage tank if TCP failures occur in the future. The Tanner Canyon and Cardenas Creek sites, which were viewed from a helicopter, seem to provide a large flat area for construction of a diversion structure and pumping plant. See drawings 4-1, 4-2, and 4-3.

4.3.6.1 Tanner Canyon Site (Alternative 6A).—The Tanner Canyon site would be accessed by an overland route following an existing trail. Alternative 6A would require about 31,000 feet of overland pipe.

4.3.6.2 Cardenas Creek Site (Alternative 6B).—The Cardenas Creek site would be accessed by directional drilling (section 4.2.4, "Directional Drilling Technology") and then overland by pipeline through an area that does not follow an existing trail (drawing No. 4-1.) The Cardenas Creek site for the drill rig is about 1 mile southwest of Desert View. The directional drilling would extend for 11,000 feet to the bottom of a ridge at elevation 3800± amsl. The remainder of the pipeline would take an overland route for 10,000 feet to the pumping plant site at elevation 2560 amsl. The rig would require a 300-foot by 300-foot (approximate) staging area.

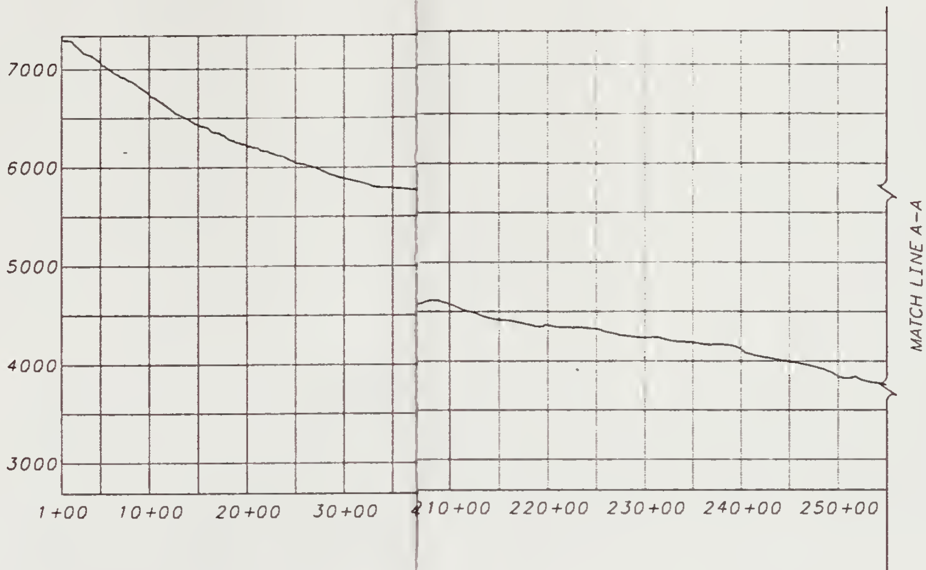
4.3.6.3 Comanche Alignment (Alternative 6C).—Under alternative 6C, a directional hole would be drilled (section 4.2.4, "Directional Drilling Technology") from Comanche Point to a location where the remainder of the route would be completed overland with pipe. The drill rig would be located 2 miles northwest of Desert View at Comanche Point. This alternative would require constructing a road into the site through a potential wilderness site but would reduce the length of directional drilling to about 1 mile. The remaining 4,000 feet of pipe would be overland.

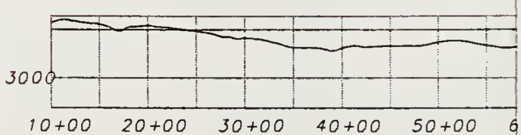
4.3.6.4 Overland Routes.—As discussed previously, the TCP was constructed by "cold bending" aluminum pipe, which has led to frequent maintenance problems. One solution to these problems would be to conduct an intensive field survey of the trail and determine as accurately as possible the actual alignment required. The contractor would then manufacture bends to fit the surveyed alignment, which should minimize the amount of field changes required during construction. The pipeline construction would assume 100-percent rock excavation and a minimum trail width of 3 feet. A track-mounted vehicle, such as the Vermeer T455, may be required for rock excavation.

4.3.6.5 Hydraulics.—Alternatives 6A, 6B, and 6C would require an 8-inch pipe from the pumping plant to the South Rim.

4.3.6.6 Diversion Structures.—Reclamation assumed all subalternatives would require construction of an infiltration gallery for an intake structure. All three subalternatives have sites where a pumping plant could be located above the 100-year flood level of the river and are relatively close to the 5,000-foot level of the Canyon. Drawing No. 4-3 shows a typical layout for the diversion structure.

4.3.6.7 Pumping Plant.—The pump system would be designed for one pump unit ($Q = 2.16$ cfs and $H = 5062$ feet) and a backup pump. A 20- X 20- X 10-foot pump building to house the pumps, check valve, isolation valve and electrical cabinets would be required.





CARDENAS C

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TANNER (6A), CARDENAS (6B), AND
COMANCHE (6C) ALTERNATIVES
PROFILES

DRAWING 4–2

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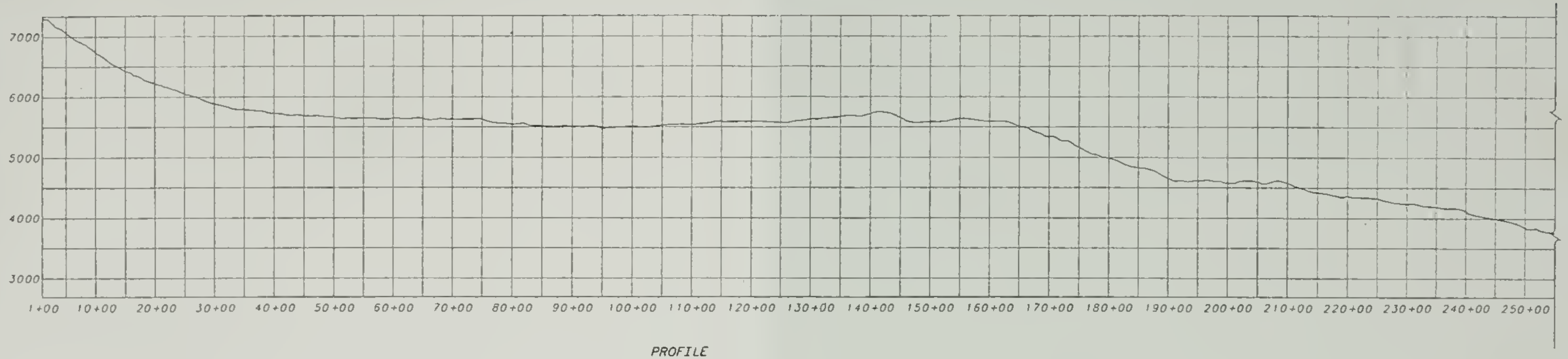
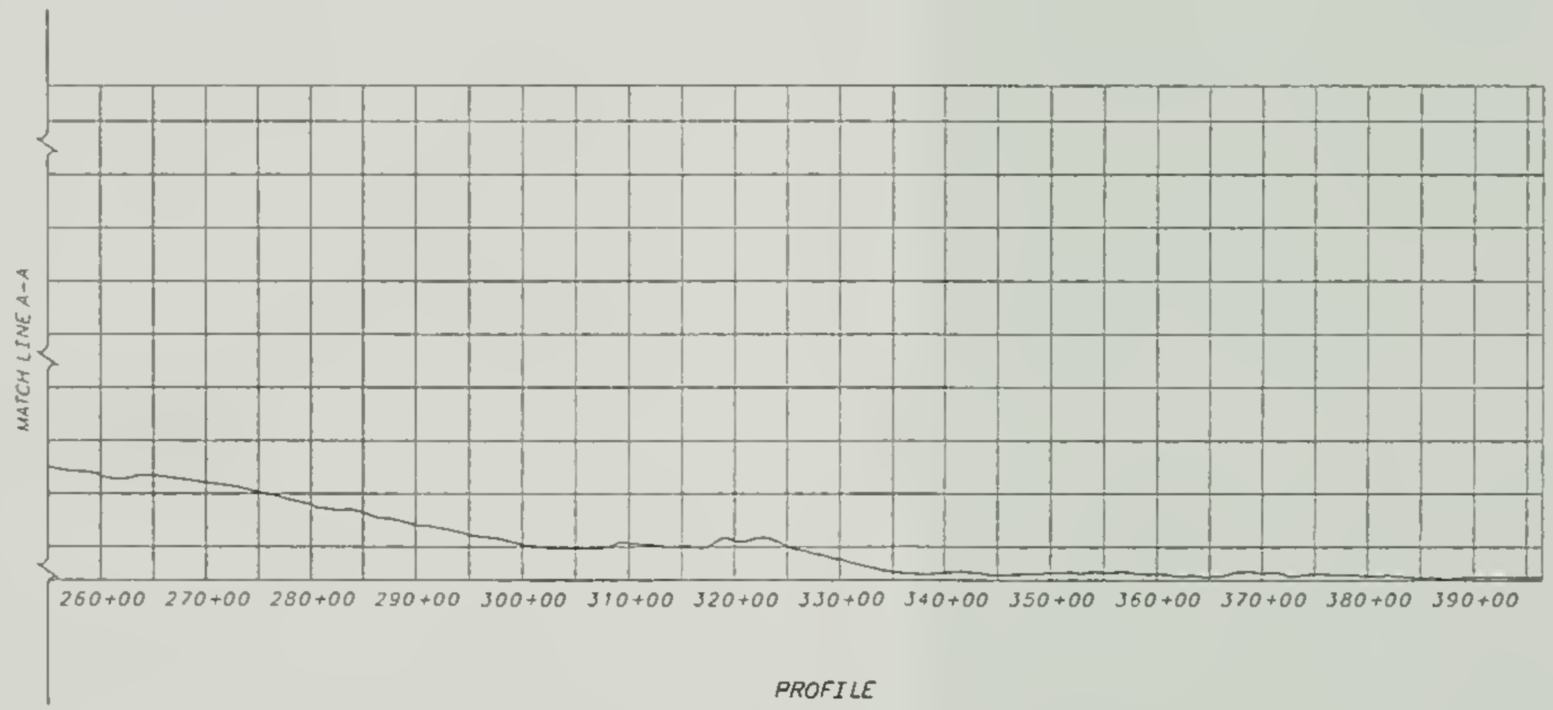


PROFILE
TANNER FOOT TRAIL PIPELINE ALIGNMENT



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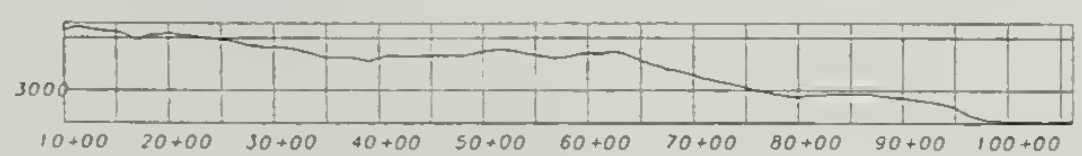
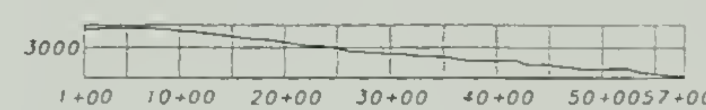


PROFILE
CARDENAS CREEK PIPELINE ALIGNMENT



PROFILE
COMANCHE POINT PIPELINE ALIGNMENT

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PROFILES

DRAWING 4-2

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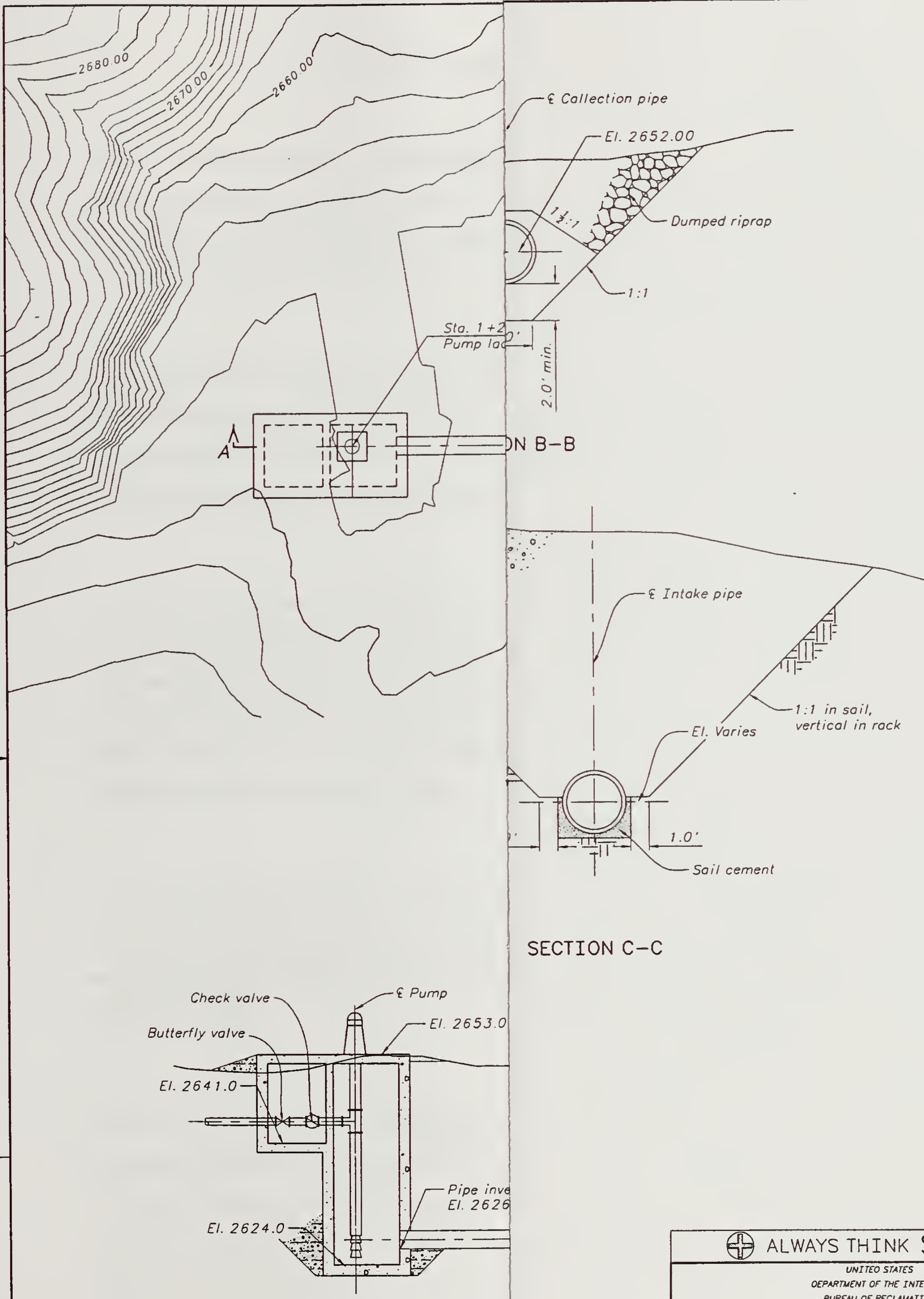

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INFILTRATION GALLERY PUMP STATION
PLAN AND SECTIONS

DRAWING 4–3

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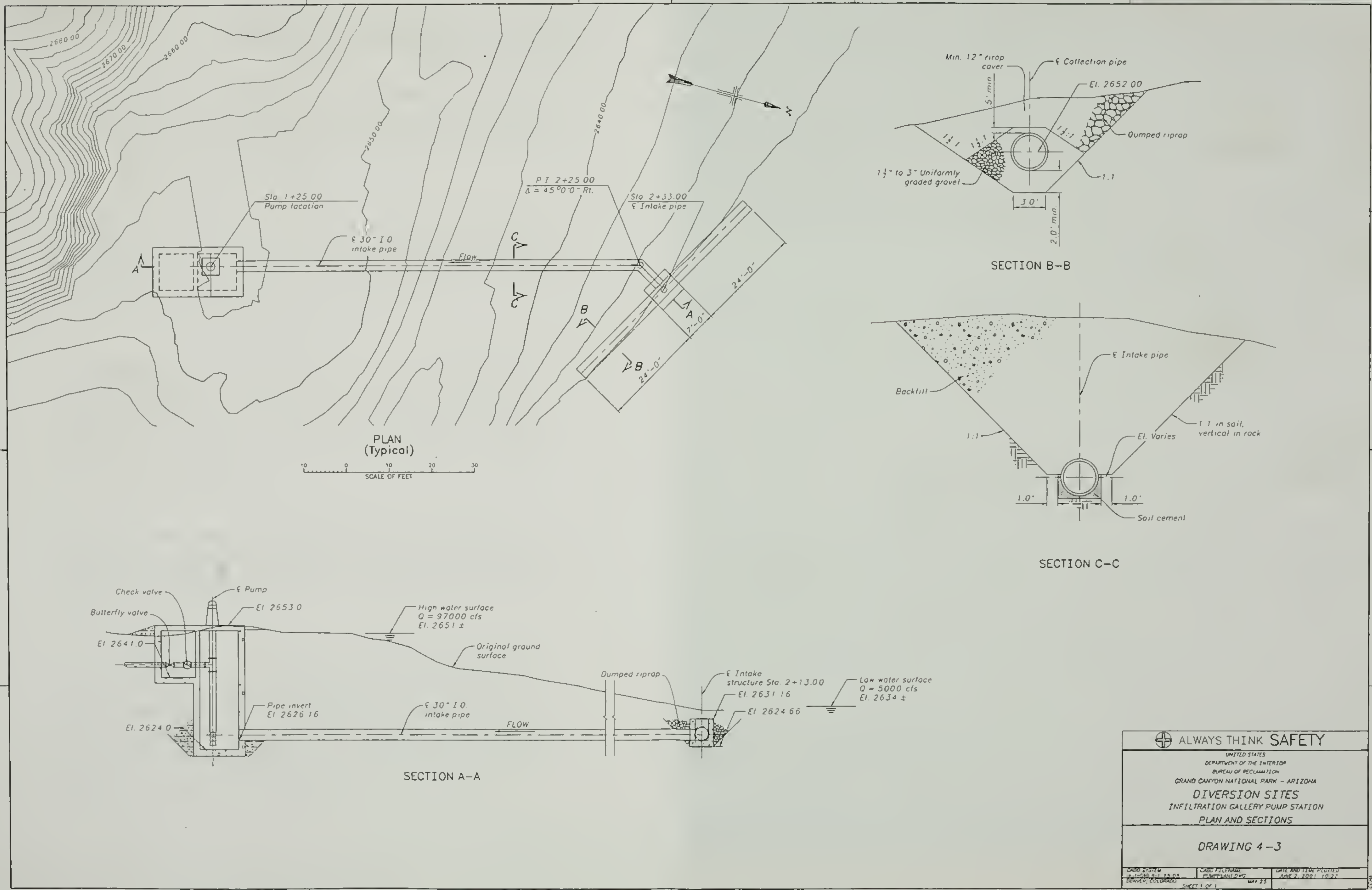
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2670.00
2660.00
2650.00
2640.00
Sta 1+25.00
Pump location
P.I. 2+25.00
Δ = 45°0'0" Rt.
Sta 2+33.00
℄ Intake pipe
℄ 30" I.D.
intake pipe
Flow
24'-0"
7'-0"
PLAN
(Typical)
SCALE OF FEET
Min. 12" riprap cover
℄ Collection pipe
El. 2652.00
5' min.
Dumped riprap
1½" to 3" Uniformly graded gravel
1:1
3.0'
2.0' min.
SECTION B-B
℄ Intake pipe
Backfill
1:1
1:1 in soil, vertical in rock
El. Varies
1.0'
1.0'
Soil cement
SECTION C-C
Check valve
℄ Pump
Butterfly valve
El. 2653.0
El. 2641.0
High water surface
Q = 97000 cfs
El. 2651 ±
Original ground surface
Dumped riprap
℄ Intake structure Sta. 2+13.00
El. 2631.16
El. 2624.66
Low water surface
Q = 5000 cfs
El. 2634 ±
Pipe invert
El. 2626.16
℄ 30" I.D. intake pipe
FLOW
El. 2624.0
SECTION A-A
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PLAN AND SECTIONS
DRAWING 4-3

4.3.6.8 Surge Control.—Reclamation conducted preliminary water hammer computer runs to determine the effects of pressure upsurges and downsurges on the system during a power failure. On the basis of these runs, an air chamber or other surge control devices would not be needed if a check valve were used.

4.3.6.9 Power.—Supplying power to the pumping plant would be another major hurdle for directional drilling. A power cable would most likely require drilling a separate hole. The assumed power was 13.9 kV. For the overland route, the power cable was assumed to be installed adjacent to the pipe in the pipe trench (drawing 4-1).

4.3.6.10 Pipe Types.—Fiberglass or steel pipe could withstand the high pressures (up to 3,500 pounds per square inch) required for the pipe sizes under consideration. The disadvantage of steel pipe is that it needs cathodic protection. (Appendix 2 includes recommendations for future study of the cathodic protection system.) The disadvantage of fiberglass pipe is that it is less durable than steel pipe, but it is lighter and requires no welding because of its threaded joints.

4.3.6.11 Estimated Costs.—Estimate sheets Nos. 8 , 9, and 10 in appendix 1 summarize the estimated quantities and costs for alternative 6. Drilling costs were based on the HDD rotary drilling method and costs incurred on the hole drilled on the South Rim in the 1980s.

4.3.6.12 Conclusions.—Alternatives 6A, 6B, and 6C would substantially affect the environment and would be expensive to construct, operate, and maintain. They would also require water treatment. Directional drilling would eliminate some of the environmental effects, but it could not be used for the entire pipeline. The Comanche site is the most desirable because it would have the least effect inside the Canyon, but it would have the greatest effects at the South Rim.

4.3.7 Construct a Wellfield Inside the Park (Alternative 7)

Under alternative 7, water would be supplied to the South Rim by constructing a wellfield and associated conveyance system within the Park boundaries. Water piped from the wellfield could be stored and used directly (depending on its quality) or treated.

Limited areas exist for establishing a wellfield inside the South Rim that are within a reasonable pipeline distance from the Grand Canyon Village area, the developed area at the South Rim. As shown on figure 4-1, the Park's southern boundary is only ½ to 1 mile south of the South Rim escarpment for most of the Park. Three locations exist where the well-to-rim distance may be adequate and the pipeline distances reasonable. Two are on either side of U.S. Highway 180, and the third is near Desert View. (See section 4.3.7.2, "Potential Wellfield Sites Within the Park.") The distance from a given wellhead to the South Rim village is relatively short (particularly compared to distances for alternative 8).For all sites, a pipeline would follow along the East Rim Drive, State Route 64. This distance could be as much as 20 miles from the farthest site (Desert View) or as short as 5 miles for the site west of U.S. Highway 180.

Pumping groundwater from the regional, confined Redwall-Muav aquifer may, in a relatively short time, reduce flows from springs along the lower South Rim. As discussed previously, these springs support diverse flora and fauna and some known sensitive species. Drilling and developing a well or wellfield within the Park would yield less water from the Redwall-Muav aquifer and decrease South Rim springflow even more than a wellfield outside the Park, such as one at Tusayan. Pumping the needed amount (750 gpm) from a new wellfield inside the Park may alter the pumping equilibrium that has developed for the Tusayan wells since 1989. In other words, the new wells could and probably would change the current equilibrium conditions in the Redwall-Muav aquifer (i.e., the existing groundwater divide), alter the flow gradient to the springs (thus, spring discharge), and take water that otherwise would be available for the Tusayan wells.

The Tusayan Growth Environmental Impact Statement (EIS) (U.S. Department of Agriculture [USDA], 1999) concluded that any water pumped in the Coconino Plateau region would make less water available to support (South Rim) springflow. The extent of the effect and when it would occur is not well understood, although predictions have been made using groundwater modeling and spring capture zone analysis by

Montgomery (1996), Northern Arizona University (Wilson, 2000), and visual observations after precipitation. Figure 8 in the Tusayan Growth EIS appendix shows that the effects of pumping 300 gpm for 50 to more than 100 years, from either Valle or Airport Graben, would decrease the discharge from Indian Garden and Hermit Springs by about 8 to 15 percent, respectively. Pumping at Valle would decrease discharge from these springs and Havasu Spring by 3 percent or less. Montgomery estimated that current pumping reduces discharge from the springs about 2 percent (Coconino Plateau Hydrology Workshop, 2000).

Table 4-4 summarizes the predicted reduction in discharge from major springs from pumping at Valle and Tusayan (Airport Graben).

Table 4-4.—Predicted springflow reduction from pumping at Valle and Tusayan

Pumping center	Pump rate (gpm)	Duration (years)	Major spring	Predicted effects on flows	At 500 gpm for 50 Years
Valle	300	50 to 500	Indian Garden	2 to 3 % less	3 % less
Valle	300	50 to 500	Hermit	1 to 2% less	2% less
Valle	300	50 to 500	Havasu	0.7 to 1% less	1.1% less
Tusayan	300	50 to 500	Indian Garden	14.5 to 15.5% less	23.5% less
Tusayan	300	50 to 500	Hermit	8 to 9% less	13.5% less
Tusayan	300	50 to 500	Havasu	0.5 to 0.8% less	0.9% less

Note: Modified from figures 8 and 9 in the Tusayan Growth EIS appendix (USDA, 1999).

Because any pumping within the Park would put the radius of pumping influence for a given well even closer to the springs than pumping farther away (such as at Tusayan), the flow reduction should be more than 15 percent for the Indian Garden or Hermit Springs.

Although the effects in table 4-4 are predicted, it is reasonable to conclude that any pumping would reduce the springflow, especially so close to the Rim. Reduced springflow should occur more quickly than for pumping in Tusayan or at the Markham Dam fracture zone (MDFZ) area. (See figure 1-1.)

4.3.7.2 Potential Wellfield Sites Within the Park.—Reclamation identified three potential wellfield sites within the Park: (1) railroad, (2) Long Jim Canyon (LJC), and (3) Desert View. Unlike alternative 8, which selected a wellfield site (the MDFZ) based on the area expected to yield the most water to wells in the Redwall-Muav aquifer, a wellfield site within the Park is constrained by location. A wellfield must be as far as possible from the South Rim yet still be inside the Park, a distance of only ¼ to 3 miles. Of these, the LJC site was selected and is discussed in this report. Reclamation did not consider a North Rim, inside-the-Park wellfield (because it would require conveyance across the Canyon) or a western Grand Canyon area site (because pipeline distances may be prohibitive).

The railroad site is the largest parcel. It includes about a 10-square-mile rectangular area west of U.S. Highway 180. Here, the Park boundary is about 2 miles south of the Rim. The LJC site is on the east side of U.S. Highway 180 and includes about the eastern 2 miles from the highway. Its Park boundary is about 3 miles south of the Rim. The Desert View site is about 15 miles east of U. S. Highway 180/State Route 64 in the southeastern corner of the Park. Here, a wellfield might lie between 1 and 2 miles southeast of the Rim.

Although the Desert View site should least affect the South Rim springs (or possibly not affect them at all), its location may place the site in a somewhat different hydro-stratigraphic regime. Aquifer characteristics may be less favorable.

The Desert View site is outside and northeast of the modeled groundwater divide. Groundwater here may flow towards Blue Springs along the Little Colorado River (Huntoon, 1982). Therefore, pumping water here may affect Blue Springs flows. This site falls outside the domain covered by the Montgomery model. More data gathering is necessary to evaluate this site as a feasible location.

The south boundary of the railroad site (the 10-mile by 2-mile parcel west of U.S. Highway 180) is only 2 miles from the Rim. For the LJC site, it is 2 to generally 3 miles between the south Park boundary and the nearest overlook. The railroad site is closer to Indian Garden and Hermit Springs than the LJC site. Any new pumping would be expected to affect those springs (and the other lesser South Rim springs) to some greater degree and sooner than new wells in the LJC area.

4.3.7.3 LJC Wellfield and Pipeline Conveyance.—Up to 15 wells, each 3,000 to 3,400 feet deep, would be drilled to the Redwall-Muav aquifer using the air-rotary drilling method. Mud rotary drilling may not be feasible because large volumes of drill fluid (water and mud) could be lost in voids too large to seal off with lost circulation materials or cement, as occurred in 2000 with an 1,800-foot deep exploratory well drilled to the Redwall-Muav aquifer in Strawberry, Arizona. To coincide with the thickness of the Redwall-Muav aquifer, each LJC well would need about 300 feet of well screen to maximize intercepting water-bearing fractures. Or, if quantity and quality of water-bearing zones (perched zones) delineated while drilling through the Supai Group sediments were adequate, screened sections could be placed to collect that water.

Reclamation estimated that up to 15 wells may be required to provide the annual 2050 South Rim demand of 1,255 af (about 778 gpm or about 52 gpm per well). Reclamation based its estimate on data from a number of existing wells that pump from the Redwall-Muav aquifer in the Coconino Plateau (table 4-1) and cross-checked these data with a query of 77 registered water production wells in the Arizona Department of Water Resource's well registry database, for a northern Arizona area defined by township 21N to 30N, range 6W to 7E. The query returned five 3,000-foot-plus depth wells in townships T26N, T29N, and T30N, ranges R2E and R3E. All five wells had test pumping rates of 40 to 85 gpm using electrical submersible pumps of 100 horsepower (HP) or greater.

One wellfield layout could use two lines of seven or eight wells (assume 15 total) spaced about ¼ mile apart (figure 4-15). Each well should be far enough apart (about a ¼ mile apart) so that no one well captures a disproportionate share of fracture flow from an adjacent one. The locations for successive wells would be adjusted based on the information from previous wells.

These lines of wells could extend east-west and could be located just north of the Long Jim Canyon drainage between U.S. Highway 180 on the west and the East Rim Drive road to the east. Each well would be connected by buried 4- to 8-inch pipe to a larger, centrally located and buried trunk pipeline extending west to U.S. Highway 180 (the South Rim entrance road). Topography across the wellfield would range from about 7050 feet amsl for east end wells to about 6800 feet amsl for west end wells near the road. Pumped water from each wellhead would flow by gravity to a pump station and storage tank near U.S. Highway 180. The trunk pipeline would be installed along the right-of-way northward to the South Rim (the average grade is about 2 percent; note in figure 4-15 that the vertical scale is five times the horizontal scale so the profile appears steeper than it actually is). The maximum elevation rise from the pump station near the road to where the ground crests north of the South Rim campground is about 250 feet. From the campground, the trunkline would drop 40 feet to the South Rim water storage tanks. The reported storage capacity of the water tanks is 13 million gallons but may require upgrading or another tank for the larger demand.

The pipeline costs were based on a central trunk header pipeline of 12-inch diameter along one row of wells extending to the south entrance road (U.S. Highway 180/State Route 64), and then north to the South Rim water storage tanks. If, as discussed previously, each well were spaced about ¼ mile apart in a row, and the two rows were ¼ mile apart, seven wells would use 9,240 feet (1,320 feet x 7 wells) of 4- to 8-inch pipe to reach the 12-inch trunk header pipeline in the first row. Another four miles of 12-inch pipe would be required to reach the South Rim water storage tanks.

The pipeline trench would be in Kaibab Limestone. Another option would be to share an existing utility trench. Although much of the excavation would be common excavation or involve placement in pre-existing utility trenches, a worst case rock excavation scenario of 6 miles of pipe is assumed. Rock trenches are assumed to be 5 feet deep by 3 feet wide with vertical sidewalls. Sand bedding would be 4 inches deep, compacted backfill would be placed to springline, and select backfill (from excavated materials) would be placed and compacted to the surface. backfill (from excavated materials) would be placed and compacted to the surface.

4.3.7.4 Estimated CostsDrilling costs were based on using the rotary drilling method. Costs were reviewed from bids received for the city of Williams, Arizona, second "Dogtown Well No. 2," a 3,500- to 4,000-foot deep well in mostly similar hard rock conditions. The total costs for two bids were $2.1 million and $3.6 million. These costs did not include a submersible pump ($200,000). The city's first "Dogtown Well No. 2" cost about $1.5 million. The proposed wells are anticipated to be a little shallower and have a smaller diameter than those in Williams, but at current prices and with a pump, each well could cost about $2 million.

Figure 4-15.—Proposed Long Jim Canon wellfield and pipeline route profile.

Pipe costs and excavation and backfill costs are available in *Water Delivery System Analysis, Appraisal Level Peer Review Study of the ADWR Phase 1, North Central Arizona Water Supply Study* (Reclamation, 2000b). These costs, especially the rock trenching costs, are thought to be representative, because the costs in that report were com-piled for much of the same general area and geologic conditions as for this alternative.

Estimate sheet No. 11 in appendix 1 summarizes the estimated quantities and costs for alternative 7.

4.3.7.5 Conclusions.—Average depth to water and well yield in two existing Tusayan deep wells that pump water from the Redwall-Muav aquifer is about 2,500 feet and 50 gpm, respectively. The estimated depth to water near the South Rim is 2,700 to 3,100 feet. Based on data from existing deep wells that pump from the regional Redwall-Muav aquifer, any new well drilled in the Coconino Plateau area may only yield 50 to 75 gpm under long-term pumping, and may cost around $1.5 to $2 million or more each. The estimated costs to develop a wellfield inside the Park could be about $38 million. A deep well near Williams, Arizona, that had a similar target zone in the Redwall-Muav aquifer, cost about $1.5 million. Assuming these low yields, as many as 15 wells, each between 3,000 and 3,400 feet deep, may be required to supply the desired year 2050 demand. It is possible that one or several wells could supply the entire amount if the well screen were to tap high volume fracture flow, but this is unlikely.

Depth to water is 2,500 feet or more. Pumping costs are high. Costs were estimated for one 100-HP submersible pump operating 24 hours a day. Costs to provide water quality treatment and storage facilities/tanks were not included. Land costs may not be the issue as they are for alternative 8, but construction disruption would be significant.

A wellfield east of U.S. Highway 180/State Route 64 just above Long Jim Canyon (the LJC site) is considered the best of three locations within the Park limits because a given well would be farther from the Rim than a well in the other two sites. Additionally, this area is the most undeveloped. The Desert View site is too far from the South Rim, and its aquifer characteristics may be unsuitable (into another groundwater basin). The railroad site, located west of the highway, is larger but contains existing cultural features, such as the rail line and sewage disposal plant. All three locations would constrain wells within only 2 miles or so of the South Rim, so pumping would likely have a significant adverse effect on the springs and seeps in a short time.

4.3.8 Construct a Wellfield Outside the Park (Alternative 8)

Under alternative 8, NPS would acquire land to the south of the Canyon and construct a wellfield and associated conveyance system to supply water to the South Rim. Water piped from the wellfield could be stored and used directly (depending on its quality) or treated. The Tusayan Growth EIS identified two potential wellfield sites—the Markham Dam fracture zone and the Airport Graben areas—as areas with favorable hydrogeologic conditions.

The U.S. Geological Survey and consultant Errol L. Montgomery & Associates, Inc., among others, have identified the MDFZ and Airport Graben areas as the best places to drill water supply wells. The MDFZ area is more likely to have the required quantity of water, as discussed in section 4.3.8.1. It is much broader in area (interpreted to have a greater fracture storage capacity at depth in the Redwall-Muav aquifer) and it is farther from the South Rim, thus reducing the effects on spring flow. The rationale for developing a wellfield in the MDFZ area is discussed in the following section. Figure 4-1 shows these areas in relation to the Coconino Plateau physiography and Grand Canyon.

The wellfield could be located north of the Cataract Canyon/Markham Dam and Moore Tank areas, just north of the transmission powerline in T27N, R1W. See figure 4-16 for layout and topography. For this appraisal study, sections 3, and 4, and 9, and 10 were chosen because they are on Federal land, are bisected by the powerline right-of-way, and are near an improved road for ease of access; the area is also relatively flat here. Locations would be further evaluated during the feasibility study.

This alternative could adversely affect the Park's economy and environment. Special legislation is required to accept newly acquired lands as part of the Park. Potential wellfield sites or pipeline may occur in private landholdings, and agreements and purchase would be necessary. Pumping water could, over time, reduce flows from springs along the lower South Rim. As stated previously, these springs support diverse flora and fauna, and some known critical species.

As discussed for alternative 7, the Tusayan Growth EIS concluded that any water pumped in the Coconino Plateau region would make less water available to support (South Rim) springflow. The extent of the effect and when it would occur are not well understood, although predictions have been made using groundwater modeling and spring capture zone analysis by Montgomery (1996), Northern Arizona University (Wilson, 2000), and visual observations after precipitation. Figure 8 in the Tusayan Growth EIS appendix shows that the effects of pumping 300 gpm for 50 to more than100 years, from either Valle or Airport Graben, would decrease the discharge from Indian Garden and Hermit Springs by about 8 to 15 percent, respectively. Pumping at Valle would decrease discharge from these springs and Havasu Springs by 3 percent or less. Montgomery estimated that current pumping reduces discharge from the springs about 2 percent (Coconino Plateau Hydrology Workshop, 2000).

Table 4-4 summarizes the predicted springflow effects from pumping at Valle and Tusayan (Airport Graben).

Fitzgerald (1996) estimated that groundwater in the Redwall-Muav aquifer has a residence time (from recharge to discharge at springs) of 40 years. Vertical travel time would account for most of this. Billingsley (1996), as cited in Huntoon (2000), observed that Havasu Spring water was cooler and had less TDS than normal on April 1, 1995, attributable to 1993 flood water effects. Although the effects in table 4-4 are predicted, it is reasonable to conclude that any pumping would reduce the springflow to some degree, even though springflow may not be reduced for several decades.

As discussed under section 4.1.2.2, "Depth to Water," although one or several wells possibly could supply the entire amount of water the Park needs in the future if, for example, the zone of influence were to tap a good water-bearing karstic feature, as many as 15 new wells, each 3,000 to 3,500 feet deep, may be required to produce the needed amount. This premise is based on data from the six deep wells completed in the Redwall-Muav aquifer (table 4-4) and assumes that sustained yields of 50 gpm are available from any given new well, while assuming minimal drawdown interference in a wellfield setting.

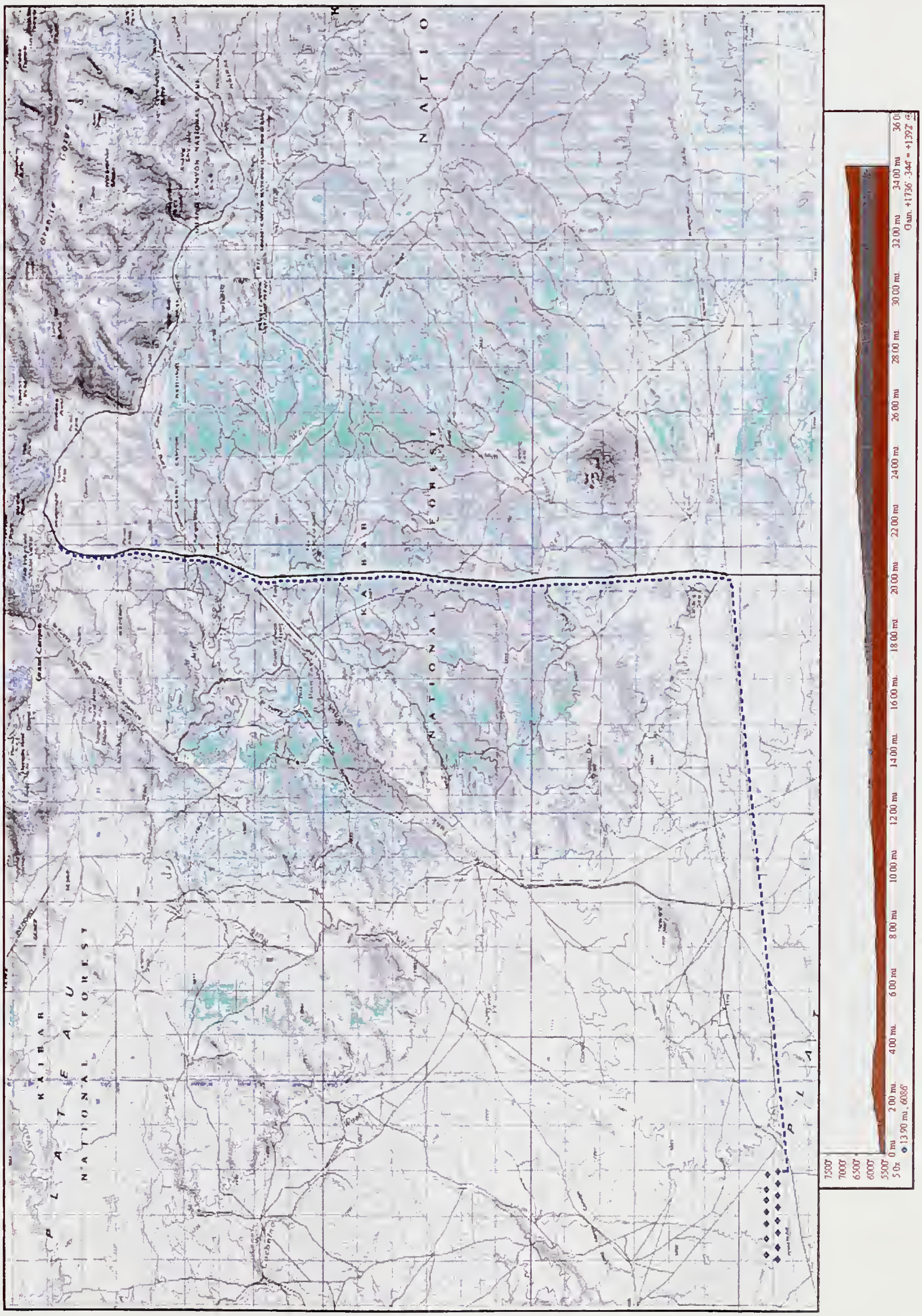

Figure 4-16.—Proposed MDFZ area wellfield and pipeline route profile.

4.3.8.1 MDFZ Area Drilling.—This section presents the rationale for choosing the MDFZ as the most favorable area (in terms of expected water quantity) in which to develop a wellfield, regardless of cost or effect on the environment.

- The MDFZ area is bounded by two major exposed faults—the Williams fault to the south and the Red Horse Fault to the north—both of which are projected to penetrate the entire Paleozoic section. These faults should serve as good vertical conduits or avenues for precipitation infiltration recharge into the Paleozoic Kaibab Limestone. The MDFZ is near Valle and, according to Montgomery (1996),

  ". . . is by two faults with great displacement and that intersect the Williams Fault zone. . . zone of extensive fracturing northwest of Williams. . .believed to be a major conduit for groundwater flow in the Redwall-Muav aquifer. A well field in this area may be capable of producing a substantial quantity of water."

The two faults are presumably the Bright Angel and Red Horse Fault (Montgomery 1996; figures 3 and 4).

- The exposed Kaibab Limestone is extensively fractured at both sites, but especially at the MDFZ site, from intersecting faults. Down-dropped fault blocks should be the best recharge areas. These fractures allow precipitation and surface flows to migrate down via faults, eventually recharging the Redwall-Muav aquifer. Groundwater flow in the sub-basin converges towards the Valle/MDFZ area from the south, east, and north then drains toward Havasu Spring.

- The MDFZ is an extension of the densely fractured Williams fault zone, where the high incidence of surface fracture open area should give the best chance for precipitation to enter the subsurface.

- The MDFZ is thought to be hydraulically connected to the Williams fault zone, the Red Horse, Vishnu, and Bright Angel faults, and in alignment with the Havasu downwarp (synclinal trough), a fault-controlled seepage path. Thus, the MDFZ appears to be a focal point for recharge and groundwater flow. Pre-pumping (steady-state) groundwater level contour maps (Montgomery, 1996; figure 5), using measured water levels in the six area wells, show that most of the groundwater in the Coconino Plateau subbasin (from the groundwater divides), converges from all directions into the MDFZ before flowing northwest along the Havasu downwarp and ultimately discharging at Havasu Spring.

- The topography drops from northeast of the MDFZ to the southwest across the MDFZ. Given the large surface expanse (surface area) of the brittle (fractured/ faulted) Kaibab Limestone and some large areas of tertiary sediments and volcanics, the plateau area around the MDFZ should serve as a good catchment area for precipitation and sheetflow/runoff into the MDFZ subsurface. In contrast, less favorable drilling locations occur in exposures of Mesozoic sediments, such as the Moenkopi Formation. This unit typically acts as an aquitard or a surface seal, thus inhibiting downward infiltration.

- The MDFZ is far enough from the South Rim so that the smaller Indian Garden and Hermit Springs would be minimally affected. A wellfield in the MDFZ probably would take more water from Havasu Spring compared to a wellfield in the Airport Graben, but because of the 29,000 gpm discharge from Havasu Spring, the effects of pumping would be less noticeable. Figure 8 in the Tusayan Growth EIS appendix shows that long-term pumping at 300 gpm in Valle would reduce the projected discharge from Indian Garden and Hermit Springs by 1 to 3 percent. The same pumping in Tusayan may reduce discharges from Indian Garden and Hermit Springs by 8 to 15 percent (table 4-4).

- No nearby deep wells exist in the MDFZ area; thus, there would be no well interference effects from existing wells, only from those new wells completed in the MDFZ. One 300-foot deep, 3-inch diameter well (Arizona Department of Water Resources [ADWR] 613919) in section 28 had a reported water level of 100 feet at 18 gpm at installation. This would be a perched zone, not the Redwall-Muav aquifer.

- The quality of water from Valle wells is reportedly good. Water from MDFZ wells should be of similar quality. Reported yields from the two Valle wells are among the best of all the wells completed in the Redwall-Muav aquifer. The water quality database identified only one deep well in the area, which presumably pumps from the Redwall-Muav aquifer. This 3,450-foot deep well near Valle (A-26-02 11 DDB, ADWR well registry 543573, GWSI No. 353843112083301) was sampled in April 1997. TDS was about 517 ppm, temperature was 26.5 degrees Celsius (°C); pH was 7.3; flouride was 0.5 milligrams per liter (mg/L); alkalinity was 248 mg/L; and dissolved oxygen was 4 percent. This water is of potable quality.

- A wellfield in the MDFZ is only about 15 miles from Valle. A pipeline could extend along existing roads to the powerline, then east to Highway 180, and then north to the South Rim. Net elevation difference is about 1,350 feet (5600 to 6950 feet), and the average grade is less than 1 percent.

- A nearby well, (B-28-1) 35 cab, was drilled through the Redwall-Muav aquifer into the Tapeats Sandstone for oil and gas exploration. The upper part of the borehole was left open for possible future development. This well could be developed and used as a water supply/monitor well.

- The Paleozoic sedimentary section shows the formation contacts dipping toward the MDFZ from the South Rim, and from Williams, dipping north/east towards the MDFZ. Precipitation flow would infiltrate surface fractures/faults and seep vertically, with some component flowing downdip along bedding planes, contacts, and unconformities toward the synclinal axis (trough) trending through the Valle/MDFZ area.

4.3.8.2 MDFZ Wellfield and Pipeline Conveyance.— Like alternative 7, the MDFZ wellfield of alternative 8 may require up to 15 wells, each 3,000 to 3,400 feet deep, drilled to the Redwall-Muav aquifer using the air-rotary drilling method. Section 4.2.7.3 explains why mud rotary drilling methods may be impractical and why up to15 wells may be required to meet a 2050 annual demand of 1255 af. A buried 12-inch to 16-inch-diameter pipeline would be constructed to the South Rim water storage tanks.

To coincide with the thickness of the Redwall-Muav aquifer, each well would need about 500 feet of well screen to maximize intercepting water-bearing fractures. Using alternating screened/blank casing sections could reduce costs especially if quantity and quality of water-bearing zones (perched zones) in the Supai Group sediments are favorable.

Although actual wellfield placement would probably vary based on the information gleaned from previously drilled wells, one wellfield layout scheme could use two lines of wells spaced about ¼ mile apart or far enough apart that the wells would not capture significant fracture flow volumes supplying an adjacent well. A similar configuration (see section 4.2.7.3) of buried 4-inch to 8-inch lateral pipelines from each wellhead collected into a central header trunkline could be constructed and laid out as shown in figure 4-14.

The wells would be collared in the Kaibab Limestone, and the entire pipeline route to the South Rim water storage tanks would be primarily in this unit. The limestone may include softer calcareous sandstone interbeds but, overall the unit is hard. The pipeline could traverse local soft remnants of the Triassic-aged Moenkopi Formation or harder tertiary volcanic bedrock, and/or thin deposits of alluvium (AGS, 1988). One to 2 feet of clayey to gravelly soil typically caps the bedrock on the Coconino Plateau. This soil has a low to moderate shrink-swell potential and low, to mostly moderate or high, corrosivity to concrete and uncoated steel, respectively (Soil Conservation Service, Coconino County Soil Map, 1972). Although much of the excavation would be common excavation, a worse case rock excavation scenario of 33 miles of pipe is assumed. Rock trenching details are similar to those discussed for alternative 7.

The net elevation rise from the MDFZ wellfield area (T27N, R1W, Sections 3,4, 9, and 10) to the Grand Canyon Village via the powerline and U.S. Highway 180/State Route 64 is about 1350 feet. The average grade is 1 percent or less, but pump station(s) and wellfield storage would still be necessary.

Pipeline costs are based on a route from each wellhead to the powerline alignment, east to Highway 180/64, then north to the South Rim. (See figure 4-16.) The profile (shown in figure 4-16 with 5x vertical exaggeration) gives an example of the approximate ground surface topography for the pipeline route. The dot is where the profile bends north along State Route 64 about 13 miles from the wellfield. If each well were spaced about ¼ mile apart in a row, the two rows of 15 wells are ¼ mile apart, and the nearest row is as close to the transmission powerlines as practicable, seven wells would use 9,240 feet (1,320 feet x 7 wells) of 4- to 8-inch pipe to reach the 12- to 16-inch main header trunkline pipe in the first row of eight wells. This trunkline pipe would extend another 30 miles or so to the South Rim along the U.S. Highway 180 easement.

4.3.8.3 Estimated Costs.—Reclamation estimated the costs for alternative 8 in the same manner as for alternative 7. Estimate sheet No. 12 in appendix 1 summarizes the estimated quantities and costs for alternative 8.

4.3.8.4 Conclusions.—Average depth to water and well yield in the Coconino Plateau, based on six existing deep wells that pump water from the Redwall-Muav aquifer, is about 2,500 feet and 50 gpm, respectively. The estimated costs to develop a wellfield outside the Park could be more than $30 million and may not include conveyance costs. Based on data from six deep wells that pump from the regional Redwall-Muav aquifer, any new well drilled in the Coconino Plateau area may only yield 50 to 75 gpm under long-term pumping, and may cost about $2 million dollars or more each. Some similar deep wells near Williams, Arizona, cost more than $1 million (although one supplies more than 200 gpm). Assuming sustained yields of 50 to 75 gpm, 15 wells, each 3,000 to 3,500 feet deep, may be required to supply the desired 2.16 cfs.

Depth to water is 2,500 feet or more. Pumping costs are high. Costs were estimated for one100-HP submersible pump running 24 hours a day. Costs to provide water quality treatment, storage facilities/tanks, or land costs were not included. Pipeline costs were estimated at $5-$10 million for a buried pipeline running from the wellfield east along the powerline route, then over to Highway 64/180 and north to the Grand Canyon Village. From sparse, existing well sampling data, water quality should be good, with only minor point-of-distribution treatment necessary.

Investigators have determined that the two most promising sites for developing a wellfield are the Airport Graben area near Tusayan, and the MDFZ area 15 miles west of Valle. Of these areas, the MDFZ area appears to be the most favorable site because of the expected hydraulic connections with other saturated fractured areas (i.e., the Williams fault zone). These fractured areas are expected to be the best recharge areas (from precipitation) in the Coconino Plateau to replenish the Redwall-Muav aquifer. Although the MDFZ area is about 35 miles from the South Rim, its location as a wellfield should have less adverse effect on South Rim springs than a Tusayan area wellfield. A wellfield in the Airport Graben area near Tusayan could have a greater effect on Indian Garden and Hermit Springs.

4.3.9 Obtain a Dependable Water Supply from Water Providers or Companies (Alternative 9)

Under alternative 9, Roaring Springs would continue to supply water to the North Rim, and water companies or larger communities (Flagstaff, Williams, etc.) located within 100 miles of the Park would supply water to the South Rim. Water would have to be transported to the South Rim by pipeline, truck, or rail. In 1995, failure of the TCP disrupted the water supply to the South Rim. The Park was able to remain open by transporting 360,000 gallons of water per day by truck from outside sources.

4.3.10 Truck or Train Water into Park (Alternative 10)

Under alternative 10, Roaring Springs would continue to supply water to the North Rim, and water would be transported by rail or truck to the South Rim. This alternative was explored in the Tusayan Growth EIS (USDA, 1999). Under Alternative H of that EIS, excess Central Arizona Project water would be purchased and stockpiled in underground aquifers for water credits. Fifth priority water would be drawn from the Colorado River near Topock, Arizona, during water surplus years. When fifth priority water is not available, the CAP water credits would be exchanged for Colorado River water. Colorado River water would hauled by railcar from Topock to Williams on the Burlington Northern Santa Fe Railroad. Then, under one option, water would continue via railcar on the Grand Canyon railroad. Under the second option the water would be delivered in an underground pipeline or hauled by truck to developed areas.

4.3.11 Develop Water Conservation Measures (Alternative 11)

Under alternative 11, the Park would implement water conservation measures and maximize reuse of treated effluent for irrigation and the potable water supply at the Park.

4.4 Cost Estimates

This section discusses expected construction completion times; estimated construction and nonconstruction costs; estimated annual operation, maintenance, replacement, and energy (OMR&E) costs; and summarizes estimated costs for alternatives through 8. Reclamation did not develop cost estimates for alternatives 9, 10, or 11.

4.4.1 Construction Completion Times

Reclamation estimated the construction time for the mainstem diversion pipelines (alternatives 6A, 6B, and 6C) would be 3 to 6 years. The estimated construction time for

Table 4-5.—Construction duration times
(crewdays, except as noted)

Alterna-tive No.	Installing pipe	Directional drilling	Well drilling	Other Features	Mobilization	Total duration (crew days)	Length of construction
1	35			150	30	180	9 mos.
2	60				15	75 per yr	13 yrs
3	1,000				45	1,045	4 yrs
4	185			365	45	410	1 yr 7 mos
5A		190		60	45	240	1 yr
5B1	60	80			45	125	6 mos.
5B2	60	160			45	205	10 mos
6A	1,100			365	60	1,160	4 yrs 6 mos
6B	680	440		365	60	740	2 yrs 10 m
6C	1,600	220		365	60	1,660	6 yrs
7	140		490	270	45	535	2yrs
8	650		490	270	60	710	2 yrs 9 mos

the TCP from Roaring Springs to the Colorado River (alternative 3) is 4 years. Table 4-5 shows construction duration times for alternatives 1 through 8.

4.4.2 Construction Cost Estimates

Table 4-6 summarizes construction cost estimates for alternatives 1 through 8.

Table 4-6.—Summary of construction cost estimates

Alternative No.	Description	Estimated Cost
1	No Action. Add storage at Phantom Ranch	$1,350,000
2	Repair or Replace Portions of Transcanyon Pipeline	$21,000,000
3	Replace the TCP from Roaring Springs to the Colorado River	$24,000,000
4	Construct an Infiltration Gallery and Pumping Plant on Bright Angel Creek to Supply the South Rim and Phantom Ranch	$14,000,000
5A	Drill a Well from the North Rim to Roaring Springs	$10,500,000
5B1	Drill a Directional Drill Hole for New Pipe to Roaring Springs Pumping Plant	$5,200,000
5B2	Drill a Directional Drill Hole for New Pipe and Power Cable to Roaring Springs Pumping Plant	$9,400,000
6A	Use the Colorado River to Supply the South Rim (Tanner Canyon Alignment) and Continue to Use Roaring Springs to Supply the North Rim	$23,000,000
6B	Use the Colorado River to Supply the South Rim (Cardenas Creek Alignment) and Continue to Use Roaring Springs to Supply the North Rim	$39,000,000
6C	Use the Colorado River to Supply the South Rim (Comanche Point Alignment) and Continue to Use Roaring Springs to Supply the North Rim	$33,000,000
7	Construct a Wellfield Inside the Park	$38,000,000
8	Construct a Wellfield Outside Park	$50,000,000

4.4.3 Nonconstruction Cost Estimates

Table 4-7 shows the "rule-of-thumb" percentage of construction costs estimated for nonconstruction contract activities. Table 4-8 summarizes nonconstruction costs.

Table 4-7.—Percent of construction costs for nonconstruction activities

Activity	Percent of construction costs
Planning	5.0
Investigations	3.5
Design and specifications	3.0
Contract administration	7.0
Water rights	0.5
Environmental permits	5.0
Right-of -way (ROW)	2.0

4.4.4 Annual OMR&E Costs

The Reclamation computer program PMPOM generated annual OMR&E costs for pumping plants. The computer program is derived from information in Guidelines for Estimating Pumping Plant Operation and Maintenance Costs (Reclamation, 1965). Estimates of annual OMR&E costs were derived from records of 174 existing electric and hydropowered pumping plants. The procedures cover direct OMR&E costs for pumps, motors, accessory electrical equipment, and plant structures for plants up through 15,000 total horsepower and consider wage rates and price levels. Price levels were updated from 1965 to 2001 levels. The costs are for the maximum pump discharge using the peak pumping rate.

4.4.4.1 Power Costs.—The annual power costs at each pumping plant were computed using the following formulas

Table 4-8.—Summary of nonconstruction costs

Item	Alternative											
	1	2	3	4	5A	5B1	5B2	6A	6B	6C	7	8
Planning	$67,500	$1,050,000	$1,200,000	$700,000	$525,000	$260,000	$470,000	$1,150,000	$1,950,000	$1,650,000	$1,900,000	$2,500,000
Investigations	$47,250	$735,000	$840,000	$490,000	$367,500	$182,000	$329,000	$805,000	$1,365,000	$1,155,000	$1,330,000	$1,750,000
Design and specifications	$40,500	$630,000	$720,000	$420,000	$315,000	$156,000	$282,000	$690,000	$1,170,000	$990,000	$1,140,000	$1,500,000
Contract administration	$94,500	$1,470,000	$1,680,000	$980,000	$735,000	$364,000	$658,000	$1,610,000	$2,370,000	$2,310,000	$2,660,000	$3,500,000
Water rights	$6,750	$105,000	$120,000	$70,000	$52,500	$26,000	$47,000	$115,000	$195,000	$165,000	$190,000	$250,000
Environmental permits	$67,500	$1,050,000	$1,200,000	$700,000	$525,000	$260,000	$470,000	$1,115,000	$1,950,000	$1,650,000	$1,900,000	$2,500,000
Rights-of-way	$27,000	$420,000	$480,000	$280,000	$210,000	$104,000	$188,000	$460,000	$780,000	$660,000	$760,000	$1,000,000
Totals	$351,000	$5,460,000	$6,240,000	$3,640,000	$2,730,000	$1,352,000	$2,444,000	$5,945,000	$9,780,000	$8,580,000	$9,880,000	$13,000,000

HP = QH/8.8 or HP = QH/ (8.8 x Eff)

Where: HP = Horsepower

Q = Flow in cfs

H = Pump head in feet

Eff = 0.8 (Assumed combined pump and motor efficiency)

kW = 0.746 HP Where: kW = Kilowatts of energy

For each alternative, Reclamation converted the peak flow requirement to acre feet/year and determined that the annual diversion could be delivered by pumping at the peak demand for 80 percent of the time (total hours in a year). By assuming that the energy cost would be 52 mils/kW hour, then the annual cost of power would be:

Energy cost ($/year) = (0.80) kW ($0.065) **NOTE: $.052 may change**

By assuming that the pumping plants would deliver water at the peak demand for (0.77) x (8760 hrs/year), Reclamation believes that using this approach to estimate the energy cost per year at each pumping plant was very conservative. (With the expected energy crisis in California and perhaps the southwestern portion of the United State this summer, this methodology might prove not to be very conservative. Reclamation's Central Valley Project in California may see $100 per megawatt hours this year.[1]) The pipe diameters, pumping plant locations, and pump heads will be more precisely defined in the feasibility level of study. Also, the required delivery in acre feet should be known for each month of the year. By knowing the flow in cfs per month, new pipe friction losses and pump heads can then be computed based on the monthly flow requirement. By computing the energy required for each pumping plant for each month of the year, Reclamation will be able to compute a more realistic yearly energy cost. Table 4-9 summarizes pumping plant and water treatment plant OMR&E costs.

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[1]FERC Approves PG&E Rate Increase, Significantly Impacting Reclamation's Central Valley Project Customers: The Federal Energy Regulatory Commission (FERC) issued a ruling conditionally accepting Pacific Gas & Electric's (PG&E) proposed modifications to its power purchase agreement with the Bureau of Reclamation. The effect of this ruling, if it stands, is that Central Valley Project costs for pumping will be substantially increased. Although irrigators will ultimately bear these costs, initially monies will be required up front to pay for power purchases. The ultimate effect is that if irrigators are unable or unwilling to pay these increased costs, then repayment of the CVP is in jeopardy, with substantial loss to the U.S. Treasury. Based on $100 per megawatt hours power costs, the rate increase to Reclamation water users is around $30,000,000 annually. Actual costs could double or triple depending on the actual purchase costs. Memorandum From Amy Holley, Acting Chief of Staff, Office of the Assistant Secretary for Water and Science, Weekly Highlights, June 4-8, 2001.

4.4.4.2 Major Replacement Costs.—According to Reclamation estimating guidelines, the replacement costs for pumping plants of less than 7,000 HP are included in the annual maintenance costs. Equipment replacement analysis procedures for pumping plants of more than 7,000 HP do not require replacements over the service life.

Table 4-9.—Summary of pumping plant and water treatment OMR&E costs

	Alternative											
Item	1	2	3	4	5A	5B1	5B2	6A	6B	6C	7	8
Flow rate (cfs)	1.56	2.16	2.16	2.16	0.54	0.54	0.54	2.16	2.16	2.16	2.16	2.16
Acre-feet per year	72.5	1004	1004	1004	251	251	251	1004	1004	1004	1004	1004
Annual operation	$6,402			$6,574	$4,229	$4,229	$4,229	$8,250	$8,250	$8,250	$34,826	$46,179
Main-tenance	$39,874			$39,111	$25,773	$25,773	$25,773	$57,598	$55,948	$55,948	$14,800	$80,799
Energy	$142,944	$142,944*	$142,944*	$409,766**	$82,465	$82,465	$82,465	$360,920	$336,728	$336,728	$295,737	$410,592
Water treatment (conven-tional system)				$602,000				$602,000	$602,000	$602,000		
Totals	$184,220	$142,944	$142,944	$1,057,451	$112,467	$112,467	$112,467	$1,028,768	$1,002,926	$1,002,926	$345,363	$537,570

* Indian Garden Pumping Plant
**Includes Indian Garden Pumping Plant

4.4.4.3 Pipelines.—Annual operation and maintenance costs for pipelines can be determined as a percentage of the initial costs. These percentages vary from 0.25 to 0.50 percent of the initial pipe cost (Jensen, 1983). Pipeline maintenance represents a very small portion of the OMR&E cost for the system, and Reclamation determined that a detailed analysis of this item was unnecessary.

4.4.4.4 Economic Costs.—Costs of all alternatives were based on a 20-year repayment period for the pumping plants, a 40-year repayment period for the pipelines, and the current repayment interest rate of 6 percent. Table 4-10 summarizes project costs for alternatives 1 through 8.

Table 4-10.—Project costs
Grand Canyon National Park Water Supply Study

Alternative No.	Construction cost	Nonconstruction cost	Total project cost	Annual O&M cost
1	$1,350,000	$351,000	$1,701,001	$189,220
2	$21,000,000	$5,460,000	$26,460,000	$142,944
3	$24,000,000	$6,240,000	$30,240,000	$142,944
4	$14,000,000	$3,640,000	$17,640,000	$1,057,451
5A	$10,500,000	$2,730,000	$13,230,000	$112,467
5B1	$5,200,000	$1,352,000	$6,552,000	$112,467
5B2	$9,400,000	$2,444,000	$11,844,000	$112,467
6A	$23,000,000	$5,980,000	$28,980,000	$1,028,768
6B	$39,000,000	$10,140,000	$49,140,000	$1,002,926
6C	$33,000,000	$8,580,000	$41,580,000	$1,002,926
7	$38,000,000	$9,880,000	$47,880,000	$345,363
8	$50,000,000	$13,000,000	$63,000,000	$537,570

4.5 Alternative Ranking

Table 4-11 ranks the 11 alternatives according to eight factors for alternatives that would affect the South Rim and according to six factors for alternatives that would affect the North Rim only. Each factor was weighted according to its relative importance.

Reclamation evaluated each alternative on the basis of how well it met the criteria. As shown in the table, alternative 4, with a score of 195 out of a maximum of 225, had the highest ranking.

Table 4-11.—Ranking of alternatives that affect the South Rim, Grand Canyon National Park Water Supply Study

Factor	Weight	% Weight	Alterna-tive 1	Alterna-tive 2	Alterna-tive 3	Alterna-tive 4	Alterna-tive 6A	Alterna-tive 6B	Alterna-tive 6C	Alterna-tive 7	Alterna-tive 8	Alterna-tive 9	Altern-ative 10	Alterna tive 11
Restore flow to Bright Angel Creek	3	6.7%	NO 0	NO 0	NO 0	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5
Reduce or eliminate flow augmentation of Garden Creek	3	6.7%	NO 0	NO 0	NO 0	MAYBE 2	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5
Protect prehistoric and historical cultural resources	6	13.3%	YES 5	YES 5	YES 5	YES 5	NO 0	NO 0	NO 0	YES 4	YES 4	YES 5	YES 5	YES 5
Deliver water to Tusayan	2	4.5%	NO 0	NO 0	NO 0	MAYBE 2	MAYBE 2	MAYBE 2	MAYBE 2	MAYBE 2	MAYBE 2	MAYBE 2	MAYBE 2	MAYBE 2
Keep development in TCP corridor and out of proposed wilderness areas	6	13.3%	YES 5	YES 5	YES 5	YES 5	NO 0	NO 0	NO 0	YES 5	YES 5	YES 5	YES 5	YES 5
Protect South Rim aquifer, seeps, and springs	5	11.1%	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	YES 5	NO 0	MAYBE 3	YES 5	YES 5	YES 5
Capital cost	15	33.3%	$1,701,0 00 5	$26,460,00 0 3	$30,240,00 0 3	$17,640,000 4	$28,980,00 0 3	$49,140,000 1	$41,580,00 0 2	$47,880,00 0 1	$63,000,00 0 1	$0 1	$0 1	$0 5
Maintenance	5	11.1%	HIGH 1	Moderate 3	LOW 5	LOW 5	LOW 5	LOW 5	LOW 5	LOW 5	LOW 5	LOW 5	LOW 5	LOW 5
Totals (maximum = 225)	45	100.0%	165	145	155	195	129	99	114	128	143	159	159	159

Table 4-11A.—Ranking criteria for alternatives that affect the North Rim, Grand Canyon National Park Water Supply Study

Factor	Weight	% Weight	Alternative 5A	Alternative 5B1	Alternative 5B2
Capital cost	10	34.4%	$10,500,000 1	$5,200,000 5	$9,400,000 2
Maintenance	7	24.1%	LOW 5	MODERATE 3	LOW 4
Aesthetics	5	17.2%	No Pumping Plant or Pipeline 5	No Pipeline 2	No Power Lines or Pipeline 4
Complexity of system operation	2	7.0%	SIMPLE 5	MODERATE 3	MODERATE 3
Water source reliability	3	10.3%	MODERATE 3	HIGH 5	HIGH 5
Construction difficulty	2	7.0%	HIGH 3	MODERATE 5	HIGH 3
Totals (maximum = 145)	29	100.0%	95	112	95

Table 4-12 summarizes the effects of the alternatives on various resources within the study area, including water, wilderness and wildlife, geology, air quality, geology, economics, social environment/environmental justice, cultural resources, Indian trust assets, aesthetics, noise, and transportation.

Table 4-12.—Potential effects of alternatives on resources, Grand Canyon National Park Water Supply Study

Alternative	Water Resources	Wilderness and wildlife (See table 4-12a)	Geology	Air Quality	Recreation	Economics	Social Environment/ Environmental Justice	Cultural Resources	ITAs	Aesthetics	Noise	Trans-portation
No Action Alternative (Alternative 1)	No effect.		No effect.	Federal and State standards would not be exceeded.	Potential significant effect on recreation because water availability constraints would limit recreation activities.	No significant effect.	No effect.	No effect.	No effect.	Minor effect.	No significant effect.	Minor effect.
Repair or Replace Certain Portions of the TCP (Alternative 2)	No effect on water quantity or quality.		No effect.	Air quality would degraded during construction.	Substantial effect because of major construction activity.	No significant effect.	No effect.	Consultation with the SHPO and affected Tribes would occur early in the planning process to determine survey needs, effects, and mitigation in accordance with Section 106 of NHPA.	No effect.	Slightly greater effects than alternative 1.	Possible significant effect.	Moder-ate effect.
Replace the TCP from Roaring Springs to the Colorado River (Alternative 3)	No effect on water quantity or quality.		No effect.	Air quality would degraded during construction.	Substantial effect because of major construction activity.	Minor beneficial effect.	No effect.	Same as alternative 2.	No effect.	Greatest effect.	Possible significant effect.	Moder-ate effect.
Construct an Infiltration Gallery and Pumping Plant on Bright Angel Creek to Supply the South Rim and Phantom Ranch (Alternative 4)	Would eliminate current excess unused flows (overflow) at Garden Creek		No effect.	Air quality would degraded during construction.	Minimal effect.	Minor beneficial effect.	No effect.	Same as alternative 2.	No effect.	Long-term beneficial effect.	Significant effect.	Moder-ate effect.
Drill a Well from the North Rim to Roaring Springs (Alternative 5)	No effect on water quantity or quality.		No effect.	Federal and State standards would not be exceeded.	Minimal effect.	No significant effect.	No effect.	Same as alternative 2.	No effect.	Minor effect.	No significant effect.	Moder-ate effect.
Use the Colorado River to Supply the South Rim and Continue to Use Roaring Springs to Supply the North Rim (Alternative 6)	No effect on water quantity. Water treatment would be required.		No effect.	Air quality would degraded during construction.	Minimal effect.	Minor beneficial effect.	No effect.	Same as alternative 2.	No effect.	Greatest effect.	Significant effect.	Greatest effect.

Table 4-12.—Potential effects of alternatives on resources, Grand Canyon National Park Water Supply Study (continued)

Alternative	Water Resources	Biological Resources (See table 4-12A)	Geology	Air Quality	Recreation	Economics	Social Environment/ Environmental Justice	Cultural Resources	ITAs	Aesthetics	Noise	Trans-portation
Construct a Wellfield Inside the Park (Alternative 7)	Would affect water quality and quantity at the Park. Could significantly affect springs and seeps inside and outside Park.		No effect.	Air quality would degraded during construction.	Minimal effect.	Minor beneficial effect.	No effect.	Same as alternative 2.	No effect.	Minor effect.	Would generate noise inside Park.	Moder-ate-to-signif-icant effects.
Construct a Wellfield Outside the Park (Alternative 8)	Same as alternative 8.		No effect.	Air quality would degraded during construction.	Minimal effect.	Minor beneficial effect.	No effect.	Same as alternative 2.	No effect.	Minor effect.	Would generate noise inside and outside Park.	Moder-ate-to-signifi-cant effects.
Obtain a Dependable Water Supply from Water Providers or Companies (Alternative 9)	No effect on water quantity or quality.		No effect.	Federal and State standards would not be exceeded	Minimal effect.	No effect.	No effect.	Same as alternative 2.	No effect.	No effect.	Minimal effect.	No signifi-cant effect
Truck or Train Water into Park (Alternative 10)	No effect on water quantity or quality.		No effect.	Federal and State standards would not be exceeded	No effect.	No effect.	No effect.	Same as alternative 2.	No effect.	No effect.	Minimal effect.	No signifi-cant effect.
Develop Water Conservation Measures (Alternative 11)	No effect on water quantity or quality.		No effect.	Federal and State standards would not be exceeded.	No effect.	No effect.	No effect.	Same as alternative 2.	No effect.	No effect.	Minimal effect.	

Table 4-12A.—Potential effects of alternatives on wilderness and wildlife, Grand Canyon National Park Water Supply Study

Alternative No.	Wilderness	Section 7	Critical habitat	MSO surveys	SWF surveys	T&E Fish	T&E Plant surveys	Springs and seeps	Sensitive species	Historic buildings, districts, landscapes	Archeological sites	Traditional Cultural Properties	Caves	Wetlands	Habitat loss
1		/													
2		/		/		/									
3		X		X		X	X								
4		X	X		/	X									X
5		X	X	/	/	X			/						X
6	X	X	X	X	X	X	X		X						X
7	/	/		X				X	/						
8		/		/				X	/						
9															
10															
11															

/ = possible X = likely
Sensitive species = desert bighorn sheep, peregrine falcon, bats, goshawk, etc.
MSO = Mexican spotted owl
SWF = Southwestern willow flycatcher
TE = Threatened or endangered species

CHAPTER 5

Existing Conditions and Potential Effects of Alternatives

5.1 Setting

The Colorado Plateau is the regional setting for the Grand Canyon. The plateau is a vast, semi-arid land of raised plains and basins typical of the southwestern United States. The National Park Service, Bureau of Land Management (BLM), and the U.S. Forest Service (USFS) administer approximately half of the land on the plateau. The 1,218,375 acres within the Park are adjacent to the Colorado River in northern Arizona. Within the Park are 277 miles of the Colorado River, from the Paria River confluence to the Grand Wash Cliffs. Lees Ferry is the divide between the upper and lower Colorado River Basin (considered river mile 0.0). It is located about 8 miles downstream from Glen Canyon Dam. The 277-mile-long Grand Canyon ranges from 1 to 25 miles wide and up to 1 mile deep. Elevations range from 1,200 feet mean sea level (msl) at the western boundary where the Colorado River enters Lake Mead, to 9,165 feet msl at the North Rim.

5.2 Water Resources

5.2.1 Existing Conditions

5.2.1.1 Colorado River.—The Colorado River originates in the Rocky Mountains of Colorado. It is 1,450 miles long from its source to the Gulf of California. The Colorado River system drains approximately 245,000 square miles, or one-twelfth of the continental United States. The mainstream flow of the Colorado River through the Park is water that has been impounded at Lake Powell behind Glen Canyon Dam.

At Lees Ferry, the mean concentration of sediment ranges from 2 to 124 mg/L. At Phantom Ranch, approximately 87 miles river miles below Lees Ferry and below several tributaries (Paria River, Little Colorado River, and Clear Creek) the turbidity ranges from 6 to 47,100 mg/L. The amount of turbidity of the river depends on the annual runoff into the Colorado River below Lees Ferry. The present silt load is about 80,000 tons per day, or less than one-sixth the load before Glen Canyon Dam was built.

5.2.1.2 Aquifer.—The primary water-bearing unit of the Coconino Plateau is the Redwall-Muav aquifer. The Coconino aquifer and numerous perched aquifers in the Supai formation also contribute to groundwater but to a far lesser degree. The Redwall-Muav aquifer is a deep aquifer found in the Redwall, Temple Butte, and Muav limestones at 3,000 feet below the ground surface. This aquifer is the only region-wide source of groundwater in the area.

5.2.1.3 Groundwater.—Most of the groundwater in the Grand Canyon is recharged to the Redwall-Muav aquifer via faults that propagate from the surface down through all the strata. Spring discharge points on the South Rim of the Grand Canyon tend to be found where faults intersect the rim. This is evidence that the faults act as conduits in this system. For example, the Havasu downwarp leads directly to Havasu Spring, the Hermit Fault leads to Hermit Springs and its associated springs, and the Bright Angel Fault leads to Indian Garden Spring.

More than 98 percent of the reported discharge occurs at Havasu, Hermit, and Indian Garden Springs. The largest discharge from the aquifer in the Coconino Plateau groundwater subbasin is 29,000 gpm at Havasu Springs. Groundwater discharge at Hermit and Indian Garden Springs occurs along faults and related fracture systems. The base rate of discharge at each of these springs is 300 gpm.

A number of other seeps and small springs issue from the Redwall-Muav aquifer within the Grand Canyon. The seasonal nature and unsteady base flow of many of these seeps and small springs compared to the steady flow of Havasu, Hermit, and Indian Garden Springs support the conclusion that discharge from these seeps and small springs result mainly or solely from local near-rim recharge.

5.2.1.4 Water Usage.—Currently, the South Rim uses 596 af of water a year. The projected water use on the South Rim is expected to increase to about double by the year 2050, based on a 1.5 percent per year increase in visitor growth. If this trend continues, an estimated 9.6 million people would visit the park in year 2050, compared to the 4.6 million that visit now (NPS, 2000).

NPS has a Federal Reserve Right to both groundwater and surface water in the Colorado River. This water right is designated for current and future administrative uses and natural/cultural resource protection. NPS has asked Reclamation to reserve 1,500 acre-feet of which 1,255 af would be used to meet the Park's anticipated growth and visitation needs through 2050.

5.2.1.5 Waste Water.—The Park has its own sewage and wastewater treatment facilities. The wastewater treatment plant (WWTP) is located on the South Rim and has a capacity of 900,000 gallons per day (gpd). This facility treats all wastewater generated at the South Rim. The maximum wastewater flow is approximately 600,000 gpd during the peak summer season and approximately 300,000 gpd during the winter. Therefore, the facility has the capacity to accommodate an additional 300,000 gpd when operating at maximum capacity.

Three smaller wastewater treatment facilities operate inside the Park: at the North Rim, Desert View, and Phantom Ranch. The treatment facility at the North Rim has a capacity of 100,000 gpd; Desert View a capacity of 60,000 gpd; and Phantom Ranch a capacity of 9,000 gpd. The Desert View facility uses a facultative lagoon system. The lagoon system requires hauling 50,000 gpd of effluent by truck to the WWTP for further treatment.

5.2.1.6 Effluent Reuse/Conservation Practices.—Currently, the Park uses recycled water is used for all irrigation. The Park has also implemented a water conservation program that includes low-flow toilets and low-flow shower devices. NPS requires installation of water conservation equipment in all new housing at the Park.

5.2.2 Potential Effects

This section describes the potential effects of the alternatives on water quality and water quantity and on springs inside and outside the Grand Canyon.

Alternatives 1, 2, 3, and 5 would not affect water quality or water quantity. These alternatives would continue to use Roaring Springs as the source of water for both the North and South Rims. Roaring Springs discharges an average of 3,500 gpm, and the trans-canyon pipeline delivers between 650-700 gpm. In addition, the water requires minimal treatment (chlorinated) before it is delivered for use at the Park. Thus, these alternatives are not expected to affect water quality or water quantity.

Alternative 4 would eliminate the TCP north of Phantom Ranch, return Roaring Springs flows to Bright Angel Creek, eliminate the current excess unused flows (overflow) at Garden Creek (below Indian Garden), and, in general, would be less costly to operate and maintain than the TCP.

Alternative 6 would use Colorado River water to supply the Park. Thus, water quantity would not be a factor. Treatment would be required to remove contaminants found in Colorado River water. Alternative 6 would not only be the most expensive to build, operate, and maintain but would also be the most costly in terms of treatment required to meet water quality standards. See chapter 6 for Clean Water Act (CWA) permit requirements.

Alternatives 7 and 8 would likely adversely affect both water quality and water quantity at the Park. In addition, they could significantly affect springs and seeps both inside and outside the Park.

Very little data exist about the groundwater system or aquifer from which springs discharge and well water is pumped. No hydraulic conductivity measurements have been recorded, nor is it known which springs are connected to the regional aquifer.

Montgomery and Associates conducted the most pertinent work on this issue in 1996 and 1999. The consultants conducted a numerical model of groundwater flow; the results of this study were incorporated into the Tusayan Growth EIS. The study concluded that every gallon of water withdrawn from the Redwall-Muav aquifer would result in a gallon of water being removed from discharge to springs in the Grand Canyon. The report also indicated most of the decrease would occur to the largest springs (i.e., Havasu, Indian Garden, and Hermit Springs). The study did not investigate the effect of groundwater withdrawal on the small springs or seeps.

Reducing discharge to Havasu Spring or other springs within the Havasupai and Hualapai Indian Reservations, as well as the Kaibab National Forest, could significantly affect these water supplies. The Park shares the concerns about potential effects on Havasu Springs and other springs within the watershed or reservation. Thus, these alternatives are not considered viable for implementation.

Alternatives 9 and 10 would not affect water quality or water quantity at the Grand Canyon because the water source would not draw on the regional aquifer, springs, or seeps in the region. Concern exists, however, that water shortages in the region could preclude or interrupt water transfers to the Park from a regional source (water companies/communities). Thus, these alternatives are not considered viable unless a regional water supply system can be developed to ensure regional water supplies are available.

Alternative 11 would not affect water quality or water quantity.

5.3 Biological Resources

5.3.1 Existing Conditions

5.3.1.1 Natural Setting.—Most of the information for this section was taken from *Grand Canyon National Park, Resource Management Plan, Part One, Narrative*, January 1997 and *Biotic Communities Southwestern United States and Northwestern Mexico*, David E. Brown editor, 1994.

As a World Heritage Site, Grand Canyon National Park is recognized as a place of universal value, containing superlative natural and cultural features that should be preserved as part of the heritage of all the world’s people.

In September 1989, NPS recommended the immediate designation of 980,088 acres of Grand Canyon lands as Wilderness and consideration of an additional 131,814 acres for potential Wilderness designation. If adopted, more than 1,111,902 acres would be established as Wilderness. Although NPS submitted the environmental impact statement and wilderness recommendation to the Congress, designation was never finalized.

In 1993, the National Park Service revised the original Wilderness recommendation, and called for the immediate designation of 1,109,257 acres as Wilderness and 29,820 acres for potential wilderness, for a total of 1,139,077 acres. While not designated, Park policy states that all categories of Wilderness (e.g. potential, proposed study) will be considered and managed as though they were designated Wilderness until legislative action occurs. The following are characteristics of Wilderness areas as defined by the Park (Linda Jalbert, personal communication);

- Where the earth and its community of life are untrammeled by man—where man himself is a visitor who does not remain...
- Undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation. . .
- Which generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable...
- Which is protected and managed so as to preserve its natural conditions....
- Which has outstanding opportunities for solitude or a primitive and unconfined type of recreation.

The Park's great biological diversity includes five of seven life zones and the four deserts in North America; from rim to river one encounters the Lower Sonoran, Upper Sonoran, Transition, Canadian, Hudsonian life zones. Six major vegetation communities occur within the Park: Great Basin conifer woodland, Rocky Mountain conifer forest, Mohave Desert scrub, Great Basin desertscrub, Sonoran desertscrub, Chihuahuan desertscrub, and riparian scrublands (Brown, 1994).

More than 1,500 plant species, 287 bird species, 88 mammalian species, 58 reptile and amphibian species, and 26 fish species occur in the Park.

For this section, three broad habitat types can be delineated within the study area: the Colorado River corridor and inner canyon riparian areas, inner canyon desert uplands, and coniferous forests. The following sections describe the characteristics of these habitat types.

5.3.1.1.1 River Canyon and Inner Canyon Riparian Habitat.—The riparian habitat along the Colorado River corridor has developed since 1963 in response to controlled releases from Glen Canyon Dam, making the Grand Canyon the only place in the southwest where large riparian habitats have been created rather than degraded or destroyed. The riparian community along the river and its perennial tributaries are characterized by the exotic saltcedar, coyote willow, arrowweed, seep willow, western honey mesquite, and catclaw acacia (*camelthorn,* etc.).

This patchily distributed habitat type supports diverse and abundant wildlife assemblages and provides critical habitat for riparian dependent species. Most animal species that inhabit the inner canyon depend on these riparian areas directly or indirectly for food and cover during at least part of their annual cycles.

Hanging gardens, seeps, and springs also contain many rare and unique plant species. The Park is very concerned about the status and persistence of the springs on the North and, especially, the South Rims. The Park is monitoring spring flow at Hermit, Cottonwood, and Pumphouse Springs to determine seasonal and annual variability and may expand this monitoring to include additional South Rim springs. The major concern is the community of Tusayan's groundwater withdrawals from the Redwall-Muav aquifer.

Until Glen Canyon Dam was completed in 1963, the Colorado River's aquatic system was dominated by native fishes. These native species were specifically adapted to highly variable seasonal fluctuations in sediment load, flow, and temperature and were severely affected by dramatic changes resulting from the dam. The introduction of non-native fish contributed to competition and direct mortality. Of the eight native species found in the river before 1963, three species are now extirpated in the Grand Canyon: the Colorado squawfish, bonytail chub, roundtail chub; two are barely holding on: humpback chub and razorback sucker; and three are still considered common: speckled dace, flannelmouth sucker, and bluehead sucker (Miller, 1959). According to more recent studies, four species are now extirpated: Colorado pikeminnow (formerly Colorado squawfish), bonytail and roundtail chubs, and razorback sucker; one is endangered: humpback chub; and three are fairly common: bluehead sucker, flannelmouth sucker, and speckled dace (Valdez and Ryel, 1997; Douglas and Marsh,1998).

Programs to introduce non-native species for sport and food began at the turn of the century. Since the late 1950s, 24 species of non-native fishes have been reported from Grand Canyon; 13 species are present today (Arizona Game and Fish Department, 1996; Valdez and Ryel, 1997).

Plant species' diversity and lush growth along the newly created riparian zone provide many bird habitats in a relatively small area. River corridor bird use illustrates this habitats' importance. Of the 315 bird species recorded in the Grand Canyon region, 250 (79 percent) were found in the river corridor. Only 48 species regularly nest along the river; others use the river as a corridor through the desert or as overwintering habitat.

Under post-dam conditions, large numbers of waterfowl have begun using this stretch below Glen Canyon Dam during winter, peaking in late December and early January. Nineteen species have been regularly reported between Lees Ferry and Soap Creek at a density of 136 ducks per mile.

Of the 34 mammals species found along the river corridor, 15 are rodents and 8 are bats. While river otters and muskrats are extremely rare, beavers and other rodents have probably benefitted from the dam's presence, increasing their distribution. While bats typically roost and inhabit desert uplands, the insect abundance along the river and tributaries attracts foraging bats from throughout the inner canyons and conifer forests on both rims.

Coyotes, ringtails, and spotted skunks are the most numerous riparian predators. Raccoon, weasel, bobcat, gray fox, and mountain lion are also present but much rarer.

Mule deer and desert bighorn sheep frequent the river corridor. Mule deer are generally not permanent residents along the river, but travel from the rim when food and water resources become scarce there. Permanent mule deer populations occur around Phantom Ranch, Nankoweap Canyon, Saddle Canyon, and Buck Farm Canyon.

Twenty-seven known amphibian and reptile species reside along the river corridor. The three most common amphibians (canyon treefrog, red-spotted toad, Woodhouse's toad) need the river corridor or tributary riparian areas with perennial water for breeding. Leopard frogs have recently been observed at two locations along the river corridor.

Of the remaining 23 reptile species, 10 are considered common along the river corridor. Reptiles use both upland desert and riparian sites, but higher densities are supported in riparian areas because of the rich invertebrate food sources and vegetation. Gila monsters and chuckwallas are the two largest lizards in the canyon, with chuckwallas much more common. Five rattlesnake species have been recorded in the Park. Two are distinct species rarely encountered: the Southwestern speckled rattlesnake and the Northern black-tailed rattlesnake. The other three snakes are subspecies of the western diamondback rattlesnake complex: the Grand Canyon rattlesnake, Great Basin rattlesnake, and the Hopi rattlesnake.

The greatest abundance of Park invertebrates occurs in the river corridor. Invertebrates play a major role in food pyramids that link the aquatic and terrestrial systems and also serve as the basis for the vertebrates in the canyon. The rare Kaibab swallowtail butterfly can be found at Roaring Springs.

Kanab ambersnails, discovered in 1991 at Vaseys Paradise, are known to exist at only one other site in southern Utah. The Vaseys population size is not known definitively, but was estimated in fall 1995 to be around 106,000 individuals. Searches at more than seventy other springs and seeps along the Colorado River have failed to locate any other Kanab ambersnail populations.

5.3.1.1.2 Inner Canyon Desert Uplands.—The biotic communities of the desertscrub uplands are influenced by the four North American deserts from which they are derived. A Mohavean desertscrub extends from the Grand Wash Cliffs in extreme western Grand Canyon to near the Colorado River's confluence with the Little Colorado. It is typified by warm desert species, such as creosote bush and white bursage. Frost sensitive species more characteristic of the Sonoran Desert, such as brittle bush, catclaw acacia, and ocotillo, can also be found. Chihuahuan species, such as mariola, western honey mesquite, and four-wing saltbush, also occur. Upstream of the Little Colorado in Marble Canyon and on the Tonto Platform, species more characteristic of the Great Basin desertscrub predominate, such as big sagebrush, blackbrush, and rubber rabbitbrush.

Widespread erosion and rock weathering has created numerous scree slopes and talus fields that provide numerous animal hiding places. The arid conditions of the desertscrub uplands favor a fauna comprised chiefly of reptiles and desert-adapted rodents, although birds also breed in the uplands and cliff areas.

Thirty bird species breed primarily in the desert uplands and cliffs of the inner canyon. Mammals include about 50 species, mainly rodents and bats. Amphibians are generally absent from the upland areas that are more than a mile from water. All reptiles known to inhabit the river corridor also appear in the uplands, although in lower densities.

At least 100 pairs of peregrine falcons nest along the cliffs of the inner canyon. The abundance of bats, swifts, and riparian birds provide ample food for peregrines and suitable aerie sites are plentiful along the steep canyons. Unless overwintering survival is a limiting factor in population regulation, the peregrine population is likely to continue to increase.

5.3.1.1.3 Coniferous Forests.—Past practices of cutting, fire suppression, and overgrazing have extensively altered the conifer forests of the Grand Canyon. Fire suppression has transformed the forests from an open parklike setting into thick, dense forest choked with many young trees. These changes have presumably affected wildlife species that prefer open canopy forests, such as Kaibab squirrels and goshawks. Goshawks, in particular, and, to a lesser extent, spotted owls find refuge in the Park, primarily in the conifer forests and upper side canyons along the North Rim.

Above the desertscrub and up to 6,200 feet is a woodland consisting of pinyon pine and one seed and Utah junipers. Other species include big sagebrush, snakeweed, Mormon tea, Utah agave, narrowleaf and banana yucca, winterfat, Indian ricegrass, dropseed, and needlegrass.

A forest characterized by ponderosa pine occurs above the woodland elevations between 6,500 and 8,200 feet on both the North and South Rims. Typical plants in this community are Gambel oak, New Mexico locust, mountain mahogany, elderberry, creeping mahonia, and fescue. Another forest type is found on the North Rim above 8,200 feet: a spruce-fir forest characterized by Englemann spruce, blue spruce, Douglas fir, white fir, aspen, and mountain ash. Typical plants include several species of perennial grasses, groundsels, yarrow, cinquefoil, lupines, sedges, and asters.

Mule deer on the Kaibab Plateau migrate from the lower elevation pinon-juniper forests in the winter to higher elevation mixed-conifer forests in the summer. Park boundaries include 5 percent of their available overwintering habitat and 25 percent of their summering habitat. Arizona's native elk, *Cervus merriami,* were hunted to extinction by the early 1900s. Rocky Mountain elk were subsequently transplanted into Arizona, and populations have become established as far north as the South Rim

Of the approximately 90 bird species that breed in coniferous forests, 51 are summer residents and at least 15 of these are known to be neotropical migrants. The conifer forests provide habitat for 52 mammal species. On the Kaibab Plateau are small mammal species more typical of northern latitudes, including porcupines, shrews, red squirrels, and several bat species.

5.3.1.2 Threatened and Endangered Species.—Reclamation consulted the Fish and Wildlife Service's list of threatened and endangered species for Coconino County to determine what federally threatened and endangered species the alternatives might affect. Reclamation identified eight listed species. Reclamation also gathered additional information from Park staff.

5.3.1.2.1 Sentry Milk-Vetch.—A member of the pea family, this endangered plant grows at greater than 4,000 feet in elevation on Kaibab limestone with little soil in unshaded openings within the pinyon-juniper habitat type. The two previously known populations of this variety occur on the South Rim, and a third population was recently discovered from the North Rim. No critical habitat has been designated nor is there a recovery plan for the species.

5.3.1.2.2 Kanab Ambersnail.—Although no critical habitat has been designated for this endangered landsnail, there is a recovery plan for the species. Of the two known populations, one is in the Park. Habitat for the snail is semiaquatic vegetation watered by springs or seeps at the base of sandstone or limestone cliffs. It requires either shallow standing water or a perennially wet soil surface. Grass or sedge cover is also necessary.

5.3.1.2.3 Humpback Chub.—This endangered fish currently occurs in the Grand Canyon and Marble Canyon portions of the mainstem Colorado River and in the lower Little Colorado River. It is also found in portions of the Colorado and Green Rivers of Utah and Colorado as well as portions of the Yampa River in Colorado. The chub occurs in a variety of riverine habitats, especially canyon areas with fast current, deep pools, and boulder habitat. Critical habitat includes the Colorado River from river mile 34 (Nautiloid Canyon) to river mile 208 (Granite Park) as well as the confluence of the Little Colorado River.

5.3.1.2.4 Razorback Sucker.—This endangered fish is endemic to the Colorado River Basin; the largest population is now found in Lake Mohave in the Lower Basin. In the Upper Basin, small remnant populations are found in the Green, Yampa, and mainstem Colorado Rivers. It is also found in the San Juan River near the New Mexico-Utah border. Razorbacks suckers are found in backwaters, flooded bottomlands, pools, side channels and slower moving habitats. Critical habitat includes the 100-year floodplain of the Colorado River through the Grand Canyon from the confluence with the Paria River to Hoover Dam.

5.3.1.2.5 Bald Eagle.—In Arizona, nesting sites for this threatened bird are usually isolated high in trees, on cliffs, or on pinnacles with a commanding view of the area and in close proximity to water. Arizona currently supports 43 breeding areas primarily along the Salt and Verde Rivers. Between 200-250 wintering birds can be found throughout the State but mainly in the White Mountains and along the Mogollon Rim. Bald eagles are not known to nest within the Park, but migrating bald eagles use the Colorado River corridor through the Grand Canyon in the winter. The bald eagle is currently being proposed for delisting.

5.3.1.2.6 California Condor.—Currently, 23 of the endangered condors exist in the wild in Arizona (Jamey Driscoll, Arizona Game and Fish Department, personnel communication, January 2000). There is no designated critical habitat for the condor in the Park. However, condors spend 87 percent of their time roosting and scavenging within Park boundaries. During winter, they spend nearly 90 percent of their time in the upper reaches of Marble Canyon along the river corridor.

5.3.1.2.7 Mexican Spotted Owl.—In Arizona, populations of this threatened bird are patchily distributed and occur in all but the arid southwestern portion of the State and much of the lowland riparian zones. Recent information shows that on the Colorado Plateau, narrow, cool, shaded canyons support most of the nesting activity of Mexicanspotted owls. Call surveys have elicited vocal responses from roosting owls, and there have been numerous observations of owls within the Park. The data suggest that spotted owls breed and nest within Park boundaries.

5.3.1.2.8 Southwestern Willow Flycatcher.—Critical habitat in the Park for this endangered bird occurs from Colorado River mile 39 downstream to river mile 71.5. The boundaries include areas within the 100-year floodplain where thickets of riparian trees and shrubs occur or may be established as a result of natural floodplain processes or rehabilitation.

Researchers have surveyed a number of sites along the river for southwestern willow flycatchers from Glen Canyon Dam to the confluence of Bright Angel Creek. Flycatchers were recorded at Lower Cardenas (milepost 72.2 to 72.0) in 1993, Lava Chuar (milepost 65.3) in 1994 and 1995, and between milepost 51.5 and 50.5 between 1993 and 2000. Flycatchers nested here during this same period (Tracy McCarthey, Arizona Game and Fish Department, personal communication).

5.3.2 Potential Effects

This section discusses the potential effects of the alternatives on biological resources.

5.3.2.1 Alternative 1.—Under the No Action Alternative, the following effects are anticipated:

- Roaring Springs would continue to be drawn down approximately 20 percent, and Indian Garden Creek would continue to be augmented by overflows at Indian Garden campground.

- This alternative may require Section 7 consultation with the FWS on potential effects to listed species, depending on the location of pipeline to be replaced.

5.3.2.2 Alternative 2.—Under alternative 2, the following effects are anticipated:

- Roaring Springs would continue to be drawn down approximately 20 percent, and Indian Garden Creek would continue to be augmented by overflows at Indian Garden campground.

- This alternative may require consultation with the Fish and Wildlife Service on the humpback chub, razorback sucker, Mexican spotted owl, and California condor if any excavation is proposed in Garden Creek or Bright Angel Creek. The decision on whether or not to consult will depend on the location of the repairs and the results of surveys.

- The Fish and Wildlife Service accepted the following guidelines from the Park for previous excavation activities in Bright Angel Creek. These guidelines would apply to any excavation in Bright Angel or Garden Creek associated with repair of the TCP:

    1. Take measures to ensure that no pollutants (such as petroleum products) enter Bright Angel Creek or adjacent waters. If a leak should occur, operations must discontinue and repairs initiated immediately.

2. Keep sediment discharge to a minimum.

   - Limit the number of site access points to a minimum.
   - Preserve and protect stream banks.
   - Do not place debris removed from work sites into standing or flowing water.
   - Use, excavate, and manipulate only gravel, cobble, and boulder size materials to the maximum allowable level.

3. To the best possible extent, maintain channel gradient and channel width/depth ratio.

   - Leave the affected steam channel with essentially the same cross-sectional shape, dimensions, and longitudinal slope as was originally present.
   - Restrict excavations to riffle (high-energy) sections of the stream and do not leave any head-cuts in the channel.
   - Ensure shallow excavations (spread out the impact).
   - If necessary and/or applicable, restore riffle-pool-glide sequence and proportions if possible.
   - Maintain an unobstructed floodplain.

4. Photo-document all work performed, including photographs of all sites before work has begun and after work is completed.

5. Maintain daily logs of the type of equipment used, amounts of material moved, location and extent of actual work area, and other information pertinent to an understanding of the work and its impact to the stream and floodplain.

6. Preserve and protect fish habitat. Protect pools, streambanks, riparian vegetation/root wads, and all structures that maintain cover and temperature.

7. Rehabilitate streambanks, dozer tracks, and all other features produced by operations.

These or similar restrictions likely would apply to any construction activities from this project. Unless existing quarry sites are used, excavation for borrow material may also require surveys for plant or wildlife species.

➤ Any excavation or repair work near the North or South Rim or near side canyons with potentially suitable habitat will require spotted owl surveys. The current protocol requires that call points be ½ kilometer from each other and that four visits be made to each call point. Two years of calling in a row are needed to ensure adequate coverage, and construction must take place during the year of the last survey.

➤ Because the TCP is outside of designated Wilderness, Wilderness associated restrictions would not apply.

➤ There would be no effect on South Rim springs and seeps.

➤ Although listed as an experimental, nonessential population, California condors could occur in the project area during the summer months. Construction personnel will need to be briefed on recommended actions to avoid or minimize human-condor interactions.

5.3.2.3 Alternative 3.—Under alternative 3, the following effects are anticipated:

➤ This alternative would require Section 7 consultation with the Fish and Wildlife Service on potential effects to the razorback sucker, humpback chub, Mexican spotted owl, California condor, and possibly the sentry milk-vetch. The mitigation activities listed under alternative 2 would likely need to be implemented and additional actions might be required to ensure the containment of pollutants and sediments into waters occupied by these fish.

- Spotted owl surveys would be needed near the South and North Rims and inside canyons with potentially suitable habitat. Two years of calling in a row are needed to ensure adequate coverage, and construction must take place during the year of the last survey.

- Because the TCP is outside of designated Wilderness, Wilderness associated restrictions would not apply.

- Construction personnel would need to receive an orientation on the California condor. Biologists permitted by the U.S. Fish and Wildlife Service to deal with condors would be needed at the construction sites.

- South Rim springs and seeps would not be affected.

- Sections of the alignment above 4000 feet in elevation would need to be surveyed for the sentry milk-vetch.

5.3.2.4 Alternative 4.—Under alternative 4, the following effects are anticipated:

- This alternative would require Section 7 consultation with the Fish and Wildlife Service on potential effects to the California condor, razorback sucker and humpback chub (and their critical habitat), and bald eagle. The southwestern willow flycatcher, Mexican spotted owl, and sentry milk-vetch also may need to be addressed in this consultation. The mitigation activities listed under alternative 2 would likely need to be implemented, and additional actions might be required to ensure the containment of pollutants and sediments into waters occupied by the fish.

- Depending on the location of the pumping plant and associated facilities, surveys for the southwestern willow flycatcher may be required. If any sections of the TCP were replaced, surveys for Mexican spotted owl and sentry milk-vetch may be needed.

- Construction personnel would need to receive an orientation on the California condor.

- South Rim springs and seeps would not be affected.

- Because the TCP is outside of designated Wilderness, Wilderness associated restrictions would not apply.

5.3.2.5 Alternative 5.—Under alternative 5, the following effects are anticipated:

- This alternative would require Section 7 consultation with the Fish and Wildlife Service on potential effects to the razorback sucker and humpback chub (and their critical habitat), the California condor and the bald eagle. Consultation may be required for the Mexican spotted owl and the southwestern willow flycatcher. The mitigation activities listed under alternative 2 would likely need to be implemented, and additional actions might be required to ensure the containment of pollutants and sediments into waters occupied by these fish.

- Depending on the location of the drill pad, surveys for the Mexican spotted owl and northern goshawk may be needed.

- Drilling activities would lead to temporary noise disturbance to wildlife and the eventually loss of wildlife habitat.

- South Rim springs and seeps would not be affected.

- Depending on the location of the pumping plant and associated facilities, surveys for the southwestern willow flycatcher may be needed.

- No known Wilderness would be affected.

5.3.2.6 Alternative 6.—Any new pipeline and associated facilities in either Cardenas Canyon or Tanner Canyon would be in proposed Wilderness. It is NPS policy to treat proposed Wilderness as if it has, in fact, been designated.

- Section 7 consultation would be required for the Mexican spotted owl, sentry milk-vetch, California condor, bald eagle, razorback sucker and humpback chub (and their critical habitat), and southwestern willow flycatcher. This consultation would need to address the diversion of Colorado River water from designated critical habitat for the humpback chub and razorback sucker.

- River mile 71.0 - 71.3 supports potentially suitable habitat for the endangered southwestern willow flycatcher. The site was surveyed in 1993 and 1995-2000. One territory was documented in 1993. Depending on the size and location of the facilities needed for the diversion, intensive surveys would be required. The protocol for project related activities requires five visits, with at least three visits during the third survey period (June 22 to July 17). Conducting more visits during this survey period provides greater confidence in determining the presence/absence of resident southwestern willow flycatchers.

- The location of any pumping plants or other physical features adjacent to the Colorado River could affect designated critical habitat for the southwestern willow flycatcher.

- Surveys for Mexican spotted owl and sentry milk-vetch would be needed.

- Contract personnel would need to be briefed on how to discourage human/condor interactions.

- Constructing a new pipeline below the rim could disrupt the activities of several sensitive species, including lambing sites for bighorn sheep and breeding areas for peregrine falcons, golden eagles, and several sensitive species of bats. Consequently, seasonal blasting and noise abatement restrictions may be required.

- Mitigation for habitat loss and disturbances would likely require some or all of the following actions:

  - Recontouring all pits, trenches, and disturbed sites to their natural grade.
  - Fencing all open pits to prevent wildlife from falling in.
  - Revegetating with native species approved by the Park.
  - Monitoring.

- South Rim springs and seeps would not be affected.

- Surveys for goshawks would be needed in any affected coniferous habitat on either the North or South Rims.

5.3.2.7 Alternative 7.—Under alternative 7, the following effects are anticipated:

- A primary concern of this alternative are the potential effects of water withdrawals from a wellfield on the springs (and associated biota) under the South Rim.

- Indian Garden currently supports a species of ambersnail that may be classified as the Kanab ambersnail (RV Ward, personal communication). If the species is classified as a Kanab ambersnail, Section 7 consultation would be required.

- Mexican spotted owl surveys would be required at the site of the proposed wellfield as well as along the pipeline alignment.

- Surveys for northern goshawks would be needed in any affected coniferous habitat.

- Construction activities may disturb the activity patterns of wildlife such as deer and elk and their predators such as mountain lions. However, construction activities would be temporary, and these species would likely adjust their activities.

5.3.2.8 Alternative 8.—Under alternative 8, the following effects are anticipated:

- A primary concern of this alternative are the potential effects of water withdrawals from a wellfield on the springs under the South Rim.

- Indian Garden currently supports a species of ambersnail that may be classified as the Kanab ambersnail. If the species is classified as a Kanab ambersnail, Section 7 consultation would be required.

- Mexican spotted owl surveys would be required at the site of the proposed wellfield as well as along the pipeline alignment.

- Construction activities may disturb the activity patterns of wildlife such as deer and elk. However, these would be temporary, and these species can likely adjust their activities.

- Surveys for northern goshawks would be required.

5.3.2.9 Alternative 9.—Under alternative 9, no endangered species consultation or mitigation would be needed for non-listed species if no new storage facilities are constructed. Springs and seeps on the South Rim and below would not be affected.

5.3.2.10 Alternative 10.—Same as for alternative 9.

5.3.2.11 Alternative 11.—Same as for alternative 9.

5.4 Geology

5.4.1 Existing Conditions

The Grand Canyon is the deepest and most extensive canyon found in plateau country. The exposed rock layers represent all of the eras of geologic time and contain evidence of the evolution of life through more than 600 million years of earth history. The oldest dated rocks in the Canyon approach 2 billion years in age.

The Grand Canyon lies within the physiographic region known as the Colorado Plateau or Plateau Province of northern Arizona. The South Rim is considered a part of the Coconino Plateau, and the North Rim a part of the Kaibab Plateau. The stratigraphy of the Grand Canyon consists of 11 Paleozoic-Era layers that from top to bottom and include the Kaibab Formation, Toroweap Formation, Coconino Sandstone, Hermit Shale, Supai Group, Surprise Canyon Formation, Redwall Limestone, Temple Butte Formation, Muav Limestone, Bright Angel Shale, and Tapeats Sandstone. Underlying these layers is the Proterozoic Grand Canyon Supergroup and crystalline core.

5.4.1.1 Soils.—Few areas within the Park have well developed soil profiles. Soils in the area are derived primarily from surface strata from the Kaibab Formation. Soil development on the rim is influenced by the permian Kaibab Limestone Formation, with some mixed sedimentary material and aolian deposits with low to moderate erosion potential. Alluvial deposits along the Colorado River combine with colluvial deposits to form the major transported soils of the inner Canyon.

5.4.1.2 Seismicity.—The South Rim of the Grand Canyon near Grand Canyon Village continues to be the most seismically active area of northern Arizona. This seismicity began with a swarm of earthquakes in September 1988, with the largest events consisting of 4.0 to 4.5 magnitude earthquakes that struck the region in 1992.

5.4.2 Potential Effects

This section assesses whether the structural stability and integrity of the geology and soils is adequate for repairing or replacing the TCP, constructing a pump station and associated appurtenances on the mainstem of the Colorado River, and/or delivering pipelines/ groundwater wells or direction boreholes. It also assesses the local seismic activity in the area of concern for the proposed water supply features.

Because of the shallow soil depths (2 feet or less) at the Grand Canyon, most project features would be constructed on, or installed within, rock of the upper geological stratigraphy.

Existing pipelines on the South Rim have been installed within the Kaibab Formation exclusively. NPS staff has indicated previous construction projects at the Park used a number of techniques to break up this rock formation. These included ripping the rock with heavy equipment, cutting the rock with a rock saw, or blasting it with explosives. In 1985, a directional borehole was installed between the South Rim and Indian Garden. No problems were encountered during this construction, and it is believed no problems would be experienced on the North Rim. No problems are anticipated if a wellfield is developed inside, or south of the Park.

Alternatives 1 through 8 involve construction activity both on, and beneath the ground surface. The integrity of the geology at the Grand Canyon is expected to be structurally stable for all of these alternatives.

Alternatives 9 and 10 would use existing road or rail routes to transport the Park's water supply and, thus, would not affect geology or soils in any way. Alternative 11 would not affect geology or soils in any way.

Seismicity at the Grand Canyon has been of small and moderate magnitude to date, but seismic events in the past have triggered rockfalls. Following seismic activity along Bright Angel Fault, rockfall destroyed sections of the TCP. Thus, the design and construction of alternatives 1 through 8 should account for effects related to seismic activity.

5.5 Air Quality

5.5.1 Existing Conditions

The Park has been designated a Class I area under the Clean Air Act. Class I is considered the highest standard and is subject to the most stringent controls for airborne pollutants. In general, air quality at the Park is considered good, but it is influenced seasonally by weather patterns, temperature inversions, and pollutants carried from the Navajo Generating Station near Page, Arizona. The Navajo Generating Station was identified as a point source that contributes to winter haze within the Canyon. As a result, the plant is installing sulfur dioxide (SO_2) scrubbers to reduce these emissions by 90 percent.

Pollutants generated from major metropolitan areas such as Los Angeles, Las Vegas, and Phoenix also contribute to pollutants in the Park. Local air quality is affected by emissions from private vehicles, buses, trains, and stationary sources, such as wood-burning stoves.

Windblown air pollution at the Park is greatest during the summer months when haze reduces visibility by about 35 percent. The prevailing winds across the region are generally from south to west, which bring pollutants mainly from the urbanized areas of Los Angeles and Phoenix. In general, air quality is excellent during the winter months. When temperature inversions occur, however, pollutants in the canyon are trapped until the next storm event arrives.

5.5.2 Potential Effects

This section assesses whether the effects of alternatives on air quality would lead to violations of Federal and State standards for criteria pollutants.

Alternatives 1 and 5 involve minor construction activities that are not expected to generate pollutant levels that would exceed Federal and State area quality standards.

Alternatives 2, 3, 7, and 8 involve major pipeline construction. Alternatives 4 and 6 involve constructing a pumping plant with appurtenances and a conveyance system. These six alternatives would generate the greatest amount of pollutants because of the amount and length of construction. Air quality would likely degrade within the project area during construction. If appropriate measures were implemented (e.g., watering program, properly tuned equipment/engines) emissions could be reduced to acceptable levels.

Alternatives 9 and 10 would deliver water by truck or rail. Truck and locomotive engine emissions would increase pollutant levels at the Park. The emission levels would be minimal, and are not expected to exceed Federal or State standards. Alternative 11 would not affect air quality in any way.

Because the Grand Canyon is in attainment for all criteria pollutants, it would not require a Conformity Analysis to show conformity with a State Implementation Plan.

5.6 Recreation

5.6.1 Existing Conditions

The Park offer diverse resource-based recreational opportunities and support services that provide visitors a unique experience. Following are year-round and seasonal recreation activities available to the public.

- Auto touring
- Horseback riding
- Backpacking
- Nature walks
- Biking
- Sightseeing
- Bird watching
- Snow skiing
- Camping
- Snowshoeing
- Cross country skiing
- Whitewater rafting
- Fishing
- Wilderness area
- Hiking
- Wildlife viewing

In 1996, more than 4.9 million people visited the Park. Approximately 22 percent visited during the spring, 48 percent during the summer, 22 percent during the fall, and 8 percent during the winter. About 80 percent of visitors stay on the North and South Rims and do not venture below the Rims. Approximately 40 percent of all visitors come from other countries.

5.6.2 Potential Effects

This section discusses whether construction activities for the proposed alternatives (e.g., staging areas, pump stations, pipeline alignments, well or directional borehole drilling, or material hauling) would significantly affect recreation by restricting certain activities.

Alternative 1 could have a significant effect on recreation because water availability constraints would limit recreation activities.

Alternatives 2 and 3 would have the greatest effect on recreation because major construction activities would occur within the Corridor Area, the area most used by visitors for recreation. In addition, a specific section(s) or all of the Bright Angel Trail, North-Kaibab Trail, and Old Bright Angel Trail could be closed during pipeline construction, which could significantly affect recreational activities in the Corridor Area.

Phantom Ranch and Bright Angel Creek receive heavy visitor use, primarily from April through October. Under alternative 4, construction could affect recreation use in varying degrees, ranging from limiting access to the Bright Angel Trail from the river to the North Rim to allowing no access at all. Helicopter access would be essential to transport construction equipment and materials to the site. Recreation uses would be fully restored following construction, although recreation would be disrupted if major maintenance work were required.

Alternative 5 would have a minimal effect on recreation because of the minimal amount and duration of construction activity required.

Under alternative 6, the pumping plant and appurtenances would be located at the mouth of Cardenas or Tanner Canyon on the Colorado River. The delivery pipeline would be aligned from the river through one of these canyons to the South Rim. The pipeline between the South Rim and the water storage tanks would not affect recreation activities because it would be aligned within an existing utility right-of-way.

Alternative 7 and 8 construction activities would be minor and associated with the pipeline construction that occurs within the Park itself. The primary effects would be access delays to recreationists visiting the South Rim caused by additional construction traffic using park roads inside the Park. Alternative 9 would have a similar effect on recreationists accessing the South Rim.

Alternative 10 includes additional rail cars being pulled by the locomotive, which would not affect recreation activities in any way. Alternative 11 would not affect recreation in any way.

5.7 Economics

5.7.1 Existing Conditions

Currently, 4.5 to 5 million people visit the Park each year. Although visitation fluctuates from year to year, visitation has shown an overall increase since the Park's inception. Most visitors come during the peak summer season, creating overcrowded conditions and high demand on overnight accommodations and food services. NPS has estimated that visitation to the park will approach 6.8 million people by 2010. Currently, entrance fees generate about $18 million dollars a year.

The 1990 population of Grand Canyon Village was reported at 1,500, with an estimated summer peak season population of 2,100. The population has remained fairly constant since then. In 1999, NPS had a full-time staff at the Park of 330.

5.7.2 Potential Effects

This section describes the potential effects of the alternatives on the economy of the Park and communities in the area.

Alternatives 1, 2, or 5 would not significantly affect the economy of the Park. The existing TCP would remain the main water delivery system for the North and South Rims, with the exception of alternative 5. Construction of a new TCP from Roaring

Springs to the Colorado River under alternative 3 would slightly benefit the local economy; construction activity would lead to increased sales, trade, employment, government revenue, and income.

Alternatives 4 and 6 would also slightly benefit the Park's economy, as a result of the construction activities and permanent employment for NPS staff or contract personnel to operate and maintain the new facilities. Alternatives 7 and 8 would also benefit the Park's economy during construction activities.

Alternatives 9 and 10 would not affect the economy of the Park because of the small number of personnel involved in transporting water to the Park by truck or rail. Alternative 11 would not affect the economy of the Park in any way.

5.8 Social Environment and Environmental Justice

5.8.1 Existing Conditions

To the greatest extent practicable and permitted by law, and consistent with the principles set forth by the National Performance Review, each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on low-income and minority populations in the United States and its territories and possessions. Environmental justice and equity includes the fair treatment of people of all races, cultures, incomes, and educational levels with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment implies that no racial, ethnic, or socioeconomic group should bear a disproportionate share of the negative environmental consequences resulting from the operation of industrial and commercial enterprises and from the execution of Federal, State, and local programs and policies.

5.8.2 Potential Effects

This section discusses whether the proposed alternatives would have a disproportionately high and adverse effect on human health or environmental effect on minority or low-income populations.

No known minority or low-income populations inhabit areas where the alternatives would include construction within the Park boundaries (alternatives 1-7). Alternative 8 would not adversely affect these populations. Likewise, alternatives 9 and 10 would use existing public roads and railroad routes that would not adversely affect these populations. Alternative 11 would not affect these populations.

5.9 Cultural Resources

This assessment evaluates at a very general level cultural resource issues for the water supply alternatives for Grand Canyon National Park. Reclamation obtained data from Park archaeological site files and maps, Kaibab National Forest, and Arizona State Historic Preservation Office (AZSITE) , as well as from discussions with Park staff archaeologists. At the appraisal level of study, research is limited and is intended mainly to alert decision makers about known or potentially significant cultural resource issues to help them decide which alternatives to consider eliminating because of effects on significant cultural resources and the resulting costs to mitigate these effects.

The **Cultural Resources Appendix, appendix 4,** briefly summarizes Grand Canyon prehistory and history.

5.9.1 Existing Conditions

5.9.1.1 Cultural Resources.—The Park contains the remains of some 10,000 years of human occupation that waxed or waned depending on several factors, the most significant of which was climate. Water has always been the significant limiting factor for human occupation, no less today than in the past. From the river to the rim and along the rim are a variety of archaeological sites. Site density in the Park is especially high in areas where arable land, water, and access into the canyon are present, such as side canyon where trails provide routes into and out of the canyon; Unkar Delta, on the Colorado River downstream from Cardenas Creek (Euler and Chandler 1978), and Walhalla Glades on the North Rim. Archaeological site types range from areas where atlatl dart points and arrowhead were made (commonly called by archaeologists lithic chipping stations or sites) to rock art sites (either pictographs—painted designs—or petroglyphs—pecked designs) to single room field houses and habitations to multiroom pueblos. Historical sites include the remnants of mining, ranching, and tourism, as well as a scattering of Native American remains such as Navajo corrals and Hualapai *gowas*.

Survey data are generally limited, confined primarily to areas where development has occurred and continues to occur, especially on the South Rim, and to areas that are subjected to impacts from tourism such as trails and campgrounds. Selected areas, such as the Bright Angel and other popular trails; the Colorado River corridor; locations for prescribed burns; transportation, pipeline, and utility corridors; and staff and visitor support facilities such as the Mather Point Orientation Center have good survey data, especially within the last decade.

Reclamation obtained data for this assessment primarily from site record files, maps, and reports located at the Park that were reviewed over a 2-day period and from conversations with Park archaeologists.

5.9.1.2 Traditional Cultural Properties.—For a number of Native American tribes, Grand Canyon plays a significant and sacred role in their culture. The term "culture" includes, among other things, traditions, beliefs, practices, arts, and lifeways of a particular group of people. Sometimes an area, location, land form, or some other natural or cultural feature may hold special traditional cultural significance for a community or group of people. Traditional refers to "those beliefs, customs, and practices of a living community of people that have been passed down through the generations, usually orally or through practice." (Parker and King, 1990:1).

Two examples of places that can hold traditional significance for a Native American group are a location associated with traditional beliefs about a group's origin and cultural history, and a location that Native American religious practitioners have used historically, and still use today, to perform traditional ceremonial activities (Parker and King, 1990:1).

Because the traditional cultural value placed on a particular place or feature can assume great significance and importance to a group of people (not necessarily only Native Americans), damage to or infringement upon the place or feature can be deeply offensive to, perhaps even destructive to, the group that values it. "As a result, it is extremely important that traditional cultural properties [traditional cultural places] be considered carefully in planning." (Parker and King 1990:2).

Fortunately, a considerable amount of information on traditional cultural properties has been gathered in conjunction with the Reclamation's Glen Canyon Dam Environmental Impact Study. TCP consultation by archaeologists from Reclamation's Upper Colorado Region, as well as by Park archaeologists responsible for managing cultural resources in the park, has been and continues to be carried out with the Hopi, Zuni, Hualapai, Southern Paiute, Paiute Indians of Utah, Kaibab-Paiute, Havasupai, and the Navajo Nation.

As a result of tribal consultations, some generalities about traditional cultural properties and sacred sites can be made. Occasionally, tribal consultation results in the identification of specific Traditional cultural properties, but, in many cases, tribal consultants do not provide specific locational information. Some tribes consider the Grand Canyon area and the Colorado River sacred. Water is considered sacred, as are areas in the Grand Canyon where it is present. Ribbon Falls, located just off the Bright Angel Trail several miles below the North Rim, is sacred to the Zuni, and the Zuni and other tribes would view any action that could potentially affect the flow of this waterfall—and other springs—as harmful. Certain land forms and features such as a salt cave or the *Sipapuni*, a travertine cone located on the Little Colorado River upstream from where it enters the Colorado River, are sacred. Some tribes consider prehistoric archaeological sites (for example, the Bright Angel Site east of the confluence of Bright Angel Creek and the Colorado River) and petroglyphs and pictographs as Traditional cultural properties.

Because of the complex nature of TCP consultation and the limited amount of information available for areas away from the Colorado River, where most of the previous consultation effort has been directed, only general information on Traditional cultural properties is provided for the alternatives.

5.9.2 Potential Effects

According to NPS-28 CRM Guidelines, all archaeological resources in the Park are treated as irreplaceable and should not be sacrificed for development. They are studied if determined significant. Consequently, the following assessment assumes that all cultural resources affected by an alternative will be subject to some kind of mitigative data recovery.

5.9.2.1 Alternative 1.—The Bright Angel Trail TCP alignment has been surveyed for cultural resources (Brook 1974, 1979; Coulam 1986) and is one of the better known areas in the Grand Canyon for these resources. More than 25 prehistoric and historic sites are recorded along the Bright Angel Trail from Phantom Ranch to Roaring Spring. From Phantom Ranch to the South Rim, there is a major site cluster at Indian Gardens (Coulam, 1986).

Park archaeological site maps indicate that north of the Colorado River site, clusters are found along the trail for about 2 miles south of Ribbon Falls, in the Ribbon Falls area, and along the trail north of Ribbon Falls for approximately 3 to 4 miles. A cluster of sites occurs in the Phantom Ranch area and where the trail meets the Colorado River. No sites were noted along the trail for four or five miles north of Phantom Ranch, including the "Box Area." From South Rim to the Colorado River, there are no recorded sites until Indian Gardens, where 19 sites were recorded during a 1986 survey (Coulam, 1986). Many of these contained masonry foundations, although exact room counts were difficult to make because of the poor preservation of many of the sites.

Generally, prehistoric site types found within the TCP corridor include sherd and lithic scatters, storage cists, small pueblos, cliff dwellings, rock shelters, petroglyphs, and rock alignments. Human burials have been noted at some sites. Historic sites along the corridor are related to mining, tourism, and the development of the Bright Angel Trail (Coulam, 1986; see also Cleeland, n.d.). Ribbon Falls and some of the prehistoric sites in the Phantom Ranch area have been identified as Traditional cultural properties; other Traditional cultural properties may be located along the trail. A thorough review of existing TCP data combined with additional consultation with affected or interested Indian tribes can address specific issues for these resources.

A pipeline failure is an emergency situation, and repairs must be made immediately. Cultural resource impacts are assessed and are dealt with as necessary to make needed repairs. Under the No Action Alternative, when a pipe failure occurs, Park archaeologists, as they have done previously, would evaluate the effect on cultural resources and develop and implement an appropriate mitigation plan. Consultation with the State Historic Preservation Office (SHPO) and affected tribes occurs as required.

5.9.2.2 Alternative 2.—As noted for alternative 1, reliable cultural resource data are available for the Bright Angel Trail transcanyon corridor, and mitigation planning for pipeline repair or replacement can be based on these data. Early Section 106 consultation with the SHPO, Tribal Historic Preservation Officers (THPO), and the Advisory Council on Historic Preservation (ACHP), as well as applicable tribal consultation, would help in developing a mitigation plan to address adverse effects to the cultural resources. It is strongly recommended that mitigation planning start as soon as the pipeline sections requiring repair or replacement are identified, as well as any equipment storage areas and contractor staging areas that may require Class III (Intensive) survey. Cultural resources have not been recorded for some areas of the pipeline, such as the Box area. These areas should not present any cultural resource issues, unless Traditional cultural properties are present, for which specific information has not been released by the Indian tribe claiming the TCP. For this reason and because of other known Traditional cultural properties along transcanyon corridor (for example, Ribbon Falls, which the Zuni consider sacred), a thorough review of existing TCP consultation reports and additional tribal consultation is recommended as early as possible in the planning process.

Given the popularity of the trail with Canyon visitors and the difficulty of conducting excavation in a remote area where access is limited, weather is an important consideration, and logistical supply difficult at best, adequate lead and field time must be factored into project planning. Consultation, especially with affected tribes, often requires additional time and effort, another important consideration for planning and scheduling. A research design must be prepared and submitted for review the SHPO, TPHOs, and ACHP. Prehistoric human remains may be recovered, and a treatment plan for dealing with human remains should be developed in consultation all tribes that may claim affiliation with the remains.

The kind of cultural resource mitigation, as well as the scope and cost, can only be determined once the target pipeline sections are identified and the impacts to cultural resources are assessed.

5.9.2.3 Alternative 3.—As for alternative 2, early Section 106 consultation with the SHPO, ACHP, THPOs, and affected Indian tribes would be crucial. Replacing the existing TCP with a new pipeline would require major construction within the TCP corridor and the possible use of other areas outside the corridor for staging equipment, supplies, and materials. Construction could affect all cultural resources within the corridor to varying degrees, and contractor use areas may affect cultural resources outside the corridor where surveys have not been carried out.

If this alternative were selected, mitigation planning would need to begin as soon as possible. Given the popularity of the trail with Canyon visitors and the difficulty of conducting excavation in a remote area where access is limited, weather is an important consideration, and logistical supply difficult at best, adequate lead and field time must be factored into project planning. Consultation, especially with affected tribes, often requires additional time and effort, another important consideration for planning and scheduling. As for alternative 2, a research design must be prepared and consulted on, and a treatment plan for prehistoric human remains must be developed in consultation with tribes that claim affiliation with the remains.

The kinds of cultural resource mitigation, as well as the scope and cost, can be determined once the new pipeline route is identified. If possible, avoidance of as many cultural resources as possible when the designing a new route is recommended not only to reduce cost but to preserve the resources. Stabilization of some of the existing resources also may be necessary.

5.9.2.4 Alternative 4.—Like alternative 2, early Section 106 consultation with the SHPO, ACHP, THPOs, and affected Indian tribes would be crucial under alternative 4. Contractor use areas should be restricted to existing disturbed areas along Bright Angel Creek /Trail corridor and in the Phantom Ranch area as much as possible to avoid impacts to cultural resources in areas where surveys have not been carried out.

Available survey data indicate that there are no cultural resources in the immediate vicinity of the proposed infiltration gallery and pumping plant. These areas should not present any cultural resource issues, unless traditional cultural properties are present, for which specific information has not been released by the Indian tribe claiming the property. For this reason, and because of other known traditional cultural properties in the area such as the confluence of Bright Angel Creek and the Colorado River (Hart, 1995), a thorough review of existing data on Traditional Cultural Properties is recommended. To ensure a comprehensive review, additional tribal consultation is also strongly recommended. Consultation with affected tribes often requires additional time and effort, an important consideration for planning and scheduling.

Under this alternative, the TCP south of the river to the South Rim and the delivery pipeline from Roaring Spring to the North Rim would continue to delivery water. If no modification is planned for these portions of the TCP, then cultural resource issues would be the same as for the No Action Alternative (alternative 1). For this and other alternatives that may affect the Bright Angel Trail, there is another consideration. The Bright Angel Trail is listed on the National Register of Historic Places and any adverse impacts to it will require consultation with the SHPO and ACHP.

5.9.2.5 Alternative 5.—Park site maps show two cultural resource sites located immediately west of the North Rim visitor complex. TCP information is limited, although all springs are considered important, most of the Indian tribes are concerned about Grand Canyon. Therefore, any activity that affects Roaring Spring would be of particular interest to affected tribes.

Depending on the location of the drill site for the well/pipeline to Roaring Springs, additional Class III survey could be required on the North Rim and at Roaring Springs. The drill site and associated construction area could be located to avoid any effects to cultural resources. If cultural resources cannot be avoided, mitigation would be required, with the preparation of the requisite mitigation plan and associated consultation. Appropriate consultation with the SHPO, THPOs, and the ACHP should begin early in the planning process.

5.9.2.6 Alternative 6.—See discussion of alternative 5 for issues related to the well/pipeline from North Rim to Roaring Springs.

This alternative proposes a new pumping plant on the Colorado River near the mouths of Cardenas and Tanner Creeks. A new pipeline would be laid to bring the water from the pumping plant to a receiving facility on the South Rim and from here to a holding/ distribution site near main visitor facilities. Previous surveys have identified a number of cultural resource sites along the river near the mouths of Cardenas and Tanner Canyons. Most recently, the Grand Canyon River Corridor Survey (Fairley et al., 1994) investigated the alluvial portions of this stretch of the river. Relatively level alluvial lands were used prehistorically for farming and habitation. The remains of these occupations include roasting pits and single- and multi-room pueblos. Depending on the location of the pumping plant and associated construction areas, additional Class III survey may be required.

The Zuni, Hopi, and Southern Paiute consider this area (and downstream to Phantom Ranch) as culturally significant. The Zuni have indicated that there are shrines along the river (Hart, 1995), especially from milepost 50 upstream of the confluence of the Little Colorado River downstream to Bright Angel Creek. They considered this portion of the

Colorado River especially sacred. The Hopi have indicated the presence of Traditional cultural properties near the confluence of Cardenas Creek (Ferguson, 1998). In general, the Southern Paiute consider most archaeological sites along the river as significant, and possibly as traditional cultural properties, although this is not clear (Stoffle et al., 1994).

The route for a buried/surface conveyance pipeline from the pumping plant to the South Rim would likely follow either Cardenas Canyon or Tanner Canyon. Park site maps indicated no sites in Cardenas Canyon and one site at the upper end of Tanner Canyon. Neither canyon has been surveyed intensively, however. The lower end of Cardenas Canyon contains a prehistoric trail that diverges about 2 miles from river from whence it parallels Cardenas Canyon, as it continues to climb upward, eventually joining the Tanner Trail to the South Rim (Wilson, 1999).

A possible option to a buried/surface pipeline is a directional bore hole from the South Rim to a point on the river. This alternative would not affect any surface sites, except at the construction sites at each end of the bore hole and for the pumping plant.

On the South Rim, archaeological sites are numerous. Park archaeologists have carried out surveys for road construction, pipelines, utility corridors, prescribed burns, and other activities associated with development, operation, and maintenance of visitor facilities (for example, Fairley, n.d.; Moffett and others, 1998). Survey data indicate that site density increases as one moves eastward along the rim from the lodge area. Kayenta Anasazi sites predominate, although some Coconino and Havasupai sites (primarily west of the lodge area) and Navajo sites (primarily east of the lodge area) are present.

Depending on where facilities are located to receive and convey water pumped from the river, Class III surveys may be required. In the Tanner and Cardenas alternative areas along the rim, most recorded cultural resources are the result of surveys associated with the rim road and a pipeline. If a water delivery pipeline can be designed to following an existing road, pipeline, or utility right-of-way, substantial cultural resource data may be available, and additional survey may be limited. With careful planning, it may be possible to design a new pipeline that avoids some cultural resources on the South Rim. Alternatively, by using existing surveyed corridors for a new pipeline, cultural resource effects may be largely reduced.

Any cultural resource mitigation would require preparation of the mitigation plan and consultation with appropriate entities. TCP consultation with affected and interested tribes would be necessary. All consultation should be initiated early in the planning process.

5.9.2.7 Alternative 7.—Construction of a wellfield and conveyance system within the Park would likely require Class III survey and some level of mitigation. Site maps show that most cultural resources recorded on the South Rim tend to be along the rim and associated with infrastructure for the visitor and staff facilities, such as roads and utility corridors. Farther away from the rim, cultural resource survey coverage generally is less intense and data are fewer. When the wellfield and pipeline route are identified and Class III surveys carried out, it may possible to locate the wellfield and design the conveyance to avoid as many cultural resources as possible. Use of existing road, pipeline, and utility corridors can lessen effects on cultural resources and reduce survey and mitigation costs.

As with all the alternatives, consultation with the SHPO, THPOs, ACHP, and affected tribes would need to begin as soon as possible if this alternative is selected. TCP consultation has been by conducted for the River Corridor Study and for various projects of the South Rim, and some information is available to assist in planning for this alternative. Additional consultation would be required. As with archaeological sites, avoidance of Traditional cultural properties is recommended.

5.9.2.8 Alternative 8.—The Airport Graben area is located on Kaibab National Forest (NF) land south of the South Rim entrance to the Park. Cultural resource data obtained from Kaibab NF in a geographic information system (GIS) format indicate a variety of mostly prehistoric cultural resources are scattered in an approximately 2-mile-wide radius surrounding the Tusayan airport. These data are the result of a number surveys conducted in the vicinity of the airport. A considerable amount of the area within the target circle (around the airport) has not been surveyed, however.

Prehistoric sites types include lithic scatters, resource processing (wild food and lithic chipping) sites, trash scatters, rock art, storage structures, and habitation (field houses, single room, multiple but separate rooms, room blocks, and pit house/surface rooms). Historical sites include railroad grades, logging camps, and mining. Sites cluster at the northern end of the airport in and around Tusayan, at the southern end of the airport, and along the southeast side of the landing strip. The quadrant northwest of airport has very few recorded sites. This apparent clustering is the result of where surveys have been conducted rather than a reflection of prehistoric settlement patterning. Of the 82 sites identified in the GIS target circle, 12 are unevaluated but considered potentially eligible for nomination to the National Register of Historic Places; four have been removed from management consideration; and the remaining 66 sites are unevaluated as to eligibility to the National Register.

Some Class III survey would be required once a potential wellfield location has been determined. Given the potentially high site density represented by the site data (quantifying these data is not possible without knowing the total acreage that has been surveyed, a figure that was not provided in the GIS data), a new survey would identify a number of unrecorded sites. Most of these are likely to be artifact scatters, resource processing sites, field houses, and single room structures.

This alternative may offer some flexibility for siting the wellfield to avoid as many sites as possible and reduce mitigation costs accordingly. In addition to the wellfield, the conveyance pipeline to the South Rim may also be designed to avoid cultural resource sites. Keeping the pipeline within the right-of-way of U.S. Highway 180 into the Park and then within existing road or utility corridors within the park could reduce survey and mitigation costs.

TCP consultation would involve the same tribes and most of the same issues that have been consulted on for the Park. Initiating consultation early in the planning process is strongly recommended.

The MDFZ area is a checkerboard of State and private land, most of which has not be surveyed for cultural resources. Site types expected to be found here are like those identified in the Airport Graben area. A Class III survey would be required. Acquiring rights-of-entry for private lands for survey would require considerable effort and may be only partially successful. Consultation with SHPO and ACHP and with affected or interested tribes and private land owners would be required.

5.9.2.9 Alternative 9.—Under alternative 9, cultural resources issues associated with the continued use of Roaring Springs and related pipeline problems would be the same as for the No Action Alternative.

Cultural resource issues related to the delivery of water from a regional water company or municipality would depend on how water deliveries would be made. If this alternative required construction of a new pipeline to the South Rim, then archaeological surveys, TCP consultation, and mostly likely some level of mitigation for significant cultural resources that cannot be avoided would be needed.

5.9.2.10 Alternative 10.—Under alternative 10, cultural resources issues associated with the continued use of Roaring Springs and related pipeline problems would be the same as for the No Action Alternative.

Assuming that existing transportation routes and facilities are used for water delivery and that no new wells are drilled for obtaining water, cultural resources should not be affected. While no effects to traditional cultural properties are anticipated, consultation with interested tribes is recommended to avoid any misunderstandings.

5.9.2.11 Alternative 11.—Assuming no new construction is required for alternative 11, no effects on prehistoric cultural resources or traditional cultural properties are anticipated. Retrofitting plumbing and other water-related facilities in buildings listed on or eligible for listing on the National Register of Historic Places would require consultation with the SHPO and ACHP.

5.9.2.12 Conclusions.—The assessment is intended to provide decision makers with preliminary data on cultural resource issues for each alternative. Once a preferred alternative is selected, a more intensive cultural resources review can identify specific issues for that alternative. There are, however, a number of issues that apply to most, if not all, of the alternatives and need to be considered.

- Cultural resources need to be considered early in the planning process. Park archaeologists should be included on any planning team to ensure that cultural resource issues and problems are identified early and appropriate actions taken in a timely manner.

- Initiate consultation with SHPO, THPO, ACHP, and appropriate Indian tribes as soon as possible. Consultation for the Glen Canyon EIS and other Park activities has already established points of contact and relationships with tribal cultural resource specialists that should make new consultation easier.

- Cultural resources within the Park are finite and significant (NPS-28 Guidelines). Whenever possible, avoidance or preservation, or both, of cultural resources is recommended. This strategy reduces project costs by avoiding data recovery as well as reducing other costs associated with data recovery such as the level of consultation that can often be time consuming and involved.

- If mitigative data recovery is necessary, a treatment plan for dealing with prehistoric human remains is required. In addition to the SHPO and ACHP, it must be developed in consultation with all Indian tribes that claim affiliation to the remains.

- A public education component should be part of any mitigation project to inform visitors why the project is being undertaken, what was found, and why it is important to park prehistory. This is an ideal opportunity to educate the visitors to the Park not only to the prehistory of the area, but to the need to protect the fragile cultural resources in the Park.

5.10 Indian Trust Assets

5.10.1 Existing Conditions

Indian Trust Assets (ITAs) are legal interests in assets held in trust by the U.S. Government for Indian tribes or individual Indians. Assets are anything owned that has monetary value. The asset need not be owned outright, but could be some other type of property interest, such as a lease or a right-of-use. Assets can be real property, physical assets, or intangible property rights. Common examples of ITAs include lands, minerals, water rights, hunting rights, and rights to other natural resources, or claims. The United States, with the Secretary of the Interior as the trustee, holds many assets in trust for Indian tribes or individual Indians.

Legal interest means there is a primary interest for which a legal remedy, such as compensation or injunction, may be obtained if there is improper interference with the ITA. ITAs do not include things in which a tribe or individuals have no legal interest, such as off-reservation lands defined as sacred by an Indian tribe, in which the tribe has no legal property interest.

The United States has an Indian trust responsibility to protect and maintain rights reserved by or granted to Indian tribes or individual Indians by treaties, statutes, and Executive orders, which rights are sometimes further interpreted through court decisions and regulations. This trust responsibility requires that all Federal agencies take actions reasonably necessary to protect trust assets.

5.10.2 Potential Effects

If construction and permanent conveyance infrastructure do not affect water rights or land owned by tribes or individual Indians, ITAs would not be affected.

5.11 Aesthetics

5.11.1 Existing Conditions

The Grand Canyon is recognized as a place of universal value, containing superlative natural and cultural features. It is unusual in meeting both natural and cultural resource criteria for designation as a world heritage site. The Grand Canyon is internationally recognized for its scenic vistas. Its ever-changing and colorful scenery make it one of the world's most beautiful natural areas. The great variety of scenery includes canyons, deserts, forests, plains, plateaus, streams and waterfalls, and geologic/volcanic features. NPS is tasked with management responsibility to preserve and protect its natural and cultural resources, ecological processes, as well as its scenic and scientific values.

More than 1 million acres in the Park meet the criteria for wilderness designation. The Colorado River and most of its tributaries in the Park meet the criteria for wild river designation as part of the national wild and scenic river system.

5.11.2 Potential Effects

This section discusses whether, and to what degree, construction and post construction project features would affect Park aesthetics.

Alternatives 1 and 5 would minimally affect Park aesthetics. Alternative 1 would maintain existing conditions. The borehole drilling between the North Rim and Roaring Springs under alternative 5 would disturb an approximately 100-foot, by 200-foot area (0.46 acre) on the North Rim. The pumping plant on the rim would be enclosed by a 10-foot, by 10-foot, by 6-foot high building placed on a concrete pad. This would be the only permanent structure on the rim. A new pumping plant would also be required at Roaring Springs but could be located in an already disturbed area to reduce adverse impacts to park aesthetics.

Alternative 2 would have a similar effect on aesthetics as alternative 1 but to a greater degree because large sections of the TCP would be replaced. The aesthetic value of the Bright Angel, North Kaibab, and Old Bright Angel Trails would be degraded during construction under this alternative. Alternative 3 would have a far more significant aesthetic impact on the Corridor Area than alternatives 1, 2, or 5. Under alternative 3, a new TCP would be constructed, which would disturb additional areas within Bright Angel Canyon.

Under alternative 4, removing the reach of the TCP between Roaring Springs and the new pumping plant would have a long-term beneficial effect on Park aesthetics. Construction of a pumping plant on Bright Angel Creek would introduce localized, adverse impacts.

Alternative 6 includes a pumping plant on the mainstem of the Colorado River and a delivery system between the river and South Rim. It would have the greatest effect on Park aesthetics because of the size and number of permanent structures/features proposed.

Wellfield and pipeline construction under alternatives 7 and 8 would have a minor effect on aesthetics. Post-construction landscaping and revegetation efforts within the Park could minimize this effect if designed appropriately.

A pipeline into or out of the Park (alternative 9) would require a utility corridor. If the corridor did not use a previously disturbed area, then trees would be removed to dig the trench and not replanted over the pipeline, leaving a visible utility corridor through the forest.

Alternatives 10 and 11 would not affect Park aesthetics.

5.12 Noise

5.12.1 Existing Conditions

The Park is valued for its unusual and noticeable natural quiet. The major sources of noise within the Park include aircraft overflights, trains, buses, and other motorized vehicles.

5.12.2 Potential Effects

This section discusses if construction activities to haul equipment and materials or post-construction operation and maintenance activities would generate noise levels considered unacceptable to Park visitors or NPS requirements. In general, Reclamation expects sporadic and potentially significant noise effects if any alternative required the use of helicopters to airlift supplies and materials into place.

Alternative 1 and 5 would not significantly affect noise levels because of the minor amount and short duration of construction required. Alternatives 2 and 3 would involve major pipeline construction over an extended period of time, which could generate significant noise impacts within the Corridor Area. The construction noise is expected to be confined to the inner Canyon, however, and most likely would not affect Park visitors on the North or South Rims.

Under alternative 4, construction noise associated with excavation, helicopter transport, heavy equipment, rock crushers, and processors would occur. Post-construction noise would be limited to the operation of the pump, most of which could be dampened through the pump house design. Periodic maintenance flights would occur but not as many as currently support the Phantom Ranch complex.

Alternatives 6 involves construction activities that would generate significant noise levels within the inner Canyon and on the South Rim.

Alternatives 7 would generate noise inside the Park, and alternative 8 would generate noise both inside and outside the Park. The effects of noise on visitors would be greatest where construction occurs within Park boundaries, near visitor use facilities, roads, and trails.

Alternatives 9 and10 would generate minimal noise over existing conditions from increased truck traffic or additional rail cars being pulled by the locomotive. Alternative 11 would not affect noise levels.

Although most of the proposed alternatives would generate higher noise levels, very little can be done to mitigate these effects. Noise levels could be minimized for O&M activities associated with alternatives 4 and 6, however, by enclosing facilities, constructing sound walls or berms, and planting vegetation around the facilities.

5.13 Transportation

5.13.1 Existing Conditions

The primary means of transportation to the South Rim of the Park is by private vehicle through the south entrance. About 90 percent of Park visitation is to the South Rim via State Route 64. In 1998, at the south entrance, 71 percent of all visitors arrived by private vehicle, 16 percent by tour bus, and 11 percent by airport shuttle bus. The Grand Canyon Railway train provides transportation to 2 percent of those visiting the Park. The existing road network around Grand Canyon is congested during the peak visitation season, and traffic conditions at these times are typically substandard.

The two primary highways to the South Rim are U.S. 180 and State Route 64. U.S. Highway 180 connects Flagstaff to Valle, where it joins State Route 64 heading north from Williams. From Valle to Tusayan, the highway is jointly named U.S. Highway 180/State Route 64. The volume of traffic on U.S. Highway 180 between Flagstaff and Valle is 2,414 vehicles per day (vpd). On U.S. 180/State 64 between Valle and Tusayan traffic volume is 4,573 vpd. On State Route 64 inside the Grand Canyon traffic volume is 2,559 vpd.

Grand Canyon Railway provides direct rail transportation to the Park with a vintage, steam-powered train between Williams and the South Rim. In 1998, approximately 143,000 visitors accessed the Park using this train.

5.13.2 Potential Effects

This section discusses whether construction activities inside and outside the Park and/or the use of truck or rail delivery systems would affect the transportation system at the Park.

Because of limited transportation routes (U.S. Highway 180/State Route 64) to the Park, construction activities associated with the alternatives are expected to affect transportation. The extent of the effect would depend on the alternative selected.

Alternative 1 would minimally affect transportation because it involves minor truck traffic to transport the required pipeline sections needed to repair the existing TCP.

Alternatives 2, 3, and 5 would have a moderate effect on transportation. Additional truck traffic would be required to haul heavy equipment and pipe material to the Park before delivery to the inner Canyon. This effect could be reduced to insignificant levels by scheduling truck trips during off-peak hours (12:00 a.m. to 6:00 a.m.). This would include transport of pipe material to the North Rim required to drill the well between the North Rim and Roaring Springs (alternative 5).

Under alternative 4, trucks presumably would transport heavy equipment to the construction site via Highway 180. Therefore, Reclamation recommends development of a contractor use area outside of the Park to facilitate flight operations and contractor staging area requirement to minimize effects of trucks entering and operating at the South Rim. During construction, sections of the TCP would be replaced along the Bright Angel Trail and near Phantom Ranch. Thus, visitor use of these areas would be modified or limited during construction. Post-construction effects would be limited to scheduled maintenance that could require controlled access along the existing transportation corridors.

Alternatives 6 could significantly affect transportation inside and outside the Park. The major traffic disruption would occur to an already over-taxed road system within the

Park. These effects on transportation, however, could be reduced to acceptable levels if scheduled during off-peak hours or during the off-peak season visitation period (fall and winter months).

Alternatives 7 and 8 could have a moderate to significant effect on transportation. Under alternative 7, the wellfield would be developed inside the Park and could disrupt Park traffic significantly when pipeline construction occurs between the wellfield and South Rim storage tanks. This effect, however, could be reduced to moderate levels if construction traffic is confined to the construction right-of-way (ROW) during construction.

Under alternative 8, Park traffic could be disrupted by pipeline construction along U.S. Highway 180/State Route 64 between the Airport Graben or Markham Dam wellfield site and the Park, and the south Park boundary to the storage tanks on the South Rim. If construction traffic were confined to the construction ROW, the effect on transportation could be reduced to moderate levels.

Alternatives 9 and 10 would transport the Park's water supply by road or rail. Additional rail cars on the train carrying the Park's water supply would not affect rail traffic in the area. Alternative 11 would not affect transportation in any way.

5.14 Wilderness Area

5.14.1 Existing Conditions

The Wilderness Act of 1964 defines wilderness as "an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation."

The 1980 Grand Canyon Final Wilderness Recommendation was updated in 1993 and defines the area of proposed wilderness and provides the basis for initiating subsequent actions necessary for maintaining or restoring wilderness suitability. Wilderness designation for the Park was proposed for 1,109,257 acres, with an additional 29,820 acres of potential wilderness pending the resolution of Park boundary and motorized river boat issues.

The 1988 NPS Management Policies require that all wilderness study areas be managed the same as designated wilderness and that no actions be taken that would diminish wilderness suitability until the legislative process for wilderness designation is completed. The Grand Canyon NPS has recently prepared a Wilderness Management Plan that will be consistent with all NPS wilderness policy requirements.

5.14.2 Potential Effects

This section describes the potential effect of the alternatives on designated Wilderness Areas.

Construction activities associated with all alternatives except 6 would not affect designated Wilderness areas. Alternative 6 would involve construction would be within designated Wilderness area and would have a significant adverse impact on an area set aside from development because of its primeval character and influence. In addition, these facilities are considered a permanent development and may require locating permanent staff be on site, which does not comply with NPS Management Policies or the Park's Wilderness Management Plan. Thus, alternative 6 is not considered a viable water supply alternative for the Park.

CHAPTER 6

Consultation and Coordination

This chapter discusses consultation that likely would be required before any of the alternatives could be implemented.

6.1 Endangered Species Act (ESA)

Section 7 of the Endangered Species Act [16 U.S.C. 1531 *et seq.*] outlines the procedures for Federal interagency cooperation to conserve federally listed species and designated critical habitat. Section 7(a)(1) requires Federal agencies to use their authorities to further the conservation of listed species. Section 7(a)(2) requires Federal agencies to consult with the Fish and Wildlife Service (FWS) to ensure that they are not undertaking, funding, permitting, or authorizing actions likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat. Other paragraphs of this section establish the requirement to conduct conferences on proposed species; allow applicants to initiate early consultation; and require the FWS and National Marine Fisheries Services (NMFS) to prepare biological opinions (BO) and issue incidental take statements. Section 7 also establishes procedures for seeking exemptions from the requirements of Section 7(a)(2) from the Endangered Species Committee. Following are definitions of common terms used in the ESA compliance process:

Section 7 Consultation – Includes both consultation and conference if proposed species are involved. [50 CFR § 402]

Section 9 –This section of the Endangered Species Act of 1973, as amended, prohibits the taking of endangered species of fish and wildlife. Additional prohibitions include (1) import or export of endangered species products made from endangered species, (2) interstate or foreign commerce in listed species or their products, and (3) possession of unlawfully taken endangered species. [ESA § 9]

Critical Habitat – For listed species, critical habitat consists of (1) the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of Section 4 of ESA, on which are found those physical or biological features (constituent elements) (a) essential to the conservation of the species and (b) which may require special management considerations or protection and (2) specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of Section 4 of ESA, upon determination by the Secretary that such areas are essential for the conservation of the species. [ESA §3 (5)(A)] Designed critical habitats are described in 50 CFR§17 and 226.

Take – To harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect a proposed threatened and endangered species, or attempt to engage in any such conduct.

As discussed in chapter 5, the proposed project would involve a number of Section 7 and Section 9 issues and require compliance with the ESA before implementation. A description of biological assessments (BA), biological opinions, reasonable and prudent alternatives (RPA), and reasonable and prudent measures (RPM) follows.

Biological Assessment – Information prepared by, or under the direction of a Federal agency to determine whether a proposed action is likely to (1) adversely affect listed species or designated critical habitat, (2) jeopardize the continued existence of species that are proposed for listing, or (3) adversely modify proposed critical habitat. Biological assessments must be prepared for "major construction activities." The outcome of this BA determines whether formal consultation or a conference is necessary. [50 CFR §402.02, 50 CFR §402.14(h)]

Biological Opinion – Document that includes (1) the opinion of the FWS or the NMFS as to whether or not the Federal action is likely to jeopardize the continued existence of listed species, or result in the destruction or adverse modification of designated critical habitat, (2) a summary of the information on which the opinion is based, and (3) a detailed discussion of the effects of the action on listed species or designated critical habitat. [50 CFR § 402.02, 50 CFR § 402.14(h)]

Reasonable and Prudent Alternatives – Recommended alternative actions identified during formal consultation that can be implemented in a manner consistent with the intended purpose of the action, that can be implemented consistent with the scope of the Federal agency's legal authority and jurisdiction, that are economically and technologically feasible, and that the (FWS) Director believes would avoid the likelihood of jeopardizing the continued existence of listed species or the destruction or adverse modification of designated critical habitat. [50 CFR § 402.02]

Reasonable and Prudent Measures – Actions the (FWS) Director believes necessary or appropriate to minimize the impacts, i.e., amount or extent, of incidental take. [50 CFR § 402.02]

6.2 Fish and Wildlife Coordination Act (FWCA)

The Fish and Wildlife Coordination Act requires Federal agencies to consult with FWS and other Federal and State agencies before undertaking or approving water projects that impound or divert surface water. This consultation is intended to promote conservation of fish and wildlife resources in connection with water projects. Federal agencies undertaking water projects are required to fully consider recommendations made by FWS and State fish and wildlife resource agencies in project reports, such as National Environmental Policy Act (NEPA) documents, and include measures to reduce impacts on wildlife in project plans.

6.3 Federal Clean Water Act (CWA)

Most of the alternatives under consideration would require permits under at least one and maybe two sections of the CWA, as amended.

Section 402 of the CWA establishes that a permit is required to discharge pollutants into "Waters of the U.S.," under the National Pollutant Discharge Elimination System (NPDES). (See 40 CFR part 122.) If construction of project components result in discharge of pollutants into waters of the U.S. (including ephemeral washes), an NPDES (402) permit would need to be obtained through the Arizona Department of Environmental Quality (ADEQ), unless the discharge occurs on a reservation. Examples of discharges of pollutants that require a 402 permit are dewatering of streams or groundwater during excavation or fluid discharges from aggregate processing or concrete batching that are allowed to run into stream channels (wet or dry). These permits typically require 9 to 12 months to process.

A 402 stormwater discharge permit also would be required under Section 402 of the CWA before construction begins if 5 acres or more of vegetated land are disturbed. This permit requires the contractor to submit a Notice of Intent (NOI) before beginning any construction and to develop and implement a stormwater pollution prevention plan (SWPPP) to minimize impacts from runoff through construction areas on waters of the United States. This would not be an extensive or expensive effort.

Section 404 of the CWA requires acquisition of a permit from the U.S. Army Corps of Engineers (Corps) to discharge dredged or fill material into "Waters of the U.S." In general, a 404 permit is required for activities that fall below the "ordinary high water mark" (OHWM), which the Corps establishes on a project area specific basis. For this project, the following proposed activities would require a 404 permit: discharge of sediment into the Colorado River, such as excess sediment being trapped in settling ponds on the mainstem of the Colorado River being returned to the river with a sluicing operation (alternative 6) or construction of pipelines where they cross dry or wet washes (alternatives 3, 4, 5, 6, 7, and 8). A 404 permit can take anywhere from several months to over a year to obtain from the Corps.

Some alternatives would affect wetlands. Because wetlands are rare and represent an important habitat type in Arizona, the Corps generally requires the development and implementation of a rigorous habitat mitigation and monitoring plan as a condition of issuing a 404 permit. Typically, an acceptable plan consists of replacement, rehabilitation or enhancement of wetlands within the project area in an amount equal to or greater than the acreage being impacted by the project, and monitoring by the permittee for 5 years afterwards to determine whether or not the targeted number of acres have been adequately replaced or restored (the increased acreage is meant to mitigate for the temporary loss of the habitat during the restoration period). Contingency measures must be included that the permittee would implement if the targeted success rate has not been achieved within the 5-year period. Replacing or rehabilitating wetlands is generally expensive and requires an extensive effort.

To provide a more accurate estimate of the cost of complying with the anticipated requirements of a 404 permit for this project, a person qualified in delineating wetlands would need to conduct a site visit of all portions of the project area that could contain wetlands to better estimate the potentially affected acreage. This person could also determine the likelihood of achieving success in re-establishing an adequate amount of wetlands within the general project area (generally along every stream channel that would be impacted as a result of the project, and at construction site locations). If "in-kind and on-site" mitigation of wetland impacts appears infeasible, another measure that could be proposed in the habitat mitigation and monitoring plan would be to purchase land where there is existing wetland habitat that is subject to impending destruction, which the permittee would be required to manage in perpetuity for habitat preservation. In Reclamation's experience, Corps acceptance of land acquisition as adequate mitigation is difficult to obtain unless the land is clearly threatened with immediate loss of wetland habitat.

At this time, it is not possible to identify the 404 permit requirements associated with diverting Colorado River water. If, for any reason, however, a 404 permit would be needed to address a loss in flow, it is possible that the Corps could attribute any wetland impacts resulting from changes in flows downstream of the existing pipe outlet, to the proposed project, which would also require mitigation.

It is anticipated a 404 permit for the construction of pipelines through typical washes and streams would not require an extensive effort; however, an on-the-ground survey of the proposed pipeline alignments would be needed to confirm this preliminary conclusion.

Reclamation estimates the cost of process the 404 permit for this project would be about $100,000, which is comparable to the processing costs associated with the reservoirs in the Central Arizona Project (CAP). This cost estimate does not include mitigation to compensate for loss of wetlands habitat whose acreage cannot be determined at this time. According to the Corps, the basic rate to replace wetlands habitat range from $25,000 to $50,000 per acre. The higher amount is based on wetlands that require irrigation the first to year to help establish the habitat.

6.4 State Historic Preservation Officer (Section 106 Compliance)

Before constructing pumping plants, settling ponds, pipelines, sluice channel, etc., Class III (intensive) cultural resource surveys would be required. Some level of mitigation effort would be required, including but not limited to avoidance, excavation, Historic American Engineering Record (HAER) documentation, and public education. A Programmatic Agreement (PA) must be developed between the NPS, the Advisory Council on Historic Preservation, the State Historic Preservation Officer and affected land managing agencies (e.g., BLM, Kaibab National Forest), and other interested parties (i.e., the Havasupai, Hualapai, Hopi, Paiute, and San Juan Southern Paiute Tribes and the Navajo Nation).

Preparation of a PA and associated review and consultation with all parties to the PA, as well as consultation with all affected Indian Tribes and other interested parties concerning TCPs and sacred sites, would require considerable effort and time. The PA must be signed and in place before beginning planned mitigation.

Mitigation costs cannot be determined until the cultural resource surveys are completed and consultation with the SHPO and the NHPO has determined the number of significant cultural resource sites (including traditional cultural properties) affected by the project. Consultation with interested or affected tribes or other parties, or both, also would be necessary to assess the effects on traditional cultural properties and sacred sites, as well as identify appropriate forms of mitigation. While it is highly unlikely that previously unknown ruins would be identified as being affected by the project, a number of archaeological sites would be affected and would require some level of investigation. Incorporating a proactive approach to cultural resource consultations and investigations early in the project planning process can reduce cultural resource mitigation costs.

A cultural resources program that is reactive and initiated late in the planning process can result in project delays and often results in higher project costs. This may be particularly true in the case of a project in which considerable consultation can be anticipated with interested and affected tribes concerning traditional cultural properties and sacred sites.

Furthermore, development of a PA would require time to complete the necessary reviews and consultations. The sooner these initiatives can begin, the less likely the possibility of project delays and possible higher costs.

CHAPTER 7

Conclusions and Recommendations

In conclusion, alternatives 1 through 5 appear to be viable alternatives, but a number of environmental issues for each would need to be resolved. Alternative 6 would have a significant effect on a designated Wilderness area. Alternatives 7 and 8 could significantly affect springs and seeps both inside and outside the Park.

Based on the potentially viable alternatives identified in this appraisal study, it is recommended to proceed to feasibility study. The focus of the feasibility study would be investigate the potentially viable alternatives in detail and to develop a preferred plan that would meet the water supply needs of the Grand Canyon National Park through the year 2050. National Environmental Policy Act compliance would be completed in conjunction with the feasibility study.

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Appendices

Appendix 1	Cost Estimates
Appendix 2	Field Report and Cathodic Protection Recommendations
Appendix 3	Hydraulic Design Notes
Appendix 4	Cultural Resources

Cost Estimates

This appendix includes cost estimate worksheets for the construction alternatives, alternatives 1-8. The following miscellaneous components are typical items not included in the estimated costs:

- Switchyard for electrical powerlines
- Environmental surveys/clearance/mitigation
- Design and investigations
- Security, fencing, etc.
- SCADA system
- Additional storage tank(s) at wellhead and/or at the North or South Rim
- Drainage facilities/culverts

CODE: D-8140

ESTIMATE WORKSHEET

SHEET 1

FEATURE: 1-Aug-2001

Grand Canyon Pipeline Project
No Action - Add Storage at Phantom Ranch
Alternative 1

filename: C:\123R5W\WORK\Grand Canyon\[hydrgc1.xls]Estimates

PROJECT

DIVISION

UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	1	Concrete Storage Tank		LS	1	$200,000	$200,000
		Dia. = 65,000 gal. , Ht. = 23 ft, dia = 22 ft.					
	2	Pipeline Excavation		cy	216	$140	$30,240
		Assume 100% rock, trail width 8 ft, cover over pipe - 3 ft.					
	3	Pipeline Backfill		cy	124	$95	$11,780
	4	Pipeline Select Backfill		cy	76	$650	$49,400
		Assume material would be helicoptered to site					
	6	Steel Pipe					
		4B200 t=.0747		ft	1,000	$25	$25,000
	6	Pumping Plant		LS	1	$200,000	$200,000
		Q = 0.14 cfs, H = 120 ft , HP = 2, one pump					
		50 cu. ft. pressure tank, 2 isolation valves					
		Concrete slab, concrete building					
		Mobilization		LS	1	$510,000	$510,000
		Subtotal					$1,026,420 ✓
		Unlisted Items= 5%					$73,580 ✓
		Contract Cost					$1,100,000 ✓
		Contingency = 25%					$250,000 ✓
		Field Cost					$1,350,000 ✓

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED [signature] 9/20/2001
DATE PREPARED 9/17/01	DATE	DATE 9/19/01	PRICE LEVEL

CODE: D-8140

ESTIMATE WORKSHEET

SHEET 2

FEATURE: 1-Aug-2001

Grand Canyon Pipeline Project
Replace Portions of TCP
Alternative 2

filename C:\123R5W\WORK\Grand Canyon\[hydrgc1.xls]Estimates

PROJECT

DIVISION

UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMO
		Replace 1000 foot section of existing Trans Canyon Pipeline.					
		Remove existing aluminum pipe and replace with steel.					
	1	Pipeline Excavation		cy	216	$110	$23,
		Assume 100% rock, trail width 3 feet, 1,000 ft long					
		Cover over 8" pipe - 2ft.					
	2	Pipeline Backfill		cy	124	$95	$11,
	3	Pipeline Select Backfill		cy	76	$650	$49,
		Assume material would be helicoptered to site					
	4	Steel Pipe					
		8A4000 t=.416		ft	1,000	$135	$135,
		Total replacement will be 10,000 ft. in 10 yrs.					
	5	Cost for remaining 9,000 ft over 9 years		ls	1	$1,979,460	$1,979
		Replace 2000 foot section of existing Trans Canyon Pipeline.					
		Remove existing aluminum pipe and replace with steel.					
	6	Pipeline Excavation		cy	432	$110	$47,
		Assume 100% rock, trail width 8 feet, 2,000 ft long					
		Cover over 8" pipe - 2ft.					
	7	Pipeline Backfill		cy	248	$95	$23,
	8	Pipeline Select Backfill		cy	152	$650	$98,
		Assume material would be helicoptered to site					
	9	Steel Pipe					
		8A3000 t=.305		ft	2,000	$113	$226,
		Total replacement will be 26,000 ft. in 13 yrs.					
	10	Cost for remaining 24,000 ft over 12 years		ls	1	$4,750,560	$4,750
		Mobilization		ls	1	$8,350,000	$8,350
		Subtotal					$15,6
		Unlisted Items= 5%					$8
		Contract Cost					$16,5
		Contingency = 25%					$4,5
		Field Cost					$21,0

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED Craig A. [signature] 9/20/
DATE PREPARED 9/17/01	DATE	DATE 9/19/01	PRICE LEVEL

CODE: D-8140

ESTIMATE WORKSHEET

SHEET 3

FEATURE: 1-Aug-2001

Grand Canyon Pipeline Project
Replace entire TCP pipeline (Roaring Springs to Colorado River)
Alternative 3

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PROJECT

DIVISION

UNIT -

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	1	Pipeline Excavation		cy	6,580	$110	$723,825
		Remove and replace 6" aluminum pipe sta. 155+00 to sta 459+64					
		Assume 100% rock, trail width 3 feet, cover over pipe - 2 ft.					
	2	Pipeline Excavation		cy	4,205	$110	$462,550
		Remove and replace 8" aluminum pipe sta. 459+64 to sta 654+30					
		Assume 100% rock, trail width 8 ft, cover over pipe - 2 ft.					
	3	Pipeline Backfill		cy	6,191	$95	$588,145
	4	Pipeline Select Backfill		cy	3,795	$630	$2,390,850
		Assume material would be helicoptered to site					
	5	Steel Pipe					
		8A1000 t=.097 Area 2		ft	9,733	$92	$895,436
		8A2000 t=.199 Area 2		ft	9,733	$95	$963,567
		8A3000 t=.305 Area 1		ft	15,964	$11[illegible]	$1,803,932
		8A4000 t=.416 Area 1		ft	14,500	$11[illegible]	$1,957,500
		Mobilization		ls	1	$8,500,000	$8,500,000
		Subtotal					$18,285,805 ✓
		Unlisted Items= 5%					$714,195 ✓
		Contract Cost					$19,000,000 –
		Contingency = 25%					$5,000,000 ✓
		Field Cost					$24,000,000 ✓

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED Craig A. [signature] 9/20/2001
DATE PREPARED 9/17/01	DATE	DATE 9/19/01	PRICE LEVEL

CODE D-8140

ESTIMATE WORKSHEET

SHEET 4

FEATURE: 1-Aug-2001

Grand Canyon Pipeline Project
Bright Angel Creek Infiltration Gallery
Alternative 4

filename: C:\123R5W\WORK\Grand Canyon\[hydrgc1 xls]Estimates

PROJECT

DIVISION

UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	1	Pipeline Excavation		cy	1,858	$140	$260,120
		Assume 100% rock, trail 5 ft wide (cover = 3 ft over pipe)					
	2	Pipeline Backfill		cy	1,752	$95	$166,440
	3	Pipeline Select Backfill		cy	96	$650	$62,400
		Assume material would be helicoptered to site					
	4	Power Cable Excavation		cy	574	$470	$269,780
	5	Power Cable Select Backfill		cy	546	$750	$409,500
	6	Steel Pipe					
		12B100 t=.125		ft	1,500	$70	$105,000
		4B200 t=.0747		ft	4,000	$25	$100,000
	7	Power Cable - medium voltage 5 Kv line		ft	15,500	$20	$310,000
		Installed in pipe trench and along existing pipeline					
		Trench depth = 2 ft. & width = 6", backfill with select backfill					
	8	Pumping Plant		LS	1	$1,400,000	$1,400,000
		Concrete = 65 cy					
		Excavation = 726 cy					
		Compacted Backfill = 504 cy					
		2 pumps: Q=2.16 cfs, H= 4938 ft					
	9	Infiltration Gallery		LS	1	$500,000	$500,000
		36D25 concrete pipe = 55 ft.					
		Concrete = 6 cy					
		Uniformly graded gravel = 58 cy					
		Excavation = 185 cy					
		Compacted Backfill = 30 cy					
		Riprap = 105 cy					
	10	Conventional Treatment Plant at South Rim		LS	$1	$3,600,000	$3,600,000
	11	Package Treatment Plant @ Phantom Ranch		LS	1	$25,000	$25,000
		Q = 14,000 gal/day					
	12	Concrete Storage Tank (65,000 gal, 23' high, 22' dia.)		LS	1	$200,000	$200,000
		Mobilization		LS	1	$3,400,000	$3,400,000
		Subtotal					$10,808,240 ✓
		Unlisted Items= 5%					$691,760 ✓
		Contract Cost					$11,500,000 ✓
		Contingency = 25%					$2,500,000 ✓
		Field Cost					$14,000,000 ✓

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED Craig A. Funk 9/20/2001
DATE PREPARED 9/17/01	DATE	DATE 9/19/01	PRICE LEVEL

CODE D-8140

ESTIMATE WORKSHEET

SHEET 5

FEATURE: 1-Aug-2001

Grand Canyon Pipeline Project
North Rim Directional Drill
Water Tank Site
Alternative 5A

filename: C:\123R5W\WORK\Grand Canyon\[hydrgc1.xls]North Rim

PROJECT

DIVISION

UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	1	Submersible vertical turbine pump		LS	1	$50,000	$50,000
		H = 3500 ft., Q= 0.54 cfs, HP =214					
	2	Power Cable - medium voltage 5 Kv line		ft	1,000	$54	$54,000
		Installed in new trench with select backfill					
		Trench depth = 2 ft. & width = 6"					
	1	Pump house on North Rim		LS	1	$50,000	$50,000
		Assume metal building on flat slab					
	1	Steel Pipe (casing)					
		8B3000 t=.305		ft	11,300	$32	$361,600
	5	Directional Drilling		LS	1	$6,650,000	$6,650,000
		Assume 1 - 8 3/4" hole					
		Length = 9,500 ft					
		Mobilization		LS	1	$360,000	$360,000
		Subtotal					$7,525,600
		Unlisted Items = 10%					$774,400 ✓
		Contract Cost					$8,300,000 ✓
		Contingency = 25%					$2,200,000 ✓
		Field Cost					$10,500,000 ✓

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED [signature] 9/20/2001
DATE PREPARED 9/17/01	DATE	DATE 9/17/01	PRICE LEVEL

CODE D-8140

ESTIMATE WORKSHEET

SHEET 6

FEATURE: 1-Aug-2001

Grand Canyon Pipeline Project
North Rim Directional Drill
One Hole
Alternative 5B1

filename: C:\123R5W\WORK\Grand Canyon\[hydrgc1.xls]North Rim

PROJECT

DIVISION

UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	1	Pipeline Excavation		cy	344	$160	$55,040
		Assume 100% rock, follow existing trail, 1800 ft long					
		Cover over 4" pipe - 2ft.					
	2	Pipeline Backfill		cy	223	$120	$26,760
	3	Pipeline Select Backfill		cy	121	$750	$90,750
		Assume material would be helicoptered to site					
	4	Steel Pipe					
		4B3000 t=.15 (Install in directional drill hole)		ft	4,000	$32	$128,000
		4B4000 t=.20		ft	1,800	$40	$72,000
	5	Directional Drilling		LS	1	$2,800,000	$2,800,000
		Assume 1 - 8 3/4" hole					
		Length = 4,000 ft					
		Mobilization		LS	1	$760,000	$760,000
		Subtotal					$3,932,550 ✓
		Unlisted Items= 5%					$167,450 ✓
		Contract Cost					$4,100,000 ✓
		Contingency = 25%					$1,100,000 ✓
		Field Cost					$5,200,000 ✓

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED [signature] 9/20/2001
DATE PREPARED 9/17/01	DATE	DATE 9/17/01	PRICE LEVEL Appraisal

CODE D-8140

ESTIMATE WORKSHEET

SHEET 7

FEATURE: 1-Aug-2001

Grand Canyon Pipeline Project
North Rim Directional Drill
Two Holes .
Alterative 5B2

filename: C:\123R5W\WORK\Grand Canyon\[hydrgc1.xls]North Rim

PROJECT

DIVISION

UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	1	Pipeline Excavation		cy	344	$160	$55,040
		Assume 100% rock, follow existing trail, 1800 ft long					
		Cover over 4" pipe - 2ft.					
	2	Pipeline Backfill		cy	223	$120	$26,760
	1	Pipeline Select Backfill		cy	121	$750	$90,750
		Assume material would be helicoptered to site					
	4	Steel Pipe					
		4B3000 t=.15 (Install in directional drill hole)		ft	9,000	$32	$128,000
		4B4000 t=.20		ft	1,800	$40	$72,000
	4	Directional Drilling		LS	1	$5,600,000	$5,600,000
		Assume 2 - 8 3/4" holes					
		length =4,000 ft					
	4	Power Cable - medium voltage 5 Kv line		ft	9,800	$20	$196,000
		Installed in pipe trench and					
		two in the 8-inch drill hole.					
		Mobilization		LS	1	$1,000,000	$1,000,000
		Subtotal					$7,168,550 ✓
		Unlisted Items= 5%					$331,450 ✓
		Contract Cost					$7,500,000 ✓
		Contingency = 25%					$7,500,000 ✓
		Field Cost					$9,400,000 ✓

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED Craig A. [signature] 9/20/2001
DATE PREPARED 9/17/01	DATE	DATE 9/17/01	PRICE LEVEL

CODE D-8140

ESTIMATE WORKSHEET

SHEET 8

FEATURE: 1-Aug-2001

Grand Canyon Pipeline Project
Tanner Alignment
Alternative 6a

filename: C:\123R5W\WORK\Grand Canyon\[hydrgc1.xls]Estimates

PROJECT

DIVISION

UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	4	Pipeline Excavation		cy	7,128	$140	$997,920
		Assume 100% rock, trail width 3 feet, 31,000 ft long					
		Cover over 8" pipe - 2ft.					
	2	Pipeline Backfill		cy	4,092	$69	$388,740
	3	Pipeline Select Backfill		cy	2,508	$650	$1,630,200
		Assume material would be helicoptered to site					
	4	Steel Pipe					
		8A1000 t=.097		ft	2,400	$62	$148,800
		8A2000 t=.199		ft	15,500	$69	$1,069,500
		8A3000 t=.305		ft	5,500	$69	$539,500
		8A4000 t=.416		ft	5,500	$140	$577,500
		8A5000 t=.532		ft	3,100	$140	$434,000
	6	Power Cable - medium voltage 5 Kv line		ft	33,000	$20	$660,000
		Installed in pipe trench.					
	6	Pumping Plant		LS	1	$1,600,000	$1,600,000
		Concrete = 64 cy					
		Excavation = 2328 cy					
		Compacted Backfill = 2124 cy					
		2 pumps: Q=2.16 cfs, H= 4938 ft					
	4	Infiltration Gallery		LS	1	$600,000	$600,000
		36D25 concrete pipe = 55 ft.					
		30D25 concrete pipe = 122 ft.					
		Concrete = 6 cy					
		Uniformly graded gravel = 58 cy					
		Excavation = 1950 cy					
		Compacted Backfill = 30 cy					
		Riprap = 105 cy					
	4	Conventional Treatment Plant at South Rim		LS	1	$3,600,000	$3,600,000
		Mobilization		LS	1	$5,600,000	$5,600,000
		Subtotal					$17,846,160 ✓
		Unlisted Items= 5%					$653,840 ✓
		Contract Cost					$18,500,000 ✓
		Contingency = 25%					$4,500,000 ✓
		Field Cost					$23,000,000 ✓

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED Craig A. [signature] 9/20/2001
DATE PREPARED 9/17/01	DATE	DATE 9/19/01	PRICE LEVEL Appraisal

CODE: D-8140

ESTIMATE WORKSHEET

SHEET 9

FEATURE: 1-Aug-2001

Grand Canyon Pipeline Project
Cardenas Alignment
Alternative 6b

filename: C:\123R5W\WORK\Grand Canyon\[hydrgc1 xls]Estimates

PROJECT

DIVISION

UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	1	Pipeline Excavation		cy	2,052	$140	$287,280
		Assume 100% rock, pioneer trail, 6,500 ft long					
		Cover over 8" pipe - 2ft.					
	2	Pipeline Backfill		cy	1,178	$95	$111,910
	3	Pipeline Select Backfill		cy	228	$650	$148,200
		Assume material would be helicoptered to site					
	4	Steel Pipe					
		8A3000 t=.305 Install in direction drill hole		ft	11,000	$32	$352,000
		8A4000 t=.416		ft	6,500	$105	$682,500
		8A5000 t=.532		ft	3,000	$105	$420,000
	9	Power Cable - medium voltage 5 Kv line		ft	31,500	$20	$6[illegible]0,000
		Installed in pipe trench and					
		two in the 8-inch drill hole.					
	9	Pumping Plant		LS	1	$1,600,000	$1,600,000
		Concrete = 64 cy					
		Excavation = 2878 cy					
		Compacted Backfill = 2320 cy					
		2 pumps: Q=2.16 cfs, H= 4938 ft					
	7	Infiltration Gallery		LS	1	$600,000	$600,000
		36D25 concrete pipe = 55 ft.					
		30D25 concrete pipe = 122 ft.					
		Concrete = 6 cy					
		Uniformly graded gravel = 58 cy					
		Excavation = 1950 cy					
		Compacted Backfill = 30 cy					
		Riprap = 105 cy					
	9	Directional Drilling		LS	1	$19,800,000	$19,800,000
		Assume 1 -12 3/4" hole and 1 - 8 3/4" hole					
		length = 11,000 ft					
	9	Conventional Treatment Plant at South Rim		LS	1	$3,600,000	$3,600,000
		Mobilization		LS	1	$2,500,000	$2,500,000
		Subtotal					$30,731,890 ✓
		Unlisted Items= 5%					$1,268,110 ✓
		Contract Cost					$32,000,000 ✓
		Contingency = 20%					$7,000,000 ✓
		Field Cost					$39,000,000 ✓

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED Craig A. Gensh 9/20/2001
DATE PREPARED 9/17/01	DATE	DATE 9/19/01	PRICE LEVEL

CODE D-8140

ESTIMATE WORKSHEET

SHEET 10

FEATURE: 1-Aug-2001

Grand Canyon Pipeline Project
Comanche Alignment
Alternative 6c

filename C:\123R5W\WORK\Grand Canyon\[hydrgc1 xls]Estimates

PROJECT

DIVISION

UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	8	Pipeline Excavation		cy	5,282	$140	$1,288,280
		Assume 100% rock, pioneer trail 5,600 ft long in canyon					
		Follow new road on Rim. Cover over 8" pipe - 2ft.					
	8	Pipeline Backfill		cy	5,282	$95	$501,790
	8	Pipeline Select Backfill		cy	3,238	$140	$647,600
		Assume 800 cy of material would be helicoptered to site					
		in canyon					
	8	Steel Pipe					
		8A4000 t=.416 Install in direction drill hole		ft	5,500	$95	$220,000
		8A5000 t=.532		ft	5,500	$140	$784,000
		8A500 t=.0747		ft	31,500	$62	$1,953,000
	8	Power Cable - medium voltage 5 Kv line		ft	48,100	$20	$962,000
		Installed in pipe trench and					
		two in the 8-inch drill hole.					
	8	Pumping Plant		LS	1	$1,600,000	$3,600,000
		Concrete = 64 cy					
		Excavation = 2878 cy					
		Compacted Backfill = 2320 cy					
		2 pumps: Q=2.16 cfs, H= 4938 ft					
	8	Infiltration Gallery		LS	1	$600,000	$600,000
		36D25 concrete pipe = 55 ft.					
		30D25 concrete pipe = 122 ft.					
		Concrete = 6 cy					
		Uniformly graded gravel = 58 cy					
		Excavation = 1950 cy					
		Compacted Backfill = 30 cy					
		Riprap = 105 cy					
	8	Directional Drilling		LS	1	$9,900,000	$3,600,000
		Assume 1 -12 3/4" hole and 1 - 8 3/4" hole					
		Length = 5500 ft					
	8	Conventional Treatment Plant at South Rim		LS	1	$3,600,000	$3,600,000
	10	Pioneer new access road		LF	21,120	$20	$422,400
		Four miles long, 16 ft. wide, 4" gravel surfacing					
		Mobilization		LS	$1	$9,900,000	$4,000,000
		Subtotal					$26,479,070
		Unlisted Items= 5%					$1,520,930
		Contract Cost					$28,000,000
		Contingency = 20%					$5,000,000
		Field Cost					$33,000,000

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED Craig A. [signature] 9/20/2001
DATE PREPARED 9/17/01	DATE	DATE 9/19/01	PRICE LEVEL

CODE: D-8140

ESTIMATE WORKSHEET

SHEET 11

FEATURE:	1-Aug-2001	PROJECT
Grand Canyon Pipeline Project Wellfield Inside Park Long Jim Canyon Site Alternative 7		DIVISION
filename: C:\123R5W\WORK\Grand Canyon\[hydrgc1.xls]Estimates		UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	1	Submersible vertical turbine pump		pumps	15	$30,000	$[illegible]0,000
		H = 3500 ft., Q= 0.144 cfs, HP =100					
	2	Power Cable - medium voltage 5 Kv line		ft	9,000	$54	$[illegible],000
		Installed in new trench with select backfill					
		Trench depth = 2 ft. & width = 6"					
	3	Access Road		LF	9,000	$24	$216,000
		Assume 24 foot wide, 9000 ft long road pioneered to site					
		4-inch gravel surfacing					
	1	Steel Pipe (casing)					
		10B3000 t=.350 15 wells		ft	45,000	$54	$2,250,000
	6	Wellfield Drilling		LS	1	$19,312.500	$19,312,500
		Assume 15 wells, 3250 ft deep and 16" in diameter					
		Well screen = 100 feet/well.					
		Gravel pack = 400 feet/well					
	6	4" Discharge Piping		ft	45,000	$30	$1,350,000
		t = 0.14 15 wells					
	7	Forebay Tank (5000 gal steel)					
	6	Pipeline Excavation (100%rock)		cy	19,244	$20	$384,880
	6	Pipeline Select material		cy	2,077	$60	$124,620
	10	Pipeline Backfill		cy	17,310	$5	$86,550
	11	PVC pipe					
		8-inch DR41		ft	9,000	$15	$135,000
		12-inch DR41		ft	32.000	$2[illegible]	$800.000
	1[illegible]	Pumping Plant		LS	1	$700,000	$800.000
		Q= 2.16 cfs, H = 50 ft, HP =25					
		Flat slab plant					
		Mobilization		LS	1	$1,300,000	$1,350,000
		Subtotal					$27,595,550 ✓
		Unlisted Items = 10%					$2,404,450 ✓
		Contract Cost					$30,000,000 ✓
		Contingency = 25%					$8,000,000 ✓
		Field Cost					$38,000,000 ✓

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED [signature] 9/20/2001
DATE PREPARED 9/17/01	DATE	DATE 9/19/01	PRICE LEVEL

CODE: D-8140

ESTIMATE WORKSHEET

SHEET 12

FEATURE: 1-Aug-2001 Grand Canyon Pipeline Project Wellfield Outside Park Markham Dam Alternative 8 filename C:\123R5W\WORK\Grand Canyon\[hydrc1.xls]Estimates	**PROJECT** **DIVISION** **UNIT**

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	8	Submersible vertical turbine pump		pumps	15	$30,000	$450,000
		H = 3500 ft., Q= 0.144 cfs, HP =100					
	2	Power Cable - medium voltage 5 Kv line		ft	45,000	$54	$540,000
		Installed in new trench with select backfill					
		Trench depth = 2 ft. & width = 6"					
	8	Access Road		LF	10,000	$24	$240,000
		Assume 24 foot wide, 10,000 ft long road pioneered to site					
		4-inch gravel surfacing					
	3	Steel Pipe (casing)					
		10B3000 t=.350 15 wells		ft	45,000	$50	$2,250,000
	8	Wellfield Drilling		LS	1	$19,312,500	$19,312,500
		Assume 15 wells, 3250 ft deep and 16" in diameter					
		Well screen = 100 feet/well.					
		Gravel pack = 400 feet/well					
	6	4" Discharge Piping		ft	45,000	$30	$1,350,000
		t = 0.14 15 wells					
	7	Forebay Tank (5000 gal steel)					
	8	Pipeline Excavation (100 % rock)		cy	93,265	$20	$1,865,300
	9	Pipeline Select Backfill		cy	12,007	$60	$720,420
	9	Pipeline Backfill		cy	83,345	$5	$416,725
	10	PVC pipe					
		8-inch DR41		ft	10,000	$15	$150,000
		16-inch DR41		ft	185,000	$25	$4,625,000
	11	Pumping Plants (3)		Each	3	$1,000,000	$3,000,000
		Q= 2.16 cfs, H = 500 ft, HP = 125					
		Flat slab plant					
		Assume 200 cu. ft. air chamber at each plant.					
		Mobilization		LS	1	$1,600,000	$1,600,000
		Subtotal					$36,519,945 ✓
		Unlisted Items = 10%					$3,480,055 ✓
		Contract Cost					$40,000,000 ✓
		Contingency = 25%					$10,000,000 ✓
		Field Cost					$50,000,000 ✓

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED Greg A. Gush 9/20/2001
DATE PREPARED 9/17/01	DATE	DATE 9/19/01	PRICE LEVEL

APPENDIX 2

Field Report and Cathodic Protection Recommendations

A2.1 Introduction

The transcanyon pipeline (TCP) is approximately 12.5 miles long. The pipeline was originally constructed of 6- and 8-inch diameter, dielectric coated, aluminum (alloy 6061 and 6070). In 1986 a section of pipeline was replace with 8-inch diameter steel pipe (64+00 to 77+00). The aluminum pipeline was installed with in-line, cast iron valves. The cast iron valves were electrically isolated from the aluminum pipeline using isolating flange kits on each side of the valve (figure 1) and as a result the pipeline is divided into electrically isolated sections. Cathodic protection was installed on the pipeline in 1972 and consisted of magnesium anodes, rheostats, shunts, anode bonding boxes, and insulator bonding boxes. The cathodic protection design included 16 magnesium anodes which were buried in creek or river beds. The anode bonding boxes provide a means of connecting the anode to the pipeline. The anode bonding boxes contain a rheostat and shunt to adjust and determine the current output of the anode, and a test cable for pipe-to-soil potential measurements. The insulator bonding boxes (figure 2) are installed at in-line, cast iron valves and contain a rheostat and shunt to adjust and determine the current flow between the two adjacent electrically isolated pipeline sections.

The cathodic protection system was abandoned in the mid 1970's; however, no specific measures were taken to physically disconnect the anodes from the pipeline. Apparently the cathodic protection system was abandoned because numerous failures were reportedly caused by internal corrosion on the pipeline. It should be noted that the type of cathodic protection system installed on the TCP, anodes buried in the earth, will only provide cathodic protection to the pipeline surfaces in contact with the earth, i.e. the outside diameter of the pipeline. The inside diameter of the pipeline will not be effected by this type of cathodic protection system. For a cathodic protection system to provide corrosion protection to the inside diameter of a pipeline the anodes must be installed within the pipeline.

A2.2 Testing and Data Analysis

Corrosion testing planned as part of this investigation were a close interval potential survey within the area of reported external corrosion failures (Phantom Ranch area, stations 167+33 to 189+75), pipe-to-soil potentials at in-line insulators and anode locations, current across in-line insulators, and current output of anodes. The close interval potential survey is capable of identifying areas on the pipeline that are actively corroding. The remaining tests evaluate the operation of the cathodic protection system, although, if the tests were conducted periodically (once a year for multiple years) and compared to one another they could give an indication of corrosion activity.

The close interval potential survey within the Phantom Ranch area could not be conducted because the correct key for the lock of the valve vault at station 189+75 was not available and other methods to remove the lock failed. Therefore, the portion of this investigation which would identify actively corroding areas on the pipeline could not be conducted.

The data collected to evaluate the operation of the cathodic protection system are presented in the table at the end of this report. Of the sixteen anodes originally installed on the pipeline only eight could be directly tested (anodes 5, 7, 8, 10, 12, 14, 15, and 16). Anodes 1, 2, 3, 4, 6, 9, 11, and 13 could not be directly tested because their anode bonding box was not located or could not be accessed.

For the sections of pipeline protected by the anodes that were not directly tested pipe-to-soil potentials indicate that anodes 1, 6, 9, 11, and 13 are not providing adequate cathodic protection to their respective section of the pipeline. Pipe-to-soil potentials were not obtained from pipeline sections for which anodes 2 and 4 were designed to protect. Pipe-to-soil potentials indicate a protective potential on the upstream section on the pipeline at station 97+15 and, as such, anode 3 may be providing adequate cathodic protection to the section of pipeline to which it is attached (station 97+15 to 123+52).

Anodes 5 and 7 are not providing cathodic protection to the pipeline. The anode cables for anodes 5 and 7 were visually inspected and found to be severed (figure 3). The ends of the cables appeared to have been severed for some time. It is speculated that the anode cables were severed by the buildup of debris on the cables during flash floods. Several other anode cables were exposed within the creek beds and are likely severed.

Anode 8 had no measurable current output, although, the pipe-to-soil potential using the anode cable indicates that the anode is intact. Pipe-to-soil potentials for the section of pipeline for which anode 8 was designed to protect do not indicate adequate cathodic protection.

Anode 10 had a measurable current output of 2 milliamps, although, pipe-to-soil potentials do not indicate adequate cathodic protection. Anode 10 was disconnected from the pipeline during testing without a significant change in pipe-to-soil potential, this indicates that the anode is not providing adequate cathodic protection.

Anode 12 had a measurable current output of 1 milliamp, although, pipe-to-soil potentials do not indicate adequate cathodic protection. Anode 12 was disconnected from the pipeline during testing without a significant change in pipe-to-soil potential, this indicates that the anode is not providing adequate cathodic protection.

Anode 14 had no measurable current output and pipe-to-soil potentials do not indicate adequate cathodic protection.

Anode 15 had no measurable current output, although, pipe-to-soil potentials at this location indicate excessive levels cathodic protection. Pipe-to-soil potentials at this location are similar to that of the open circuit potential for a high potential magnesium anode (the open circuit potential of an anode is the "pipe-to-soil" potential of the anode when it is disconnected from pipeline). Other pipe-to-soil potentials for the section of pipeline for which anode 15 was designed to protect do not indicate excessive or adequate cathodic protection. The data indicates a possible high resistance in the circuit between the test station and pipeline, possibly severed cables or high resistance at the pipe clamp-to-pipeline connection used in the cathodic protection system design. Although the potentials measured within the anode bonding box indicate excessive levels of cathodic protection it is unlikely that these are representative of the pipeline potentials at this location.

Anode 16 had no measurable current output and pipe-to-soil potentials do not indicate adequate cathodic protection.

Two additional test stations, of different design and materials than the original cathodic protection system, were located on the pipeline at stations 563+03 (figure 4) and ~613+00 (bridge over Bright Angel Creek at confluence of Manzanita Creek). These additional test stations do not have a shunt or rheostat. It appears that the test stations are used to connect anodes to the pipeline. Pipe-to-soil potentials at both locations do not indicate adequate cathodic protection.

In summary, the test data indicates that the cathodic protection system for the TCP is not providing adequate cathodic protection and from a practical standpoint is essentially non-functional. The majority of pipe-to-soil potentials determined are typical of native pipe-to-soil potentials for buried aluminum (the potential of buried aluminum without or prior to cathodic protection) and current output of the anodes are non-measurable or minimal.

It should be noted that there is the possibility that the cathodic protection system is providing very minimal levels of protection on portions of the pipeline. This should be taken into consideration during any future corrosion related testing on the pipeline.

A2.3 Miscellaneous

The 1993 Arber Corrosion Assessment report identified corrosion on the exterior of the pipeline. Without further investigations it can only be assumed that there is active corrosion occurring on the pipeline and, as such, corrosion failures of the pipeline are expected. Corrosion failure rates on pipelines increase with time if corrosion mitigation techniques are not implemented. If the existing pipeline is to provide long term service without corrosion related failures reestablishment of cathodic protection on the pipeline should be considered. Because of the cathodic protection characteristics of aluminum and the unique site specific conditions extensive field testing of the existing pipeline is required to properly and adequately design a cathodic protection system, including determining the type of cathodic protection system (impressed or galvanic) most suited for this particular application. Cathodic protection on this pipeline must be implemented carefully and regular monitoring of the cathodic protection system is essential.

Apparently numerous pipeline failures have occurred on cold bent sections of the pipeline. The cold bent sections have higher residual stresses than the remainder of the pipeline. Corrosion has been reported on internal and external surfaces of the pipeline. Because of higher residual stresses of the bends and experienced corrosion, stress corrosion cracking as an operative failure mechanism is surmised. For stress corrosion cracking to be operative the following conditions are required: a susceptible material, presence of tensile stress, and specific environmental exposure. Metallurgical analysis is required to identify stress corrosion cracking failures. Visual corrosion products may not be present with stress corrosion cracking failures and pipe-to-soil potentials surveys conducted on pipelines are not capable of identifying areas of stress corrosion cracking. If stress corrosion cracking is operative cathodic protection is a method of mitigation.

To determine the extent of pipeline corrosion activity and pipeline failure mechanisms extensive investigations are required. To determine the extent of corrosion activity field testing is required on multiple sections of the pipeline. In addition, the field testing should be verified by physical examination of the pipeline at selected locations. To identify failure mechanisms a failure investigation is required on pipeline failures. The failure investigation should, as a minimum, document date, location, and cause of failure, including a metallurgical evaluation of the failed pipe section and fracture surfaces.

An impressed current, cathodic protection system rectifier was noted at Indian Gardens Pumping Plant. Park personnel indicated that the impressed current cathodic protection system was installed on the pipeline between the pumping plant and South Rim. Reportedly there are test stations along the pipeline between the pumping plant and portal of the directional drill hole, and the cathodic protection system has not been monitored. Although the rectifier was energized its voltage and current outputs were minimal and it is questioned if the system is providing adequate cathodic protection to the pipeline.

Typical monitoring requirements for this type of impressed current cathodic protection system includes monthly monitoring of the rectifier outputs and yearly pipe-to-soil potentials at all test stations.

A2.4 Conclusions and Recommendations

1. The test data indicates that the cathodic protection system for the TCP is not providing adequate cathodic protection and from a practical standpoint is essential non-functional.

2. The pipeline section that anode 3 was designed to protect appears to be receiving adequate cathodic protection.

3. Although the cathodic protection system was abandoned in the mid 1970's no physical means of abandonment were undertaken, i.e., disconnecting the anodes from the pipeline. It is possible that the cathodic protection system could have provided adequate cathodic protection to the pipeline for a period of time after is was abandoned.

4. If the existing pipeline is to provide long term service without corrosion related failures reestablishment of cathodic protection on the pipeline should be considered. Cathodic protection of the pipeline must be implemented carefully and regular monitoring of the cathodic protection system is essential.

5. To date pipeline failures have not been consistently documented. It is recommended that a failure investigation be conducted on pipeline failures. The failure investigation should, as a minimum, document date, location, and cause of failure, including a metallurgical evaluation of the failed pipe section and fracture surfaces.

6. To determine the extent of corrosion activity on the pipeline field testing is required, including physical examination of the pipeline at selected locations.

7. It is recommended that the impressed current cathodic protection system installed at the Indian Gardens Pumping Plant be tested to determine if it is providing adequate cathodic protection and adjusted as required. Once it is verified that the cathodic protection system is providing adequate cathodic protection is it recommended that it be monitored on a regular basis.

Figure 1. Typical valve box. Cast iron valve is electrically isolated from aluminum pipeline by insulated flange kits on each side of the valve. Cables are attached to the pipeline flanges and terminate in insulator bonding box (lower portion of figure). Isolation of the valve from the pipeline results in the aluminum pipeline being divided into electrically isolated sections.

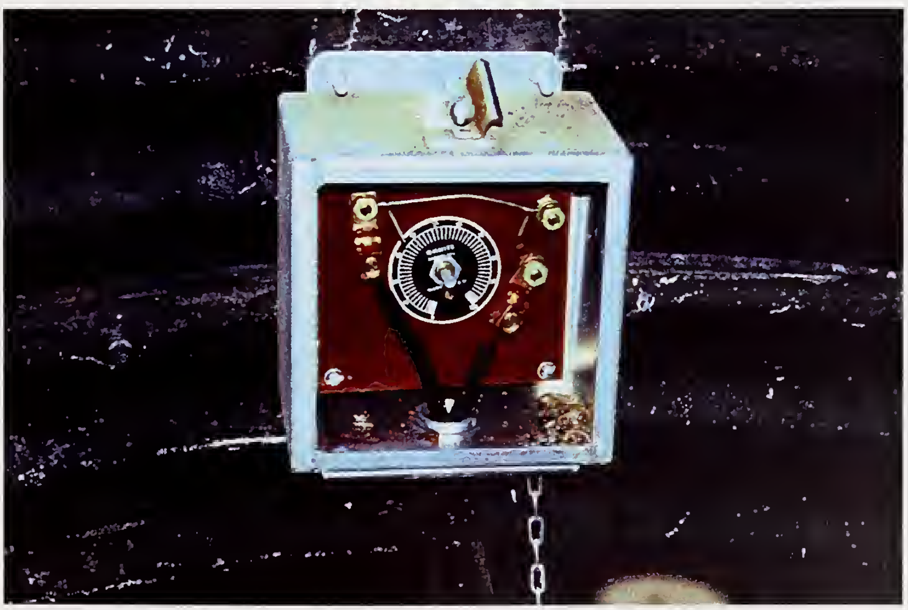

Figure 2. Typical insulator bonding box. Cables originate from the upstream and downstream pipeline sections at cast iron valves (see figure 1). Bonding box contains a rheostat (black circular faceplate, knob is missing) and shunt (wire above rheostat) to adjust and determine the current flow between the two adjacent electrically isolated pipeline sections. Anode bonding boxes are similar except they have an addition cable which freely terminates in the box and is used for measuring pipe-to-soil potentials.

Figure 3. Anode 7 at pipeline stationing 242+30. Anode cable has been severed (arrow) and appeared to have been severed for some time. It is speculated that the anode cable was severed by the buildup of debris on the cables during flash flooding.

Figure 4. Test station at pipeline station 563+03. The test station (top arrow) is of a different design and materials than the original cathodic protection system materials. The test station does not have a rheostat or shunt and appears to connect an anode to the pipeline. The anode cable is exposed between test station and lower arrow, and is susceptible to damage.

GRAND CANYON NATIONAL PARK TCP				
Cathodic Protection System Pipe-to-Soil Potentials and Shunt Measurements March 1 and 2, 2001				
Station	Description	Pipe-to-Soil[1] (mV)	Shunt (mA)	Comments
~23+80		-876		Pipe exposed at Garden Creek Crossing.
24+52	Corrugated valve box with: Insulator bonding box Anode 1 bonding box Anode 2 bonding box			Wrong keys, could not access interior of vault.
82+90	Corrugated valve box with: Insulator bonding box			Not located.
97+15	Corrugated valve box with: Insulator bonding box	-850		Downstream pipe.
		-1050		Upstream pipe.
			1	Across insulators, rheostat 100%.
123+52	Corrugated valve box with: Insulator bonding box Anode 3 bonding box			Not located.
145+25	Corrugated valve box with: Insulator bonding box Anode 4 bonding box			Not located.
163+90	Anode 5 bonding box			Box located under bridge, not accessed. Anode cable severed.
189+75	Corrugated valve box with: Insulator bonding box			Wrong keys, could not access interior of vault.

GRAND CANYON NATIONAL PARK TCP				
Cathodic Protection System Pipe-to-Soil Potentials and Shunt Measurements March 1 and 2, 2001				
Station	Description	Pipe-to-Soil[1] (mV)	Shunt (mA)	Comments
228+98	Anode 6 bonding box			New bridge, could not locate anode box.
240+90	Corrugated valve box with: Insulator bonding box	-779		Pipe downstream.
		-764		Pipe upstream.
			2	Across insulators, rheostat 100%.
242+30	Anode 7 bonding box			Anode box under bridge, but could not open. Anode cable severed.
280+67	Corrugated valve box with: Insulator bonding box	-800		Pipe downstream.
		-787		Pipe upstream.
			4	Across insulators, rheostat 100%.
287+65	Anode 8 bonding box	-1172	0	Rheostat 100%.
		-800		
326+63	Corrugated valve box with: Insulator bonding box	-781		Pipe downstream.
		-778		Pipe upstream.
			5	Across insulators, rheostat 100%.
345+00	Anode 9 bonding box			New bridge, could not locate anode box.
362+63	Corrugated valve box with: Insulator bonding box	-729		Pipe downstream.
		-702		Pipe upstream.
			3	Across insulators, rheostat 100%.
372+00	Anode 10 bonding box		2	Rheostat 100%.
		-706		#12 white, as found.
		-703		#12 white, anode disconnected.

GRAND CANYON NATIONAL PARK TCP				
Cathodic Protection System Pipe-to-Soil Potentials and Shunt Measurements March 1 and 2, 2001				
Station	Description	Pipe-to-Soil[1] (mV)	Shunt (mA)	Comments
		-702		#12 white, anode reconnected.
386+12	Corrugated valve box with: Insulator bonding box	-768		Pipe downstream.
		-755		Pipe upstream.
			5	Across insulators, rheostat 100%.
401+53	Anode 11 bonding box			Not found.
445+00	Corrugated valve box with: Insulator bonding box	-757		Pipe downstream.
		-755		Pipe upstream.
			3	Across insulators, rheostat 100%.
493+13	Corrugated valve box with: Insulator bonding box	-760		Pipe downstream, as found..
		-760		Pipe downstream, anode disconnected.
		-761		Pipe upstream.
			3	Across insulators, rheostat 100%.
	Anode 12 bonding box	-760	1	#12 white.
510+21	Anode 13 bonding box and manual air relief valve			Located air relief valve, but could not locate anode bonding box. New rock wall installed along trail.
563+03	Anode ??	-770		Test station without a shunt or rheostat.
542+58	Corrugated valve box with: Insulator bonding box	-790		Pipe downstream.
		-780		Pipe upstream.
			0	Across insulators, rheostat 100%.
579+00	Anode 14 bonding box	-791	0	# 12 white, rheostat 100%.

GRAND CANYON NATIONAL PARK TCP Cathodic Protection System Pipe-to-Soil Potentials and Shunt Measurements March 1 and 2, 2001				
Station	Description	Pipe-to-Soil[1] (mV)	Shunt (mA)	Comments
583+00	Corrugated valve box with: Insulator bonding box	-790		Pipe downstream.
		-788		Pipe upstream.
			1	Across insulators, rheostat 100%.
591+00	Anode 15 bonding box	-1795		# 6 AWG with white tape.
		-1795		# 12 AWG blue.
		-1713		# 6 AWG.
		-60		#12 AWG white.
			0	Knob of rheostat removed.
~ 613+00	Anode ??	-835		Test station without a shunt or rheostat. Test station at bridge over Bright Angel Creek at confluence of Manzanita Creek.
619+24	Corrugated valve box with: Insulator bonding box	-775		Pipe downstream.
		-801		Pipe upstream.
				Across insulators, rheostat 100%.
647+90	Corrugated valve box with: Insulator bonding box	-565		Pipe downstream.
			0	Across insulators, rheostat 0%.
	Anode 16 bonding box		0	Anode 16 rheostat 100%.

1. Pipe-to-soil potentials determined with a copper/copper sulfate reference electrode.

A2.5 Projected Cathodic Protection Investigation Costs

These cost estimates assumes two Reclamation employees onsite for each task, with transportation modes of walking and helicopter. Two options relating to tasks 1 and 2 are presented. Option 1 includes evaluating the entire cathodic protection system for the aluminum TCP (Roaring Springs to Indian Gardens). Option 2 includes evaluating the cathodic protection system on the aluminum portion of the pipeline between Phantom Ranch and Indian Gardens.

Task 1. In-depth evaluation of existing galvanic anode cathodic protection system on the aluminum TCP, including report. Evaluating the existing galvanic anode cathodic protection system will consist of the following sequential steps (each step must be completed prior to conducting the next step):

1) Determine "As Found" conditions.
   a. Protective pipe-to-soil potentials at anode locations and at each end of electrically isolated sections.
   b. Current outputs of all anodes.
   c. Current flow across all insulators.

2) Disconnect all anodes from pipeline by disconnecting anode cable from terminal in anode bonding box

.

3) Determine "Off" conditions:
   a. Pipe-to-soil potential at anode locations and at each end of electrically isolated sections.
   b. Anode-to-soil potential of disconnected anodes.
   c. Current flow across all insulators.

4) Reconnect anodes as required.

Task 2. Collect design data required to design cathodic protection system for aluminum TCP, including conceptual design(s) of cathodic protection system. Testing at selected locations may include, but not limited to, the following:

1) Current requirement testing.
2) Coating resistance testing.
3) Span resistance testing.
4) Laboratory testing for soil chemistry and resistivity.

Task 3. Evaluate and adjust existing impressed current cathodic protection system on the buried steel pipeline between Indian Gardens Pumping Plant and lower portal of the South Rim bore hole. Task 3 will be accomplished during Task 1 activities and reported in Task 1 report.

The above tasks require access to valve boxes, anode bonding boxes, and insulator bonding boxes. Prior to initial onsite work the Park Service is to locate and verify access to interior of the applicable valve boxes, anode bonding boxes, and insulator bonding boxes. In addition, the Park Service is to provide accommodations within the Canyon; helicopter service for individuals, equipment, and supplies; and a minimum of one individual to serve as a guide and to assist with testing.

The following two tables provide the estimated cost per option. The tables in the appendix were used to estimate the staff days related to onsite visits and also to provide insight into logistics and scheduling.

Option 1 - Estimated Cost 1. Task 1 and 2 - Roaring Springs to Indian Gardens 2. Task 3		
Evaluation of Existing Cathodic Protection Systems (Task 1 and 3)		
Travel - Labor (Skill Level 3)	170 hrs @ $100/hr	$17,000
Travel - Labor (Skill Level 2)	170 hrs @ $90/hr	$15,300
Travel - Non-labor	$4000	$4,000
Non-labor equipment	$500	$500
Report (Skill Level 3)	80 hrs @ $100/hr	$8,000
	Subtotal	$44,800
Cathodic Protection Design Data Collection (Task 2)		
Travel - Labor (Skill Level 3)	182 hrs @ $100/hr	$18,200
Travel - Labor (Skill Level 2)	182 hrs @ $90/hr	$16,380
Travel - Non-labor	$4000	$4,000
Non-labor equipment	$1500	$1,500
Soil Chemistry	$1500	$1,500
Data analysis and conceptual design	80 hrs. @ $100/hr	$8,000
	Subtotal	$49,580
		$94,380
	10% (Contingency)	$9,438
	Total	$103,818
	Estimated Cost	**$104,000**

Option 2 - Estimated Cost		
1. Task 1 and 2 - Phantom Ranch to Indian Gardens 2. Task 3		
Evaluation of Existing Cathodic Protection Systems (Task 1 and 3)		
Travel - Labor (Skill Level 3)	88 hrs @ $100/hr	$8.800
Travel - Labor (Skill Level 2)	88 hrs @ $90/hr	$7.920
Travel - Non-labor	$2000	$2.000
Non-labor equipment	$500	$500
Report (Skill Level 3)	80 hrs @ $100/hr	$8,000
	Subtotal	$27.220
Cathodic Protection Design Data Collection (Task 2)		
Travel - Labor (Skill Level 3)	106 hrs @ $100/hr	$10.600
Travel - Labor (Skill Level 2)	106 hrs @ $90/hr	$9.540
Travel - Non-labor	$2000	$2,000
Non-labor equipment	$1500	$1,500
Soil Chemistry	$1000	$1,000
Data analysis and conceptual design	80 hrs. @ $100/hr	$8,000
	Subtotal	$32.640
		$59.860
	10% (Contingency)	$5,986
	Total	$65.846
	Estimated Cost	**$66,000**

Attachment

Task Details

Option 1 Evaluation of Existing Cathodic Protection Systems Task 1 - Roaring Springs to Indian Gardens Task 3		
Day (Trip/Day)	Activities	Hours
Preparation	Trip preparation.	32
1/1	Travel - Denver to South Rim.	8
1/2	Helicopter to Roaring Springs. Roaring Springs to Anode 9, testing. Night at Phantom Ranch.	10
1/3	Anode 9 to Pipe Creek, testing. Night at Indian Gardens.	10
1/4	Indian Gardens to Plateau Point, testing. Discount Anodes 1 and 2. Evaluate Impressed System. Night at Indian Gardens.	10
1/5	Helicopter from Indian Gardens to Roaring Springs. Disconnect anodes 16 thru 6. Night at Phantom Ranch.	10
1/6	Disconnect anodes 5 thru 3. Helicopter from Indian Gardens to South Rim. Night on South Rim.	10
1/7	Travel - South Rim to Denver.	8
Preparation	Trip preparation.	16
2/1	Travel - Denver to South Rim.	8
2/2	Helicopter to Roaring Springs. Roaring Springs to Anode 9, testing. Night at Phantom Ranch.	10
2/3	Anode 9 to Pipe Creek, testing. Night at Indian Gardens.	10
2/4	Indian Gardens to Plateau Point, testing. Indian Gardens to Phantom Ranch, reconnecting anodes as required. Night at Phantom Ranch.	10
2/5	Phantom Ranch to Roaring Springs, reconnecting anodes as required. Helicopter from Roaring Springs to South Rim. Night at South Rim.	10
2/6	Travel - South Rim to Denver.	8
	Total hours per individual	170

Option 1 Cathodic Protection Design Data Collection Task 2 - Roaring Springs to Indian Gardens		
Day (Trip/Day)	Activities	Hours
Preparation	Trip preparation.	40
3/1	Travel - Denver to South Rim.	8
3/2	Helicopter to Indian Gardens. Testing Indian Gardens/Plateau Point area. Night at Indian Gardens.	10
3/3	Testing Indian Gardens/Plateau Point area. Night at Indian Gardens.	10
3/4	Helicopter between Indian Gardens and Phantom Ranch. Testing Phantom Ranch/Colorado River area. Night at Phantom Ranch.	10
3/5	Testing Phantom Ranch/Colorado River area. Night At Phantom Ranch	10
3/6	Testing Phantom Ranch/Colorado River area. Helicopter between Phantom Ranch and South Rim.	10
3/7	Travel - South Rim to Denver.	8
Preparation	Trip preparation.	20
4/1	Travel - Denver to South Rim.	8
4/2	Helicopter to north portion of pipeline? Testing north portion of pipeline. Night at ?	10
4/3	Testing north portion of pipeline. Night at ?	10
4/4	Testing north portion of pipeline. Night at ?	10
4/5	Testing north portion of pipeline. Helicopter to South Rim. Night at South Rim.	10
4/6	Travel - South Rim to Denver.	8
	Total hours per individual	182

Option 2 Evaluation of Existing Cathodic Protection Systems Task 1 - Phantom Ranch to Indian Gardens Task 3		
Day (Trip/Day)	Activities	Hours
Preparation	Trip preparation.	32
1/1	Travel - Denver to South Rim.	8
1/2	Helicopter to Indian Gardens. Indian Gardens to Phantom Ranch, testing. Night at Phantom Ranch.	10
1/3	Phantom Ranch to Indian Gardens, disconnecting anodes. Evaluate impressed current system at Indian Gardens. Night at Indian Gardens.	10
1/4	Evaluate impressed current system Indian Gardens. Indian Gardens to Phantom Ranch, testing. Night at Phantom Ranch.	10
1/5	Phantom Ranch to Indian Gardens, reconnecting anodes as required. Helicopter from Indian Gardens to South Rim. Night at South Rim.	10
1/6	Travel - South Rim to Denver.	8
	Total hours per individual	88

Option 2 Cathodic Protection Design Data Collection Task 2 - Phantom Ranch to Indian Gardens		
Day (Trip/Day)	Activities	Hours
Preparation	Trip preparation.	40
2/1	Travel - Denver to South Rim.	8
2/2	Helicopter to Indian Gardens. Testing Indian Gardens/Plateau Point area. Night at Indian Gardens.	10
2/3	Testing Indian Gardens/Plateau Point area. Night at Indian Gardens.	10
2/4	Helicopter between Indian Gardens and Phantom Ranch. Testing Phantom Ranch/Colorado River area. Night at Phantom Ranch.	10
2/5	Testing Phantom Ranch/Colorado River area. Night at Phantom Ranch.	10
2/6	Testing Phantom Ranch/Colorado River area. Helicopter between Phantom Ranch and South Rim.	10
2/7	Travel - South Rim to Denver.	8
	Total hours per individual	106

APPENDIX 3

Hydraulic Design Notes

	Annual flow AF	Average Flow (cfs)	Peaking Factor	Pump Factor*	Maximum Flow (cfs)
Current Demand AF	800	1.11	1.3	1.2	1.72
Current Max. Delivery					1.56
2050 Demand AF	1255	1.73	1.3	1.2	2.70
2050 Demand South Rim	1004	1.39	1.3	1.2	2.16
2050 Demand North Rim	251	0.35	1.3	1.2	0.54

Assume North rim is 20% of peak flow during summer
* Pump 20 hours out of 24

ALUMINUM - EXISTING PIPE -		CURRENT DEMAND								
Pipe dia. (in)		8	6	8	6	8	Totals			
Q(CFS)	700 gpm	1.56	1.56	1.56	1.56	1.56				
Velocity		4.471	7.949	4.471	7.949	4.471				
Station		65430	42010	7700	2454	1203				
Station		42010	7700	2454	1203	5				
Length (ft)		23420	34310	5246	1251	1198	65425.0			
Head Loss / 1000 ft	Scobey's	12.472	56.484	12.472	56.484	12.472				
Friction Loss (ft)		292.1	1938.0	65.4	70.7	14.9				
Head Loss R = .003	Darcy's	174.82	1139.19	39.16	41.54	8.94				
Hazen-Williams	143	185.20	1101.32	41.48	40.16	9.47				
Head Loss R = .0005	Darcy's	132.94	832.85	29.78	30.37	8.80				
Begin El		5206	3380	2250	3600	3700				
End El		3380	2250	3600	3700	3787		Plus Bend Losses	Total Loss	HGL @ Indian Gardens
Begin HGL		5206	5021	3919	3878	3838				
End HGL		5021	3919	3876	3838	3828				
			Hazen-Williams (143)		TOTAL LOSS =		1378	21.8	1399	3807

			Annual flow AF	Average Flow (cfs)	Peaking Factor	Pump Factor*	Maximum Flow (cfs)
Roaring Springs El.	5206						
Indian Gardens El.	3787	Current Total Park Demand	800	1.11	1.3	1.2	1.72
	1439	Current Max. Delivery to South Rim					1.56
		2050 Demand (South Rim only)	1004	1.39	1.3	1.2	2.18

* Pump 20 hours out of 24

ALUMINUM - EXISTING PIPE		2050 DEMAND								
Pipe dia. (in)		8	6	8	6	8	Totals			
Q(CFS)		2.18	2.16	2.18	2.16	2.16				
Velocity		6.201	11.024	6.201	11.024	8.201				
Station		65430	42010	7700	2454	1203				
Station		42010	7700	2454	1203	5				
Length (ft)		23420	34310	5246	1251	1198	65425.0			
Head Loss R = .003	Darcy's	336.23	2190.91	75.31	79.88	17.20	2699.5	2753.5		
Hazen-Williams	143	339.34	2016.03	76.01	73.58	17.36	2524.3	2574.6		
Begin HGL		5206	4867	2849	2773	2699				
End HGL		4867	2849	2773	2699	2682				
					TOTAL LOSS =		2524	37.9	2562	2644

STEEL PIPE - MORTAR LINED										
Pipe dia. (in)		6	8	6	8	6				
Q(CFS)		2.18	2.18	2.18	2.18	2.16				
Velocity		6.201	8.201	11.024	11.024	11.024				
Station		65430	42010	7700	2454	1203				
Station		42010	7700	2454	1203	5				
Length (ft)		23420	34310	5246	1251	1198	65425.0			
Head Loss R = .003	Darcy's	336.23	519.91	317.37	79.88	72.48	1325.9	1352.4		
Hazen-Williams	140	352.93	517.04	320.91	76.53	73.29	1340.7	1367.5		
Begin HGL		5206	4853	4336	4015					
End HGL		4853	4336	4015	3939					
					TOTAL LOSS =		1267	19.0	1286	3920

FIBERGLASS PIPE										
Pipe dia. (in)		8	8	8	8	8	Totals			
Q(CFS)		2.16	2.16	2.16	2.16	2.16				
Velocity		6.201	6.201	11.024	11.024	11.024				
Station		65430	42010	7700	2454	1203				
Station		42010	7700	2454	1203	5				
Length (ft)		23420	34310	5248	1251	1198	65425.0			
Head Loss R = .0005	Darcy's	255.68	380.10	241.34	58.40	55.11	990.6	1010.5		
Head Loss Hazen-Williams(150)		310.60	455.03	262.42	87.35	64.49	1179.9	1203.5		
Begin HGL		5206	4895	4440	4158					
End HGL		4895	4440	4158	4091					
					TOTAL LOSS =		1115	16.7	1132	4074

ALUMINUM - EXISTING PIPE		2050 DEMAND		REPAIR SECTIONS -						
Pipe dia. (in)		8	8	8	8	8	Totals			
Q(CFS)		2.16	2.18	2.18	2.18	2.16				
Velocity		8.201	6.201	6.201	11.024	6.201				
Station		65430	42010	7700	2454	1203				
Station		42010	7700	2454	1203	5				
Length (ft)		23420	34310	5246	1251	1198	65425.0			
Head Loss R = .003	Darcy's	336.23	519.91	75.31	79.88	17.20	1028.5	1049.1		
Hazen-Williams	143	339.34	497.14	76.01	73.58	17.36	1003.4	1023.5		
Begin HGL		5206	4867	4370	4294	4220				
End HGL		4867	4370	4294	4220	4203				
					TOTAL LOSS =		1003	15.1	1018	4188

Long Jim Canyon				
Pipe dia. (in)		16	12	16
Q(CFS)		2.18	2.16	2.16
Velocity		1.548	2.752	1.548
Length (ft)		185000	32000	62000
Head Loss R = .003	Darcy's	82.74	60.31	27.73
Hazen-Williams	143	91.40	64.18	30.63
Begin HGL		143	339	2018
End HGL		52	275	1987

NORTH RIM DIRECTIONAL DRILL

	Annual flow AF	Average Flow (cfs)	eaking Factor	Pump Factor*	Maximum Flow (cfs)
Current North Rim Demand	160	0.22	1.3	1.2	0.34
North Rim 2050 demand	251	0.35	1.3	1.2	0.54

Pipe dia. (in)		4	4			
Q(CFS) 700 gpm		0.54	0.54			
Velocity		6.191	6.191			
Station		5000	6800			
Station		1000	5000			
Length (ft)		4000	1800			
Hazen-Williams	143	129.67	58.35			
Begin El		5067	3950			
End El.		8262	5067			
Total Head	feet	3195	4312			
	psi	1383	1867			
Thickness	in	0.15	0.20			
Begin HGL		8262	8132			
End HGL		8132	8074			
			Hazen-Williams (143)		TOTAL LOSS =	188

North Rim El	8262
Roaring Springs El.	3950
	4312

OPERATING COSTS						TOTAL Q =	2.16	CFS		
Site			CARDENAS	TANNER	COMANCHE	Bright Angel Creek		Bright Angel Creek		
Construction Method			Drill + Overland	Overland	Drill + Overland	Overland		Overland		
Pipe dia. (in)			8	8	8	6	6	6	6	
Q(CFS)	700 gpm		2.16	2.16	2.18	2.16	2.16	2.16	2.16	
Velocity			6.2	6.2	6.2	6.2	11.0	6.2	11.0	
Total Length			21000	31000	10000	14145		20345		
Overland			9000	31000	4600	5094	9051	11294	9051	
Drill			12000	0	5400	0		0		
Hazen-Williams		143	173.37	447.86	76.01	73.59	530.80	163.17	530.80	
Begin El			2560	2560	2600	2450		2450		
End El.			7050	7050	7050	3767		7050		
Static Head (ft)			4490	4490	4450	1317		4600		
Begin HGL			4663	4938	4528	1921		5294		
End HGL			4490	4490	4450	1848		5131		
Pump Lift			4663	4938	4528	1921		5294		
HP			1143	1210	1110	471		1297		
KWH			1187	1257	1152	489		1347		
Friction/Static			4%	10%	2%	46%		15%		
Total Head		feet	4663	4938	4528	1921		5294		
		psi	2019	2138	1960	832		2292		
Thickness		in	0.44	0.47	0.43	0.18		0.50		
Pipe Excavation			3303	11377	1688	1869		4145		
Pipe Backfill			2943	10137	1504	1666		3693		
CONSTRUCTION COSTS										
Pumping Plant Cost			$200,000	$200,000	$200,000	$150,000				
Survey Cost			$34,839	$120,000	$55,200	$0				
Power Line Costs			$630,000	$930,000	$300,000	$200,000				
Pipe Cost		$2.00	$1,868,732	$2,929,019	$862,872	$0				
Pipe Excavation		$20.00	$66,080	$227,540	$33,764	$37,390				
Pipe Backfill		$15.00	$44,145	$152,055	$22,563	$24,986				
Directional Drill Costs			$3,500,000	$0	$1,200,000	$0		Note: 2 Holes Power + Water		
Water Treatment Plant Cost										
Pioneer Road					$100,000					
Storage Tank Costs										
Total Construction Costs			$6,343,776	$4,558,614	$2,774,399	$412,376				
ANNUAL COSTS										
Demand Charge		0.000	$0	$0	$0	$0				
Service pass thru		0.000	$0	$0	$0	$0				
Energy Charge		0.052	$450,466	$476,981	$437,391	$185,600				
Cost of Power ($/yr)			$450,466	$476,981	$437,391	$185,600				
Annual Cost of Pump Sta.										
over 20 yrs. @ 8%(.0871)($)			$17,420	$17,420	$17,420	$13,065				
Total annual cost of										
pumping ($/yr)			$467,886	$494,401	$454,811	$198,665				
Annual cost of pipeline over										
40 yrs @ 8%(.0664)($)			$124,084	$194,487	$57,295	$0				
Water Treatment										
Total annual costs ($)			$591,969	$688,888	$512,106	$198,665				

EXISTING PIPE SIZES

LENGTH	SIZE	STATION	STATION	
1198	8	0+05	12+03	Indian Gardens
1251	6	12+03	24+54	
5246	8	24+54	77+00	
2190	6	77+00	98+90	Pipe Creek
32210	6	98+00	420+10	
23420	8	420+10	654+30	Roaring Springs

Bend Station	Bend angle	Sheet No	Bend Loss ft	
21289	51 5	22	0 0559	Q = 1 56
214+00	54 75		0 0586	V = 4 47 ft/s
215+42	52 75		0 0573	
216+30	21		0 0228	4 47
217+21	21 75		0 0236	
217+88	33 25		0 0361	
218+23	26 8		0 0291	
218+90	34 8		0 0378	
219+49	55 7	22	0 0605	
220+57	21	23	0 0229	
221+44	31 8		0 0345	
221+98	49 8		0 0542	
223+53	15 15		0 0165	
224+03	26 6		0 0289	
225+47	16		0 0174	
225+97	29 5		0 0320	
227+30	66 75		0 0725	
228+09	14 5		0 0157	
229+03	52		0 0565	
229+32	56 8	23	0 0617	
230+48	17 4	24	0 0189	
232+15	24		0 0261	
232+53	39 6		0 0430	
233+52	4		0 0043	
234+48	10 3		0 0112	
234+83	13 2		0 0143	
236+14	19 25		0 0209	
237+52	47 6		0 0517	
238+01	54 2		0 0589	
238+72	18		0 0195	
239+41	22	24	0 0239	
240+27	14 75	25	0 0160	
241+47	20 1		0 0218	
241+83	29 5		0 0320	
243+94	30 5		0 0331	
245+04	18 5		0 0201	
245+60	20 5		0 0223	
246+10	43 4		0 0471	
246+91	27 1		0 0294	
248+81	long radius?		0 0000	
249+55	11 6	25	0 0126	
250+80	9 5	26	0 0103	
251+53	11 6		0 0126	
251+89	long radius?		0 0000	
252+60	long radius?		0 0000	
252+73	30 8		0 0334	
253+47	46 5		0 0505	
255+17	16 4		0 0178	
255+58	13 5		0 0147	
256+85	58 4		0 0645	
257+18	49 9		0 0542	
257+94	46 4		0 0504	
258+22	45 7		0 0496	
259+00	21 4		0 0232	
259+28	72 6	26	0 0788	
260+38	15	27	0 0163	
261+58	51 9		0 0564	
262+11	59 3		0 0644	
262+58	46		0 0500	
262+98	long radius?		0 0000	
263+85	long radius?		0 0000	
264+03	30 8		0 0334	
265+38	25 75		0 0280	
266+78	66 9		0 0726	
267+20	32 6		0 0354	
267+75	23		0 0250	
268+37	24		0 0261	
268+71	21 8		0 0237	
269+94	11 1	27	0 0121	
270+96	14	28	0 0152	
271+67	6 8		0 0074	
272+18	long radius?		0 0000	
273+43	long radius?		0 0000	
273+55	25 5		0 0277	
273+95	38 3		0 0416	
274+39	16 3		0 0177	
275+79	39 9		0 0433	
276+59	6 9		0 0075	
277+64	30 5		0 0331	
278+83	59		0 0641	
279+70	21	28	0 0228	
280+12	22 5	29	0 0244	
280+82	17 8		0 0193	
281+25	long radius?		0 0000	
281+90	long radius?		0 0000	
284+00	18		0 0195	
284+97	13		0 0141	
286+30	21 75		0 0236	
286+92	64 5		0 0700	
287+30	9 7		0 0105	
288+14	16 8		0 0182	
288+95	42 4		0 0460	
289+42	24 6	29	0 0267	
290+01	32 7	30	0 0355	
290+84	16 25		0 0176	
291+42	8 5		0 0092	
291+98	6 5		0 0071	
292+84	26 75		0 0290	
294+87	14 35		0 0156	
294+93	25 75		0 0280	
295+25	46		0 0500	
295+41	40		0 0434	
295+83	27 25		0 0296	
296+12	23 9		0 0260	
296+62	long radius?		0 0000	
297+95	long radius?		0 0000	
298+45	20 65		0 0224	
298+88	25 75		0 0280	
299+72	10	30	0 0109	
300+09	27 8	31	0 0302	
300+78	11 8		0 0128	
301+21	41		0 0445	
301+81	7 9		0 0086	
303+84	long radius?		0 0000	
306+00	long radius?		0 0000	
307+23	18 1		0 0197	
308+21	long radius?		0 0000	
30990	long radius?	31	0 0000	
			3 2467	Length = 9701

Bend loss per foot = 0 00033468
Total Loss = 21 58524484

265+38	25 75		0 0280
266+78	66 9		0 0726
267+20	32 6		0 0354
267+75	23		0 0250
268+37	24		0 0261
268+71	21 8		0 0237
269+94	11 1	27	0 0121
270+96	14	28	0 0152
271+67	6 8		0 0074
272+18	long radius?		0 0000
273+43	long radius?		0 0000
273+55	25 5		0 0277
273+95	38 3		0 0416
274+39	16 3		0 0177
275+79	39 9		0 0433
276+59	6 9		0 0075
277+64	30 5		0 0331
278+83	59		0 0641
279+70	21	28	0 0228
280+12	22 5	29	0 0244
280+82	17 8		0 0193
281+25	long radius?		0 0000
281+90	long radius?		0 0000
284+00	18		0 0195
284+97	13		0 0141
286+30	21 75		0 0236
286+92	64 5		0 0700
287+30	9 7		0 0105
288+14	16 8		0 0182
288+95	42 4		0 0460
289+42	24 6	29	0 0267
290+01	32 7	30	0 0355
290+84	16 25		0 0176
291+42	8 5		0 0092
291+98	6 5		0 0071
292+84	26 75		0 0290
294+87	14 35		0 0156
294+93	25 75		0 0280
295+25	46		0 0500
295+41	40		0 0434
295+83	27 25		0 0296
296+12	23 9		0 0260
296+62	long radius?		0 0000
297+95	long radius?		0 0000
298+45	20 65		0 0224
298+88	25 75		0 0280
299+72	10	30	0 0109
300+09	27 8	31	0 0302
300+78	11 8		0 0128
301+21	41		0 0445
301+81	7 9		0 0086
303+84	long radius?		0 0000
306+00	long radius?		0 0000
307+23	18 1		0 0197
308+21	long radius?		0 0000
30990	long radius?	31	0 0000

RIVER MILE STATIONING

	River Mile	Thalwag Elevation	5000 cfs Elevation	97000 cfs Elevation	Elevation Difference
Tanner Canyon	68.47	2645	2648	2666	18
Tanner Canyon Site	70	2604	2624	2643	19
Cardenas Creek Site	70.75	2607	2620	2640.7	20.7
Unkar Rapids	72.36	2606	2612	2627.4	15.4
Grand Canyon Gage	87.37	2406	2424	2449.4	25.4
Pipe Creek Site	89.2				

APPENDIX 4

Cultural Resources

Human Occupation at the Grand Canyon

Humans have been experiencing the grandeur and using the resources of the Grand Canyon for thousands of years. Native Americans hunted game, gathered wild foods, and farmed in Grand Canyon and on the South and North Rims off and on for at least 10,000 years. In order to appreciate how these hunters, gatherers, and horticulturalists lived at Grand Canyon and to better understand some of the delemmas archaeologists face when studying their remains, the following summary is excerpted from Christopher M. Coder's *An Introduction to Grand Canyon Prehistory* (2000).

Paleo-Indian Hunters

> . . .It is now accepted by all except the most conservative researchers that human beings have been in the New World much longer than previously recognized—in small numbers, perhaps as long as 30,000 years.
>
> The Clovis and subsequent Folsom were sophisticated big-game-hunting people. Evidence of their success and passing appears throughout the United States. The Colorado River Basin contains evidence aplenty of the paleohunters. Camps have been found along the San Juan and Green Rivers, as well as on the rocky benches of the Little Colorado River, but at the Grand Canyon the traces are confined to a few spear points. They were here, but most of their goods have been ground into dust by the elements, covered over by flood, or scavenged by those who came along later.
>
> Paleo-Indian people were few in number, a small group here, a small group there. They lived life on the go, moving from camp to camp, searching for or following big game. . .. The paleohunters of Grand

Canyon country were walking the tightrope of changing times. The world was warming up. Analysis of Antarctic ice cores and deep-ocean sediments conducted during the 1990s indicated a radical change in global climate right around 11,000 years ago. . .. Pleistocene megafauna — camels, mammoths, giant sloths, short-faced bears, and wolves — were slowly passing away with the glaciers.

Groups of hunters living on the Colorado Plateau changed with their world . . .. They fine tuned their hunting strategies to acquire deer, bighorn sheep, and smaller, quicker animals . . .. Folsom, Humboldt, Jay, Mohave Lake, and Pinto style blades and projectile points belonging to the Late Paleo-Indian and Early Archaic stone tool traditions are found across the uplands of Grand Canyon National Park. This indicates that small groups of people remained in the region even as big game died out. Their low population and light hand on the landscape did not generate enough material to be easily recognized or discovered.

The Archaic Period

. . .By 9000 years ago, more people had entered the Grand Canyon region from the Basin and Range Province to the northwest with all the trappings of Archaic culture: atlatl and darts, open-weave sandals, seasonal habitations, groundstone tools. Indication of human settlement in Grand Canyon country during the long centuries of the Archaic is extensive. The Archaic period in the American Southwest is such an expanse of human history that it has been divided into three parts: Early, Middle, and Late. These broad divisions are based on several factors: changes in projectile point technology, alterations in climate, and regional shifts in population.

Early Archaic culture is transitional from paleoculture reflecting the loss of the large Pleistocene game animals and a drier climate. Despite these seemingly major inconveniences, the human population on the plateau increased during this period. People slowed down a notch. The pace of life and drier climate were conducive to preserving what the human experience chose to offer up. So the record from these times is more complete and a little less mysterious than the Paleo-Indian. About 6,500 years ago the climate became drier still, signaling the beginning of the Middle-Archaic drought that would last off and on for almost 2,000 years . . ..

. . .Over the period of a person's lifetime the environment went through a perceptible change. Over three lifetimes it changed dramatically . . .. The groups that remained to weather it out with the landscape refocused their efforts on the shriveling resource base with which they were confronted.

. . . By 4,500 years ago the severe dry times were waning and populations were flowing back. There is a good deal of Late Archaic evidence found at Grand Canyon. The Gypsum points these people used are commonly found in the park north of the river. . .. The Late Archaic people of Grand Canyon acquired life's necessities from the stacked resources between the river and rim country . . .. Like the paleohunters before them, their goods were mostly perishable. So we are — again — faced with defining an entire people by a few tools, some figurines, and an occasional thought-provoking pictograph panel . . ..

The Basketmakers

. . .The earliest corn-growing people at Grand Canyon are commonly known as the Basketmaker culture. They cultivated corn, but still hunted game and gathered wild plant foods. These people were scattered around Grand Canyon in family camps and small villages . . .. They lived in rock shelters where available and otherwise in pithouses, underground homes that were entered through a hole in the roof . . ..

By 1,100 years ago most of the farmers had traded the pithouse for the above-ground stone roomblock. In the centuries to come, some of the Basketmaker groups that would become known as the prehistoric Pueblo retained the pithouse design as the ceremonial kiva.

Items that set the Basketmakers apart from other cultures were cradleboards with soft headrests, squaretoed sandals, beautiful woven bags, subterranean slab-lined storage cists, intricate baskets, and curved throwing sticks for hunting small game . . .. They did not begin to make pottery until about 1,700 years ago. About that same time, the bow and arrow were replacing the atlatl and dart . . ..

The Prehistoric Puebloans

. . .By 1,250 years ago what is today recognized as Basketmaker culture was all but replaced by the lifestyle of the pueblo. Like the evolution of the thirteen original European colonies into the European-American United States, it was a process, not an event . . ., we can say Basketmaker culture grades into Pueblo culture.

Anasazi is the popular term used to describe various maize-dependent prehistoric Puebloan cultures inhabiting the southern portions of the Colorado Plateau and the Four Corners regions from Late Basketmaker times until about seven hundred years ago . . ..

. . .The prehistoric Puebloans were not a homogenous people. Archaeologists have differentiated them roughly into eastern and western divisions and further into several traditions based on location, social organization, ceramic styles, and architecture. The traditions are Chacoan, Mesa Verde, Kayenta, Virgin River, Little Colorado River, Cohonina, and to a lesser degree, the Sinagua. At Grand Canyon the Kayenta and Virgin traditions blend and merge on the north side of the Colorado River, just as the Kayenta and Cohonina intermingle in time and space on the south side. . . .

. . .Prior to a thousand years ago isolated settlements of Puebloans lived in the uplands along the rims and farmed in the river corridor, tending small plots of corn, squash, and cotton as conditions would allow . . .. Around 1,000 years ago the climate began to shift once again, this time to the advantage of farmers. A slight increase in the amount of seasonal precipitation allowed corn, beans, squash, and cotton to be grown with reliability in more places. This change in the rain belt temporarily allowed Kayenta farmers to expand across the Colorado Plateau wherever a crop could be coaxed from the soil . . .. It also allowed the Cohonina already established along the south rim to expand and flourish . . ..

. . .Farmers are always thinking ahead and taking advantage of subtle changes in the environment. This is what happened at Grand Canyon. Farmers recognized an opportunity and expanded into the canyon like water pouring into a dry stream channel. Carrying their infants, bows, water jugs and seed, small children and dogs in tow, they moved westward from their old homes. Within a generation they had occupied virtually every delta and quarter-acre of arable land in Grand Canyon. . ..

But the people could not afford to be just farmers. The climate at Grand Canyon would not allow it. Even with broad alluvial terraces, increased precipitation, and a higher water table, which are all gone today, farming was still risky business. So in addition to farming they capitalized on the natural resources available to them . . .. Useful things were stacked one on top of the other for a verticle mile, from the river to the rim. There were in this vast arid country edible cactus, mesquite beans, yucca, agave (mescal), grass seeds, acorns, walnut and pinyon nuts, wild fruit, greens and herbs, and plants used as medicines, dyes, and for ceremony. . .. Animals utilized included bighorn sheep, deer, bear, bobcat, mountain lion, rock squirrel, mice, packrats, woodrats, eagles and hawks, waterfowl, chuckwalla, and small lizards. Like the later Hualapai, the farmers were apparently, by choice, not fishermen. . ..

The Delta Puebloans

In the eastern Grand Canyon there is a series of large side canyons that drain into the Colorado River. These tributaries breech the incredibly rugged terrain existing between the forested rims and the seemingly desolate inner canyon. Acting as the routes of daily life, the side canyons were the highways by which the inhabitants accessed the stair-step ecology of Grand Canyon.

Each of these side-canyon systems creates a large delta at river level suitable for farming. The deltas focused settlement. The big canyons, Nankoweap, Kwagunt, and Unkar, drain into the Colorado from the north, the Palisades-Tanner-Cardenas systems from the south. Several secondary side canyons such as South Canyon, Basalt Canyon, Sixty-Mile Canyon, Chuar Canyon, and Fossil Creek had small workable deltas occupied by the prehistoric Pueblo. In those days an extensive system of alluvial terraces also existed in the river corridor adding considerable ground that could be cultivated.

The delta farmers of Grand Canyon were double cropping, farming both the inner canyon and the rims while taking advantage of naturally occurring calories throughout the system. They stored food to use as needed through the winter. Below the rims in the lower elevations of the canyon's western reaches, agave (mescal) was available in the early spring, greens would be popping up along the river, and by April people could gather a variety of edible plants. As soon as the time was deemed proper, corn, beans, squash, and cotton were planted along the river. On the rims, crops planted in late spring matured through the early fall and the upland harvest would dovetail nicely with the ripening pinyon nuts and the best months for deer hunting. . ..

Puebloan Exit

By 850 years ago the cycle of increased rainfall that had instigated the Puebloans cultural flourish was reversing itself. The dry times were coming back . . .. By 750 years ago there was not enough rain to support a tenable crop on the rims. The northwestern fringes of Pueblo civilization precariously situated at Grand Canyon were the first to fold under the early stages of the regional drought which ultimately affected all of the farming people of the Southwest. . ..

The Kayenta villagers hung on in dwindling numbers for a few generations, until about A.D. 1230. During this final Puebloan phase at Grand Canyon they constructed several thick-walled, seemingly defensive fortlike structures along the south rim between Zuni Point and the Great Thumb. So there could well have been considerable tension and fear brought by the hunger accompanying the drought. Was the caution prompted by the ancestral Hualapai/Havasupai moving upstream, or advance parties of Southern Paiute on the north rim or other displaced Puebloans? We can't really say. . ..

. . .At some point around 775 years ago (A.D. 1225), village life on the deltas in eastern Grand Canyon and on the forested rims became untenable and the final Puebloan families moved out of the canyon . . .. Throughout the last millennium and into modern times the Hopi have maintained their ancient connections to the canyon, ritually in the kivas on the Hopi mesas and physically by trekking to the canyon to collect salt and visit the Sipapuni, an elevated hot spring sacred to specific clans of Hopi, representing their point of origin into this world and their destination when they depart. . ..

Newcomers to the Canyon

As Puebloan populations dwindled between 700 and 850 years ago, other cultures were moving to the canyon. From the Mohave Desert came the Cerbat/Pai to inhabit the western end on the canyon, south of the Colorado River. Paiute migrated southward from the Great Basin of Nevada and Utah and stopped north of the Colorado. Though the two cultures arrived at the canyon at about the same time, they were unrelated.

The Cerbat/Pai

The Cerbat/Pai, direct ancestors of the Hualapai and Havasupai, arrived at the canyon with low-desert skills that would allow them to flourish where the farmers could no longer be sustained. For two hundred years, from their home territory to the west, they had traded to some degree with the Puebloans, but the archaeological record does not clearly reveal when they arrived in Grand Canyon as permanent residents.

Some scholars believe the Cerbat/Pai entered the canyon a century after the prehistoric Pueblo left, but the Cerbat were moving up-canyon in reaction to the same drought that was plaguing the Puebloan farmers and were probably on the move even before the Puebloan withdrawal. Other researchers believe the newcomers pushed the prehistoric Pueblo out by force. Scattered warfare and raids were inevitable. The Kayenta Puebloans built enigmatic defensive structures along the south rim during the period of flux. Conflict, when it took place, would have been on a limited scale.... It is most plausable the majority of Puebloans were not driven out at the tip of an arrow, but prodded by an empty fork. . ..

Cerbat/Pai archaeological sites are very different from prehistoric Puebloan sites. Yet, in the canyon's west end there is amalgamation of the old and the new. . .. Artifacts blend together on the surface causing anxiety for the archaeologist. Tizon Brownware pottery is a trait of the Cerbat, originating at sites on the lower Colorado River and produced with little change between 1,200 and 250 years ago. . ..

The Cerbat/Pai moved in an established rhythm from water source to water source, hunting deer and bighorn sheep, gathering mesquite, prickly pear, their staple agave (mescal), and other plant foods. Barely discernable short-term camps typically would consist of very few artifacts: a cleared circular area and rock ring where a *gowa*, a brush shelter, had stood, a small roasting pit some hand-held tools, a grinding slab or anvil stone, a few scattered flakes, an occasional Tizon sherd. . ..

More complex, long-term camps existed under the shelter of the rims and down along the river where side canyons open into the gorge. . . overlapping conical roasting pits twenty feet in diameter and seven feet high, pictographs, digging sticks, broken pots, quids of chewed-and-spat-out mescal fibers, all the debris of daily life that time has not engulfed. . ..

Six hundred years ago the Cerbat/Pai were the dominant tribe along the south rim of Grand Canyon from the mouth of Bill Williams River below Hoover Dam, up to the confluence of the Little Colorado. Divided into eleven or twelve geographically determined bands including the Havasupai, they represented a confederation that spoke the same language, shared a heritage and an inherited landscape, and lived in what eminent Grand Canyon archaeologists Dr. Robert Euler aptly describes as territorial equilibrium. . ..

The Southern Paiute

The Paiute hunter-gatherers entered into a country on the north side of the Colorado River that had been the sparsely populated home of the Virgin Puebloans. . .. It is from these residual groups of Puebloans that the first wave of Paiute learned how to supplement their wild foods with corn and squash grown around springs and down in the side canyons.

Southern Paiute and Cerbat/Pai sites are often hard to differentiate based solely on artifacts. A rule of thumb for the Grand Canyon is "Paiute north bank, Cerbat/Pai south bank," but this only works in general. . .. The Southern Paiute cultural landscape was held together by a complex system of trails connecting the far-flung water sources in Grand Canyon. . .. The Southern Paiute efficiently gleaned a living from the spare land. It was not a shift in the climate or ecological catastrophe that pushed the Paiute out of the canyon, but the expansion of European-American culture into the region from 1850 to 1880. A lifestyle that existed for more than six hundred years in a true balance with the available resources was exterminated in a single generation. Several hundred archaeological sites at Grand Canyon mark its passing. . ..

European-American History at Grand Canyon

The following discussion is taken from "The Mather Point Orientation Center Project Supplemental Mitigation Plan" by Steven A. Moffitt and others (1998:21-23).

> The historic period begins with the first contact and written documentation of contact between the Spanish and American Indian groups inhabiting the Grand Canyon area in AD 1540. . .. In AD 1540, García López de Cárdenas, under orders from Francesco Vásquez de Coronado led a party to find the river that might serve as a waterway for transportation to the Gulf of California (Bannon 1970). With the assistance of Hopi guides, Cárdenas and the members of his party arrived at the South Rim of the Grand Canyon; this first known European people to visit the area . . .. At the time of their visit the Hopi, Navajo, Havasupai, Hualapai, and Southern Paiute groups inhabited GRCA . . .. The Spanish expeditions were followed by visitations by trappers in the late 1820s (Hughes 1978; Batman 1986). Upon ratification of the Treaty of Guadalupe Hildalgo in 1848, ending the Mexican-American War, U.S. army expeditions entered the region to survey newly acquired lands and find an expedient route of travel for those seeking gold in the West (Sitgreaves 1953; Ives 1861: Powell 1875: Jackson 1964).
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> Two scientific expeditions led by John Wesley Powell resulted in the successful navigation of the Colorado River through the Grand Canyon in 1869 and 1877-72 . . .. Tourists began visiting the Grand Canyon in the 1880s, often staying at miner's camps, some arriving by stagecoach, and many using established trails to access the inner canyon (Wahmann 1975; Alhstrom et al 1993:85). In 1883, the transcontinental railroad was completed with the line running approximately 25 miles south of GRCA (Janus Associates 1981; Babbitt 1981) . . .. By the turn of the century, tourist facilities were operating on the South Rim, ranching was in operation, and tourists were able to access the South Rim of the Grand Canyon by train (Ahlstrom et al. 1993:85; Richmond 1985).

As visitation increased to Grand Canyon efforts to regulate the area as public domain resulted in setting aside lands as Grand Canyon Forest Reserve in 1893...establishment of Grand Canyon National Monument was initiated by President Theodore Roosevelt in 1908, and National Park status was acquired...in 1919.... During the years of federal control, many changes occurred at Grand Canyon as the construction, maintenance, and destruction of buildings, facilities, and roads transpired over time.

Acronyms and Abbreviations

ACHP	Advisory Council on Historic Preservation
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
af	acre-feet
amsl	above mean sea level
AWWA	American Water Works Association
AZSITE	Arizona State Historic Preservation Office
BA	biological assessment
bgs	below ground surface
BLM	Bureau of Land Management
BO	biological opinion
Canyon	Grand Canyon
CAP	Central Arizona Project
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
CWA	Clean Water Act
EIS	environmental impact statement
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FWCA	Fish and Wildlife Coordination Act
FWS	Fish and Wildlife Service
GIS	Geographic Information System
gpd	gallons per day
gpm	gallons per minute
HDD	horizontal directional drilling
HP	horsepower
kV	kilovolts
LJC	Long Jim Canyon
MDFZ	Markham Dam fracture zone
MGD	million gallons per day
mg/L	milligrams per liter
msl	mean sea level
NEPA	National Environmental Policy Act
NF	National Forest
NMFS	National Marine Fisheries Service
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
OHWM	ordinary high water mark
OMR&E	operation, maintenance, replacement, and engergy
O&M	operation and maintenance
PA	Programmatic Agreement
Park	Grand Canyon National Park
PG&E	Pacific Gas and Electric
P.L.	Public Law
ppm	parts per million
PVC	polyvinyl chloride
Reclamation	U.S. Bureau of Reclamation
ROW	right-of-way
RPA	reasonable and prudent alternative
RPM	reasonable and prudent measures
SDWA	Safe Drinking Water Act
SWPPP	stormwater pollution prevention plan
SWTR	Surface Water Treatment Rule
TDS	total dissolved solids
TCP	transcanyon pipeline
THPO	Tribal Historic Preservation Office
U.S.C.	United States Code
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
uv	ultraviolet
vpd	vehicles per day
WWTP	wastewater treatment plant
°C	degrees Centigrade