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

APPENDIX 1

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 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	AMOUNT
		Replace 1000 foot section of existing Trans Canyon Pipeline.					
		Remove existing aluminum pipe and replace with steel.					
	1	Pipeline Excavation		cy	216	$110	$23,760
		Assume 100% rock, trail width 3 feet, 1,000 ft long					
		Cover over 8" pipe - 2ft.					
	2	Pipeline Backfill		cy	124	$95	$11,780
	3	Pipeline Select Backfill		cy	76	$650	$49,400
		Assume material would be helicoptered to site					
	4	Steel Pipe					
		8A4000 t=.416		ft	1,000	$135	$135,000
		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	$1,979,460
		Replace 2000 foot section of existing Trans Canyon Pipeline.					
		Remove existing aluminum pipe and replace with steel.					
	6	Pipeline Excavation		cy	432	$110	$47,520
		Assume 100% rock, trail width 8 feet, 2,000 ft long					
		Cover over 8" pipe - 2ft.					
	7	Pipeline Backfill		cy	248	$95	$23,560
	8	Pipeline Select Backfill		cy	152	$650	$98,800
		Assume material would be helicoptered to site					
	9	Steel Pipe					
		8A3000 t=.305		ft	2,000	$113	$226,000
		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	$4,750,560
		Mobilization		ls	1	$8,350,000	$8,350,000
		Subtotal					$15,695,840 ✓
		Unlisted Items= 5%					$804,160 ✓
		Contract Cost					$16,500,000 ✓
		Contingency = 25%					$4,500,000 ✓
		Field Cost					$21,000,000 ✓

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED [signature] 9/20/2001
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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					
	5	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	
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ESTIMATE WORKSHEET

SHEET 3

FEATURE: 1-Aug-2001

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

PROJECT

DIVISION

UNIT

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

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	$99	$963,567
		8A3000 t=.305 Area 1		ft	15,964	$113	$1,803,932
		8A4000 t=.416 Area 1		ft	14,500	$135	$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	
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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	
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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"					
	3	**Pump house on North Rim**		LS	1	$50,000	$50,000
		Assume metal building on flat slab					
	4	**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: Craig A. [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** Craig A. [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	PROJECT
Grand Canyon Pipeline Project North Rim Directional Drill Two Holes Alterative 5B2 filename: C:\123R5W\WORK\Grand Canyon\[hydrgc1.xls]North Rim	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
	6	Directional Drilling		LS	1	$5,600,000	$5,600,000
		Assume 2 - 8 3/4" holes					
		length =4,000 ft					
	7	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%					$1,900,000 ✓
		Field Cost					$9,400,000 ✓

QUANTITIES		PRICES	
BY Richard Fuerst	APPROVED	BY Daniel L. Maag DLM	CHECKED Craig A. Lust 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
	1	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	$95	$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	6,500	$83	$539,500
		8A4000 t=.416		ft	5,500	$105	$577,500
		8A5000 t=.532		ft	3,100	$140	$434,000
	5	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					
	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	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	$140	$420,000
	5	Power Cable - medium voltage 5 Kv line		ft	31,500	$20	$630,000
		Installed in pipe trench and					
		two in the 8-inch drill hole.					
	6	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					
	8	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. [signature] 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
	1	Pipeline Excavation		cy	9,202	$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.					
	2	Pipeline Backfill		cy	5,282	$95	$501,790
	3	Pipeline Select Backfill		cy	3,238	$200	$647,600
		Assume 800 cy of material would be helicoptered to site					
		in canyon					
	4	Steel Pipe					
		8A4000 t=.416 Install in direction drill hole		ft	5,500	$40	$220,000
		8A5000 t=.532		ft	5,600	$140	$784,000
		8A500 t=.0747		ft	31,500	$62	$1,953,000
	5	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.					
	6	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					
	8	Directional Drilling		LS	1	$9,900,000	$9,900,000
		Assume 1 -12 3/4" hole and 1 - 8 3/4" hole					
		Length = 5500 ft					
	9	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	$4,000,000	$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

Grand Canyon Pipeline Project
Wellfield Inside Park
Long Jim Canyon Site
Alternative 7

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

PROJECT

DIVISION

UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	1	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	9,000	$54	$486,000
		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					
	4	Steel Pipe (casing)					
		10B3000 t=.350 15 wells		ft	45,000	$50	$2,250,000
	5	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	19,244	$20	$384,880
	9	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	$25	$800,000
	12	Pumping Plant		LS	1	$700,000	$700,000
		Q= 2.16 cfs, H = 50 ft, HP =25					
		Flat slab plant					
		Mobilization		LS	1	$1,300,000	$1,300,000
		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 Craig A. Gush 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\[hydrgc1.xls]Estimates

PROJECT

DIVISION

UNIT

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	UNIT	QUANTITY	UNIT PRICE	AMOUNT
	1	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	10,000	$54	$540,000
		Installed in new trench with select backfill					
		Trench depth = 2 ft. & width = 6"					
	3	Access Road		LF	10,000	$24	$240,000
		Assume 24 foot wide, 10,000 ft long road pioneered to site					
		4-inch gravel surfacing					
	4	Steel Pipe (casing)					
		10B3000 t=.350 15 wells		ft	45,000	$50	$2,250,000
	5	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 Craig 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.

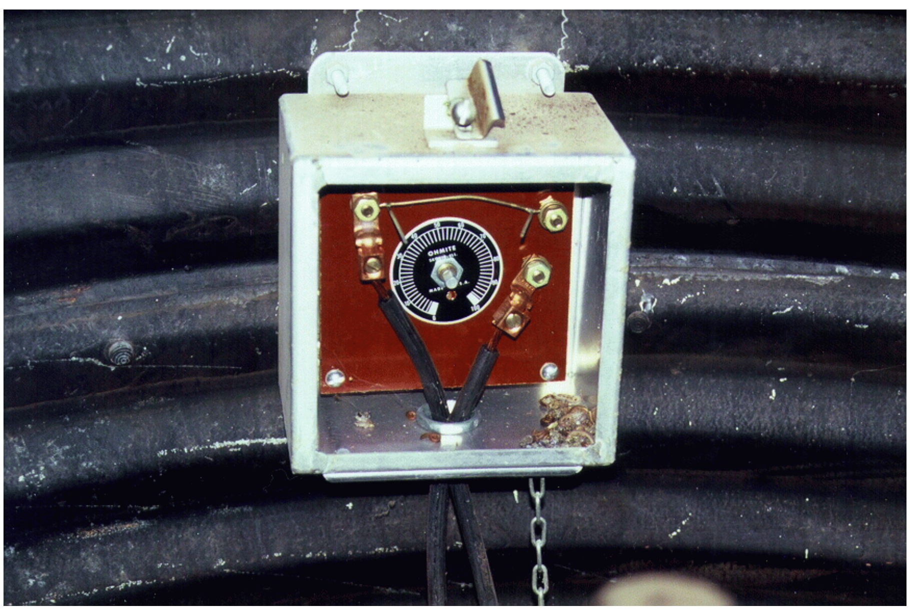

Figure 2. Typical insulator bonding box. Cables originate from the upstream and downstream pipeline sections at cast iron valves (see figure 1). Bonding box contains a rheostat (black circular faceplate, knob is missing) and shunt (wire above rheostat) to adjust and determine the current flow between 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 Anode 16 bonding box	-565		Pipe downstream.
			0	Across insulators, rheostat 0%.
			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	6.80				
Begin El		5206	3380	2250	3600	3700				
End El.		3380	2250	3600	3700	3767		Plus Bend Losses	Total Loss	HGL @ Indian Gardens
Begin HGL		5206	5021	3919	3878	3838				
End HGL		5021	3919	3878	3838	3828				
			Hazen-Williams (143)		TOTAL LOSS =		1378	21.6	1399	3807

			Annual flow AF	Average Flow (cfs)	Peaking Factor	Pump Factor*	Maximum Flow (cfs)
Roaring Springs El.	5206						
Indian Gardens El.	3767	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	2.16

* Pump 20 hours out of 24

ALUMINUM - EXISTING PIPE 2050 DEMAND

Pipe dia. (in)		8	6	8	6	8	Totals			
Q(CFS)		2.16	2.16	2.16	2.16	2.16				
Velocity		6.201	11.024	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	2190.91	75.31	79.88	17.20	2699.5	2753.5		
Hazen-Williams	143	339.34	2018.03	76.01	73.58	17.36	2524.3	2574.8		
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)		8	8	6	6	6				
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	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	6	6	6	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	5246	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	282.42	67.35	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	6	8	Totals			
Q(CFS)		2.16	2.16	2.16	2.16	2.16				
Velocity		6.201	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)		2.16	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	8	6	8	6	
Q(CFS)	**700 gpm**		2.16	2.16	2.16	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	78.01	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	$66,060	$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	$185,600				
Annual Cost of Pump Sta.										
over 20 yrs. @ 6%(.0871)($)			$17,420	$17,420	$17,420	$13,065				
Total annual cost of										
pumping ($/yr)			$467,886	$494,401	$454,811	$198,665				
Annual cost of pipeline over										
40 yrs @ 6%(.0664)($)			$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		0.0595	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+86	33.25		0.0361	
218+23	26.8		0.0291	
218+99	34.8		0.0378	
219+49	55.7	22	0.0605	
220+57	21	23	0.0228	
221+44	31.8		0.0345	
221+98	49.9		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+91	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+65	59.4		0.0645	
257+16	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+36	15	27	0.0163	
261+58	51.9		0.0564	
262+11	59.3		0.0644	
262+59	46		0.0500	
262+86	long radius?		0.0000	
263+65	long radius?		0.0000	
264+03	30.8		0.0334	
265+39	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+85	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+96	6.5		0.0071	
292+84	26.75		0.0290	
294+67	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+64	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 = 21.59524484

265+39	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+85	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+96	6.5		0.0071
292+84	26.75		0.0290
294+67	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+64	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 Francsco 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).
>
> 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