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.

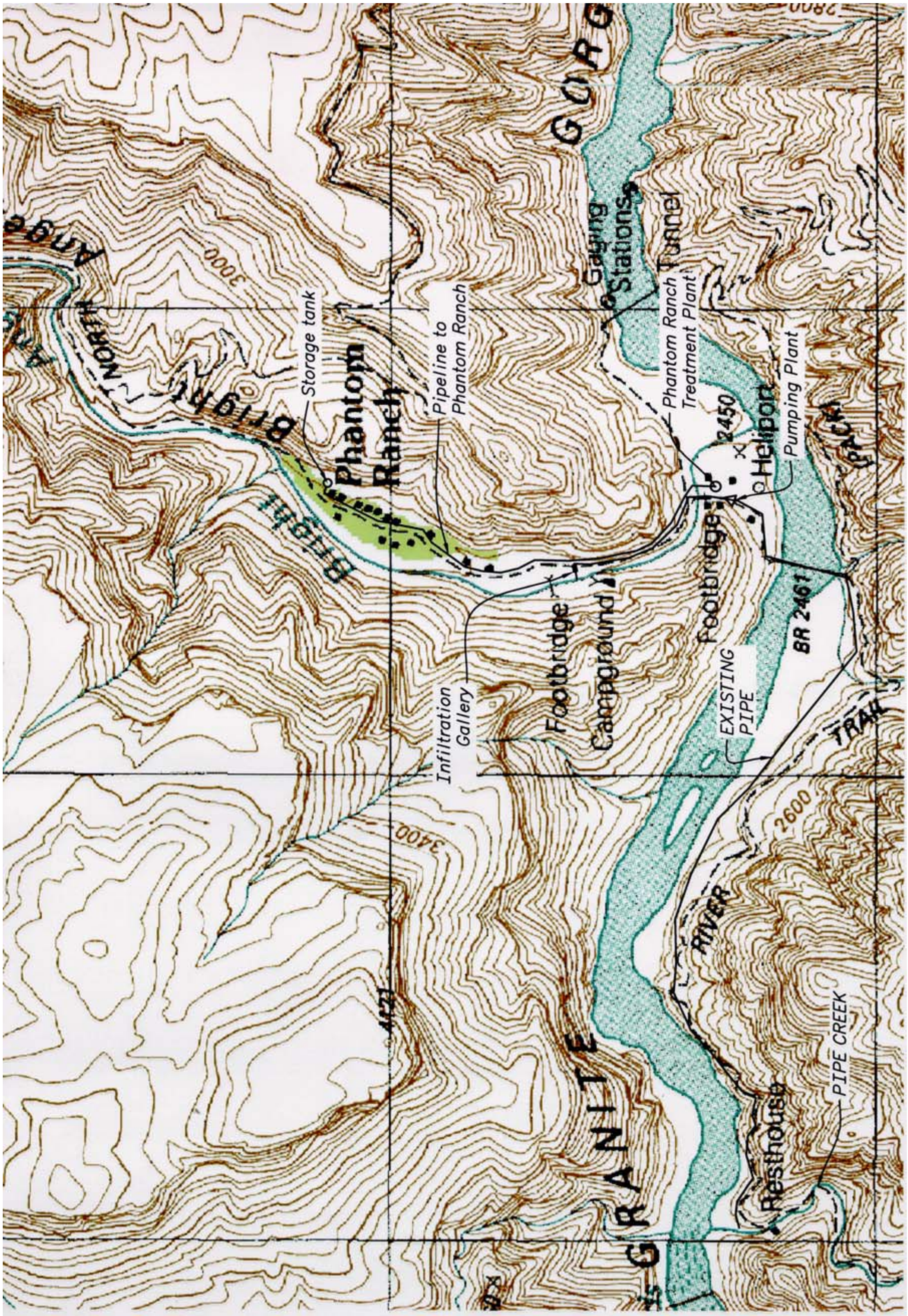


Figure 4-9.—Alternative 4.

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

[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

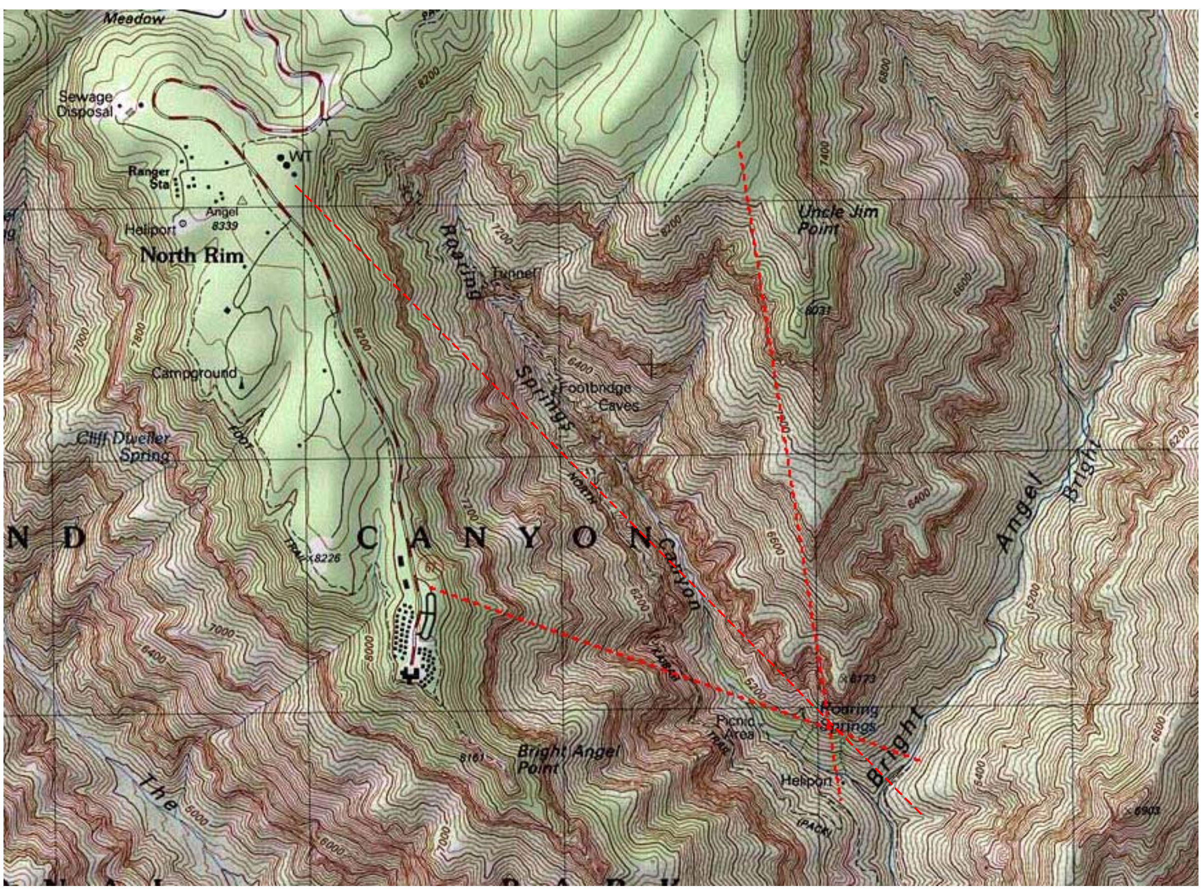


Figure 4-10.—North RIm well locations for profiles.

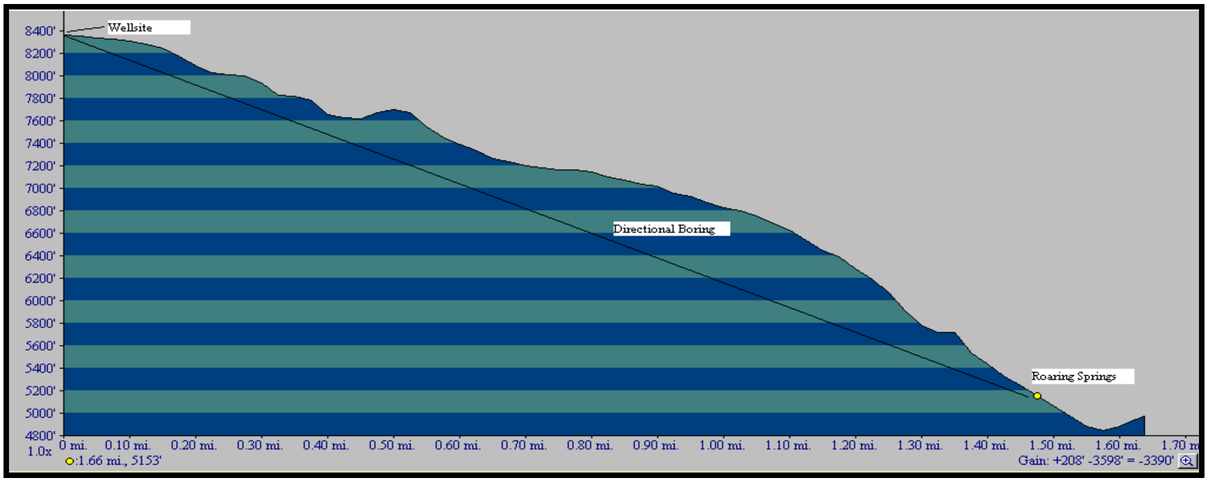


Figure 4-11.—Uncle Jim site profile.

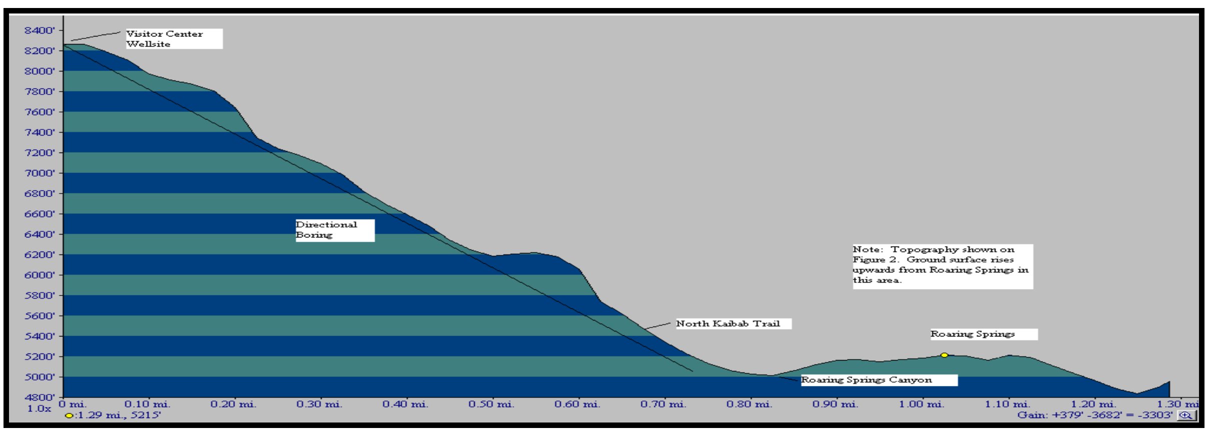


Figure 4-12.—Visitor site profile (lodge above Bright Angel Point).

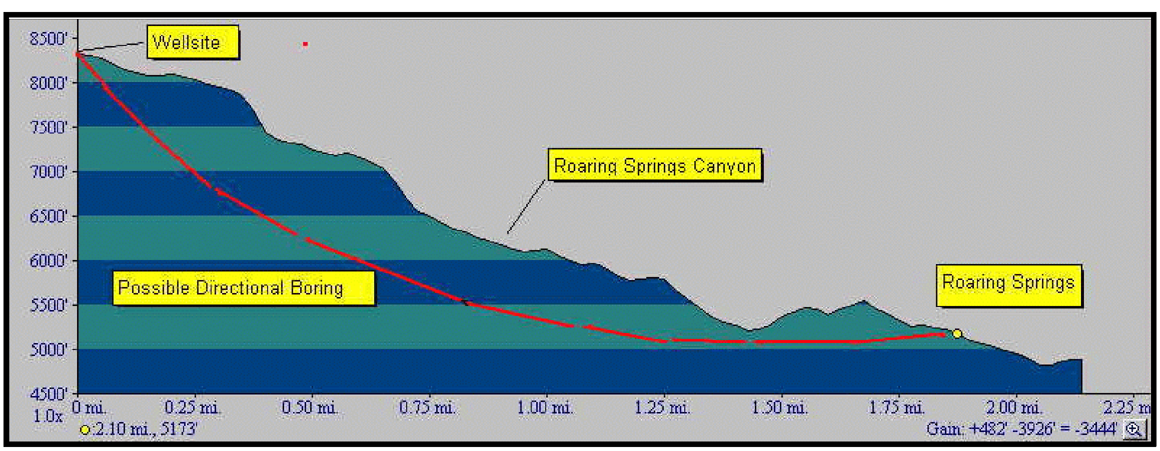


Figure 4-13.—Water tank site profile.

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

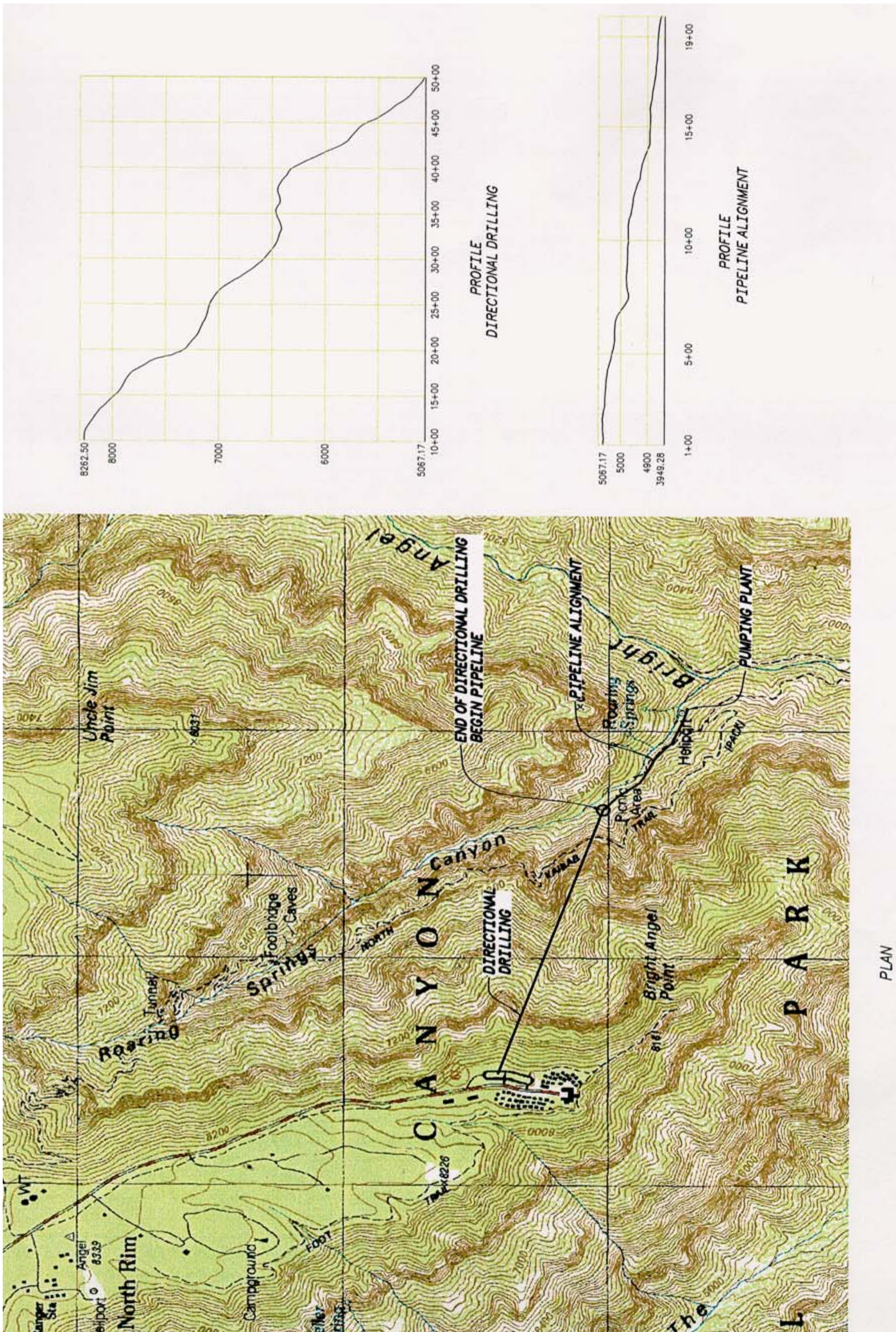


Figure 4-14.—Alternative 5B.

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.

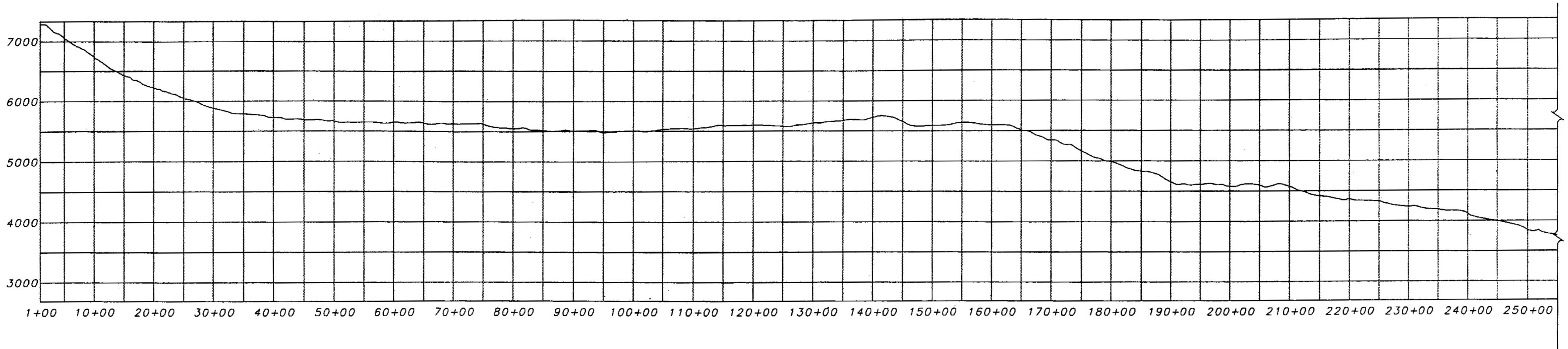
4.3.6.3 Comanche Alignment (Alternative 6C).—Under alternative 6C, a directional hole would be drilled (section 4.2.4, "Directional Drilling Technology") from Comanche Point to a location where the remainder of the route would be completed overland with pipe. The drill rig would be located 2 miles northwest 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.

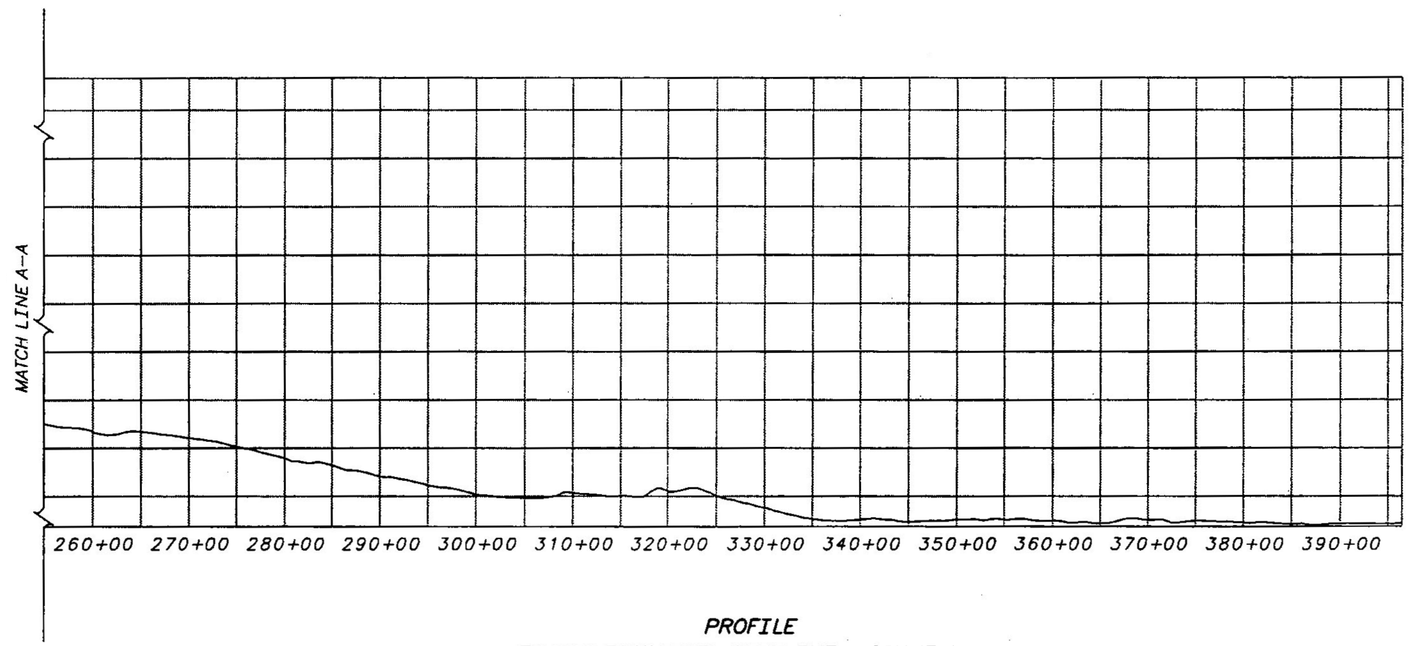
4.3.6.5 Hydraulics.—Alternatives 6A, 6B, and 6C would require an 8-inch pipe from the pumping plant to the South Rim.

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.

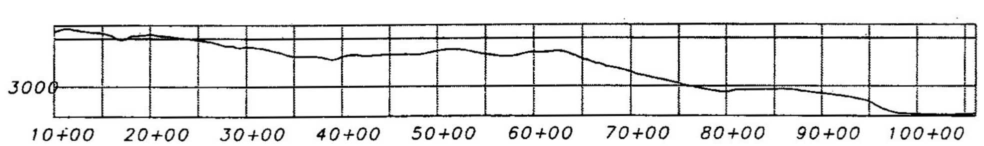
4.3.6.7 Pumping Plant.—The pump system would be designed for one pump unit ($Q = 2.16$ cfs and $H = 5062$ feet) and a backup pump. A 20- X 20- X 10-foot pump building to house the pumps, check valve, isolation valve and electrical cabinets would be required.



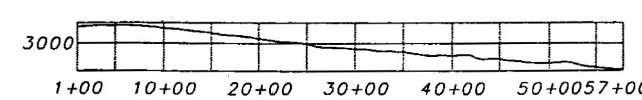
PROFILE
TANNER FOOT TRAIL PIPELINE ALIGNMENT



PROFILE
TANNER FOOT TRAIL PIPELINE ALIGNMENT



PROFILE
CARDENAS CREEK PIPELINE ALIGNMENT



PROFILE
COMANCHE POINT PIPELINE ALIGNMENT

ALWAYS THINK SAFETY

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

DRAWING 4–2

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