RECLAMATION
Managing Water in the West

Redrock Canyon Fish Barrier
Feasibility Investigations

Final Report for Central Arizona Project Fund Transfer Program Task 4-46

Submitted to:

U.S. Fish and Wildlife Service
U.S. Forest Service

Submitted by:

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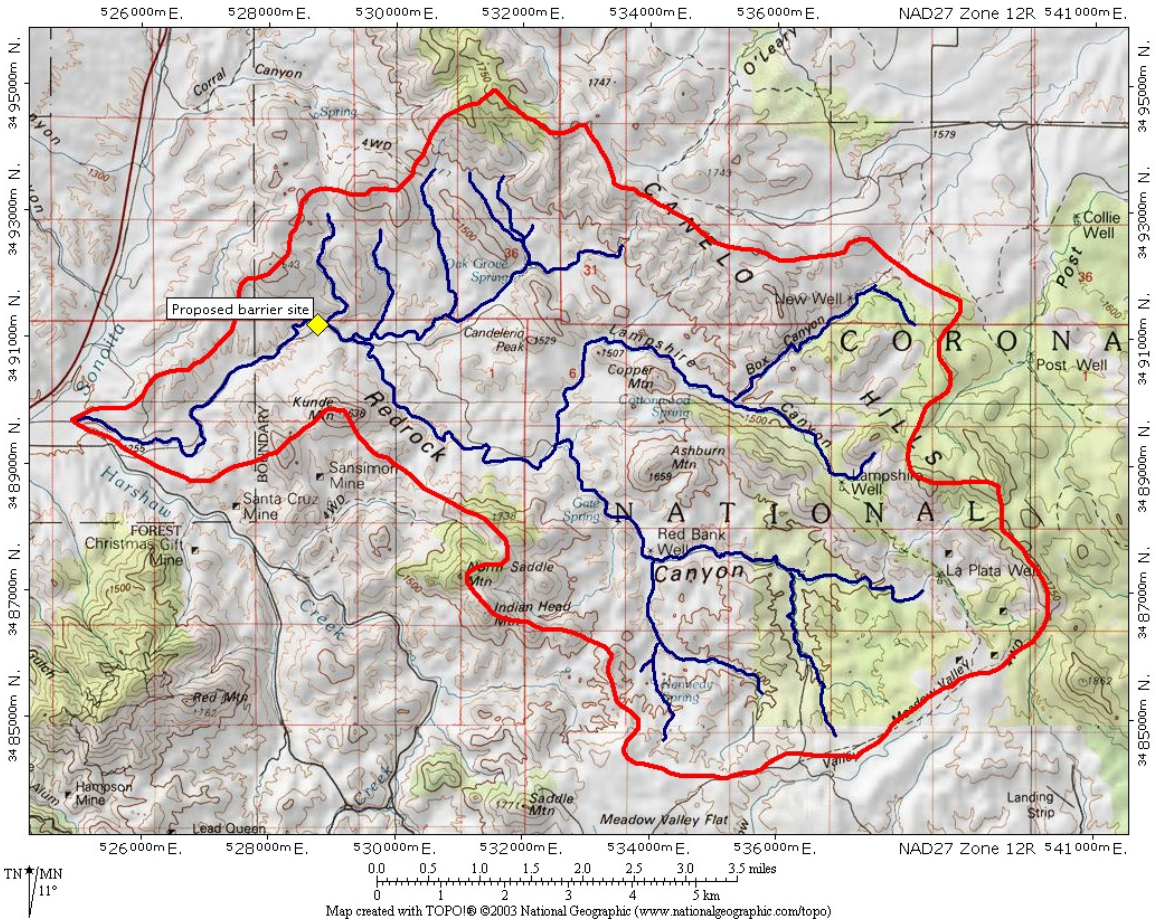
I. Introduction

The Redrock Canyon watershed drains approximately 80 km^2 (31 mi^2) of portions of the eastern Santa Rita Mountains, north-central Patagonia Mountains, and northern Canelo Hills east of Patagonia, Santa Cruz Co., Arizona (Figure 1). Four species of native fish are known from the canyon, including longfin dace, speckled dace, desert sucker, and the federally-endangered Gila topminnow. A fifth fish, the endangered Gila chub, also may have been present historically. Several native aquatic herptiles are present in the watershed, including the threatened Chiricahua leopard frog, endangered Sonora tiger salamander, Sonora mud turtle, black-necked garter snake, and possibly Mexican garter snake. All of these species are negatively impacted by invasions of nonnative species, including western mosquitofish, largemouth bass, green sunfish, bluegill, and American bullfrog that all have been recorded from Redrock Canyon.

Figure 1. Redrock Canyon Drainage Boundary, Major Watercourses, and Proposed Fish Barrier Location



The extreme importance of Redrock Canyon as one of the few remaining wild sites for Gila topminnow prompted Reclamation to investigate the feasibility of constructing a fish barrier to facilitate removal of nonnative species from the drainage, repatriation of native species, and prevention of reinvasion by nonnatives. This action is one of a suite of conservation measures being implemented by Reclamation to compensate for transfers of nonnative aquatic organisms into the Gila River basin via the Central Arizona Project.

Highest-priority streams under Reclamation's fish barrier construction program are those that can be secured to prevent extinction and stabilize rare stocks of native fishes, or that can be protected and renovated to replicate rare stocks of native fishes. A protected Redrock Canyon is intended to protect, augment, or re-establish the Redrock Canyon population of Gila topminnow and the other native aquatic species listed above.

This feasibility investigation evaluates fish barrier options on Redrock Canyon at a site approximately 5.8 km (3.6 mi) upstream from the confluence with Harshaw Creek. This report summarizes site investigations and discusses engineering and construction considerations, including geology, hydrology, geomorphology, conceptual design, construction costs, and right-of-way. National Environmental Policy Act (NEPA), Endangered Species Act (ESA), and Clean Water Act (CWA) compliance needs are also addressed.

II. Study Area

In an attempt to protect as many stream miles as possible, the lowest 3 miles of Redrock Canyon were examined. The reach that was most thoroughly investigated was upstream of the Seibold Ranch, in Section 3 on the Mt. Hughes USGS quadrangle.

The area of Redrock Canyon evaluated in this report is located within Coronado National Forest. The stream joins Harshaw Creek in the town of Patagonia, which merges within ½ mile with Sonoita Creek, a tributary of the Santa Cruz River.

Redrock Canyon drains approximately 31 square miles, of which about 29 square miles lies above the proposed fish barrier site. The stream is ungauged and typically consists of perennial stretches separated by sections of subterranean flow. The area investigated is characterized by rock canyon walls, and moveable bed alluvial materials through which the stream meanders.

III. Methods

Site investigations took place during four one-day site visits. The first took place on August 29, 2001 and involved Reclamation and U.S. Fish and Wildlife staff. The eventual preferred site was found on this first visit. A second site visit was conducted on April 30, 2002 by Reclamation for an engineering and geology purposes. The stream channel cross-section and profile were surveyed, and the surrounding geology was evaluated. The third site visit involved Reclamation biologists, archeologist, engineer, and NEPA specialist to evaluate habitat and survey for cultural remains. The fourth site visit was attended by a Reclamation engineer and two surveyors, performing investigations of the depth of alluvium at the proposed site and stream channel surveys.

IV. Results

A. General - The preferred fish barrier site is located 3 miles east of Patagonia, Arizona, which is about 18 miles northeast of Nogales on Arizona State Highway 82, in Section 3, Township 22 South, Range 16 East, (Figure 2).

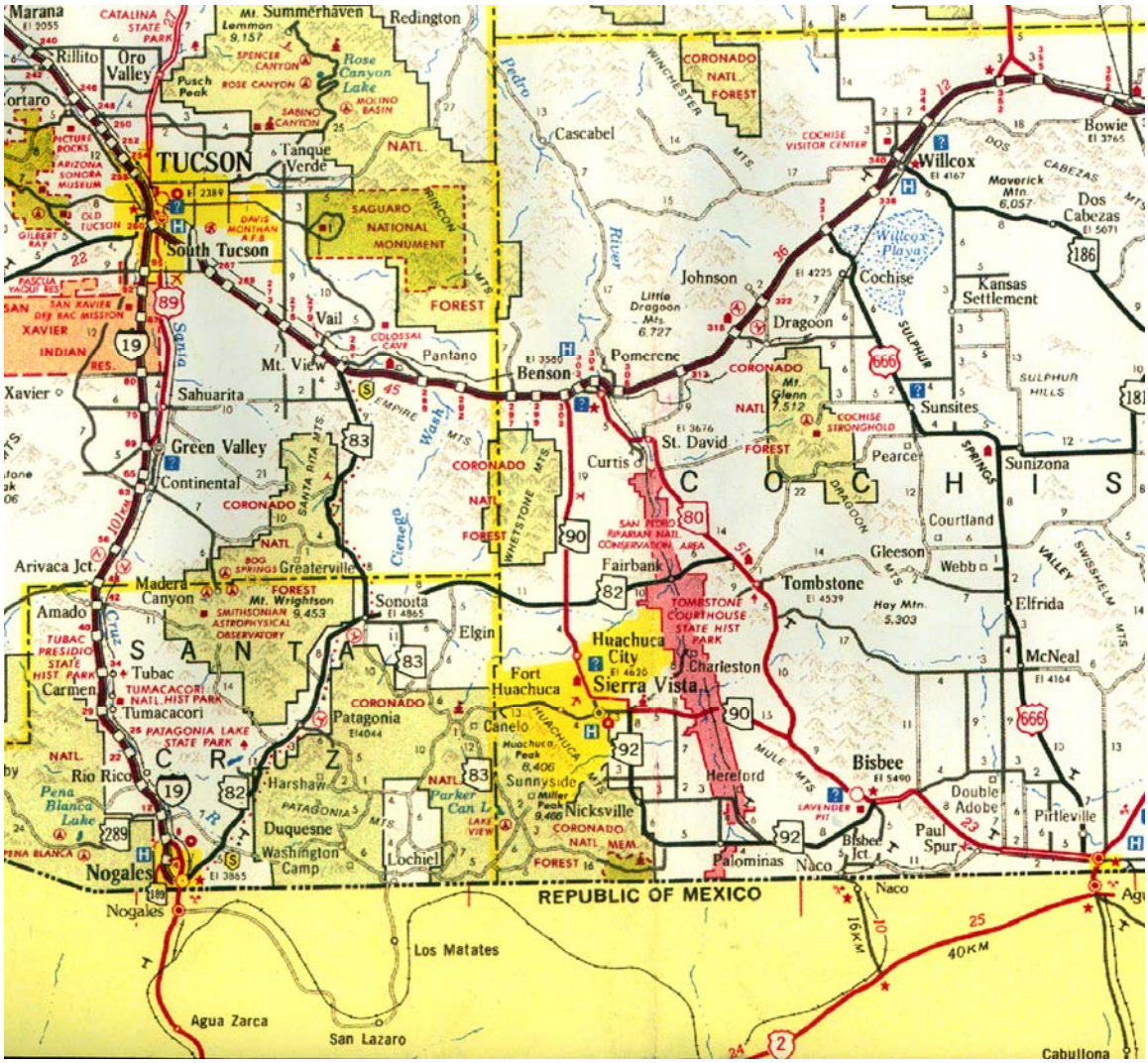


Figure 2 - Road map of Patagonia area. Patagonia can be seen 18 miles northeast of Nogales.

A rock outcrop channels the stream through a 9-foot wide gap, providing an excellent fish barrier site (Figures 3 and 4). There is a perennial reach about 20 yards upstream of the proposed barrier that maintains a trickling flow even during extremely dry periods.

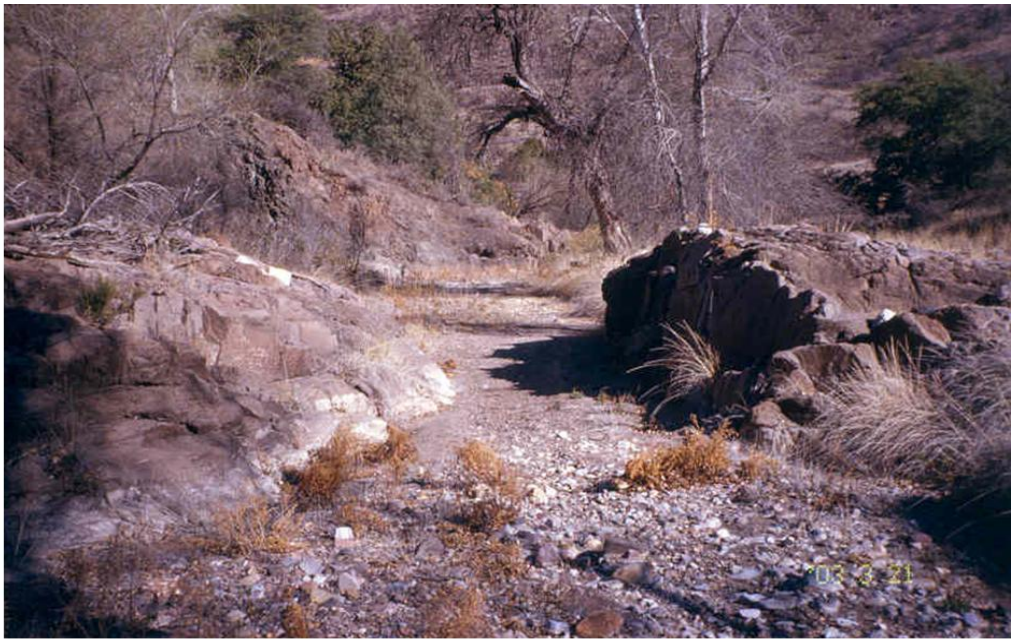


Figure 3. Photographs of the proposed Redrock Canyon fish barrier site looking upstream (top) and downstream (lower).

A fish barrier at this site would protect about 10 miles of stream channel, though the stream is not perennial for the entire distance. A natural drop exists about 1.7 miles upstream of the proposed site. While this drop may slow the movement of fish, it is not considered to have adequate fall and verticality to be considered a reliable fish barrier.

B. Geology - The stream channel is 9 feet wide measured at the top of the alluvium. The rock walls widen to 18 feet at the top of rock, about 6 feet above the alluvium.

Basalt forms both abutments and is expected to underlie the alluvium that presently fills the channel. The basalt is reddish brown to dark gray, and hard and moderately weathered. A prominent joint set strikes sub-perpendicular to the stream channel, dips near vertical and is spaced about 1-foot apart.

The right abutment is formed form a steeply dipping joint that strikes N15ºW and dips 80ºW. The right abutment consists of hard, reddish brown to gray basalt. The basalt is moderately fractured (fractures spaced 0.3 to 1.0 foot apart) and mostly slightly weathered (rock rings when struck with a hammer). Localized surface areas are moderately hard and moderately weathered (dull sound when struck by a hammer). The left abutment is similar to the right, but includes areas of intensely fractured rock (fractures spaced approximately 0.1 to 0.3 feet apart) especially at the rock surface.

Alluvium fills the channel and consists of fine to coarse sand, and fine to coarse subangular gravel with cobbles up to 8 x 4 x 5 inches at the surface. Boulders and larger cobbles are present upstream of the site and my be present in the subsurface.

The depth of the alluvium is unknown. Getting a drill rig to the site is prohibitively expensive. A hand held auger would not be effective given the cobbles that are expected to be encountered. We considered utilizing seismic refraction or ground penetrating radar to determine the depth to rock, but decided the results would be questionable and we could not justify the costs. We felt the narrowness of the channel would produce complex seismic reflections that might be impossible to interpret correctly. And difficulties associated with using ground penetrating radar equipment in wet and flowing conditions were enough to eliminate that option. The only alluvial depth investigation performed was driving 6-foot long steel fence posts into the alluvium. Three posts were driven to full depth without encountering rock. One post was located at mid-channel and the other two were located 1.5 feet from the rock abutments. So, rock is deeper than 6 feet.

Depending on long-term weather patterns, water is present as streamflow or exists just below the alluvial surface. Water will be encountered during excavation.

C. Design and Construction Considerations - This location offers a relatively straightforward site to construct a fish barrier, with the exception of the unknown depth of alluvium.

1. Abutments - Abutment rock is competent and will not need to be keyed into with the concrete. Drilled and grouted anchor bars will be adequate to prevent movement of the structure.

2. Hydrology - The Redrock Canyon watershed upstream of the barrier site covers about 29.7 square miles. The elevation at the barrier site is about 4250 feet. The highest point of the stream is about elevation 5,800. The slope of the stream in the vicinity of the barrier is 0.0123.

The Arizona Department of Transportation report "Methods For Estimating The Magnitude And Frequency of Floods In Arizona", 1978, was used to estimate frequency floods for the ungaged stream. Empirically derived regression equations are provided for five flood-frequency regions within the state of Arizona.

The 100-year flood will be considered the design flood.

Frequency Floods

Frequency (years)	Flow (cubic feet per second)
2	630
5	1,460
10	2,210
25	3,380
50	4,430
100	5,600

3. Stream diversion - Surface flows will need to be diverted or pumped around the work. Runoff events should be expected to occur during the contract, which may exceed the capacity of the diversion.

4. Dewatering - Water will be encountered during excavation. The alluvium will require dewatering to stand at a reasonable slope (1.5:1, e.g.). Well points will probably be required upstream and downstream of the structure. Specify that alluvium must be dewatered 3 feet below lowest excavation level, but require contractor to design the system.

5. Structure - The fish barrier structure will be constructed of reinforced concrete (see Figures 4, 5, and 6) to provide a durable structure capable of withstanding flooding events, while reducing maintenance costs. The main feature is a 4-foot vertical drop to prevent the upstream movement of non-native fish. A splash pad will be placed at the base of the drop to prevent a scour hole from developing adjacent to the drop. The structure will be extended about 7 feet down into the alluvium with toe-downs to prevent the structure from being undercut by large runoff flows. Anchor bars will tie the structure to rock; keying into the rock should not be necessary.

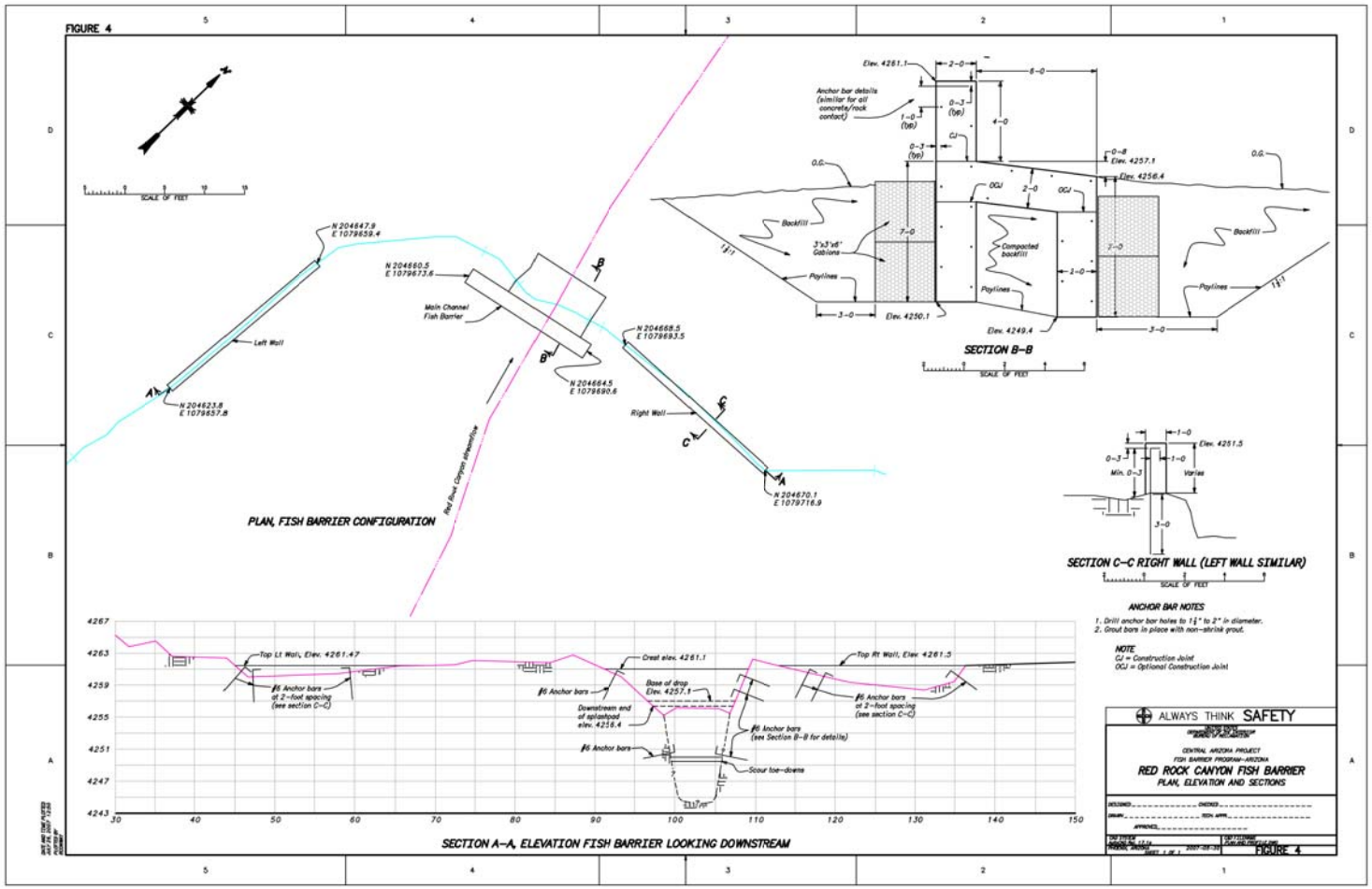


FIGURE 4
SCALE OF FEET
N 204647.9
E 1079659.4
N 204660.5
E 1079673.6
Main Channel
Fish Barrier
Left Wall
N 204623.8
E 1079657.8
N 204668.5
E 1079693.5
N 204664.5
E 1079690.6
Right Wall
N 204670.1
E 1079716.9
Red Rock Canyon streamflow
PLAN, FISH BARRIER CONFIGURATION
Elev. 4261.1
2-0
6-0
Anchor bar details
(similar for all
concrete/rock
contact)
0-3
(typ)
1-0
(typ)
4-0
CJ
0-3
(typ)
0-8
Elev. 4257.1
Elev. 4256.4
O.C.
OCJ
2-0
OCJ
Backfill
7-0
3'x3'x6'
Gabions
Paylines
Compacted
backfill
2-0
1-0
Backfill
Paylines
1:1
3-0
Elev. 4250.1
Elev. 4249.4
3-0
SECTION B-B
SCALE OF FEET
1-0
Elev. 4251.5
0-3
1-0
Min. 0-3
Varies
3-0
SECTION C-C RIGHT WALL (LEFT WALL SIMILAR)
SCALE OF FEET
ANCHOR BAR NOTES
1. Drill anchor bar holes to 1¼" to 2" in diameter.
2. Grout bars in place with non-shrink grout.
NOTE
CJ = Construction Joint
OCJ = Optional Construction Joint
4267
4263
4259
4255
4251
4247
4243
30
40
50
60
70
80
90
100
110
120
130
140
150
Top Lt Wall, Elev. 4261.47
#6 Anchor bars
at 2-foot spacing
(see section C-C)
#6 Anchor bars
Crest elev. 4261.1
Base of drop
Elev. 4257.1
Downstream end
of splashpad
elev. 4258.4
#6 Anchor bars
#6 Anchor bars
(see Section B-B for details)
Scour toe-downs
Top Rt Wall, Elev. 4261.5
#6 Anchor bars
at 2-foot spacing
(see section C-C)
SECTION A-A, ELEVATION FISH BARRIER LOOKING DOWNSTREAM
ALWAYS THINK SAFETY
CENTRAL ARIZONA PROJECT
FISH BARRIER PROGRAM-ARIZONA
RED ROCK CANYON FISH BARRIER
PLAN, ELEVATION AND SECTIONS
DESIGNED
CHECKED
DRAWN
TECH APPR.
APPROVED
FIGURE 4

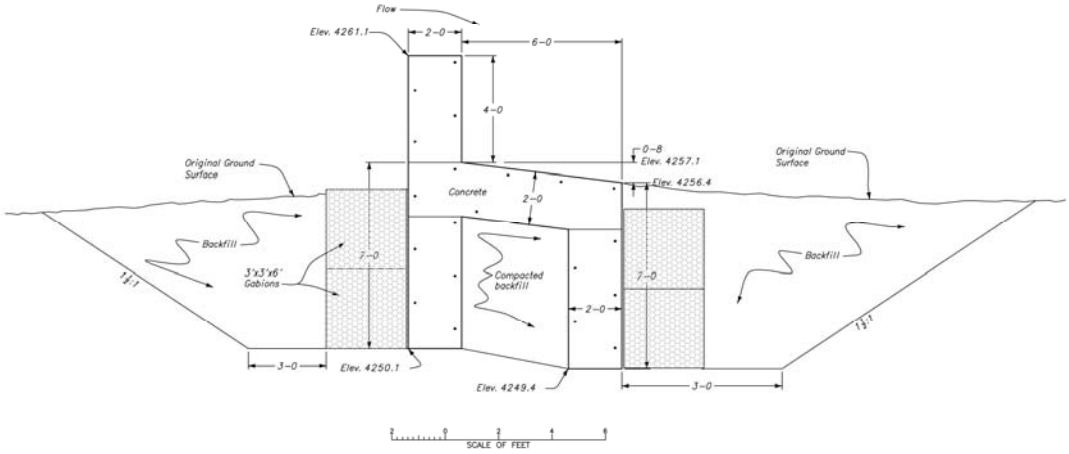

Flow
Elev. 4261.1
2–0
6–0
4–0
0–8
Elev. 4257.1
Elev. 4256.4
Original Ground Surface
Original Ground Surface
Concrete
2–0
Backfill
3'x3'x6' Gabions
7–0
Compacted backfill
7–0
Backfill
2–0
1½:1
1½:1
3–0
Elev. 4250.1
Elev. 4249.4
3–0
2 0 2 4 6
SCALE OF FEET

FIGURE 5

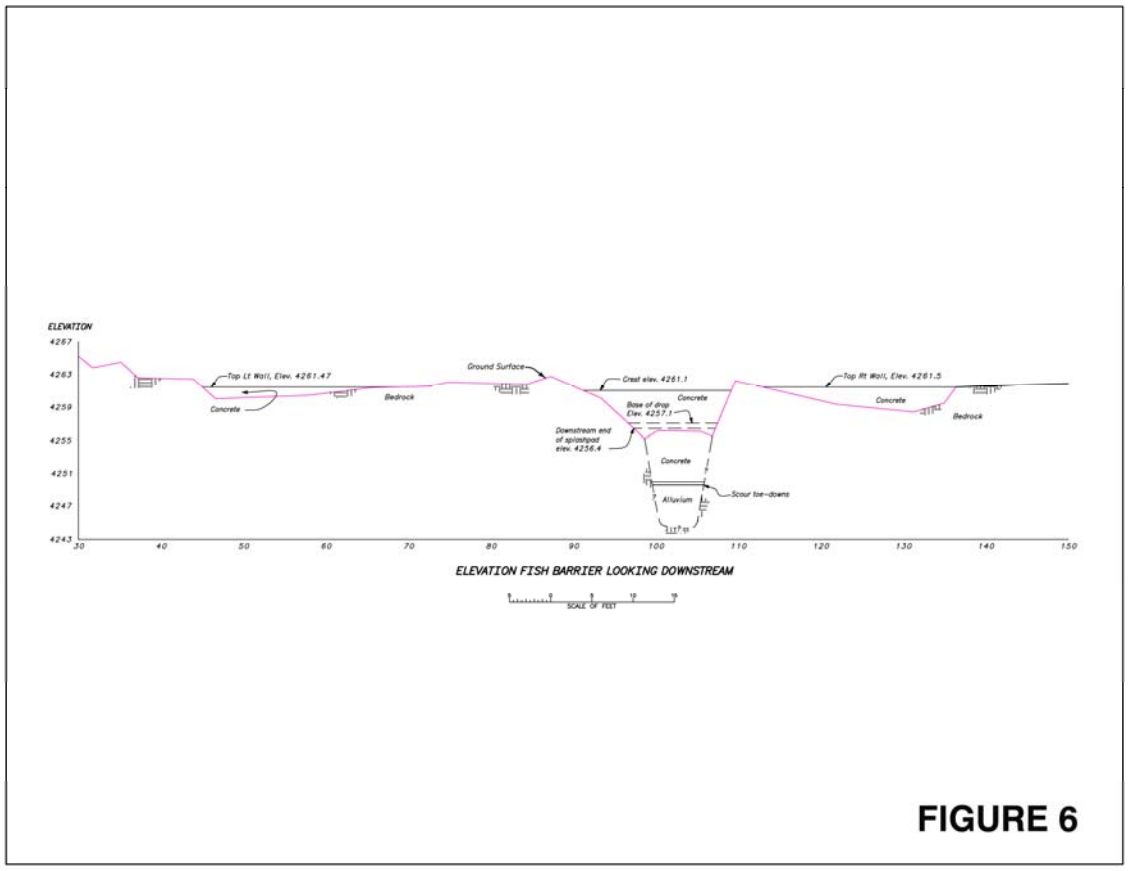


FIGURE 6

The depth of alluvium to rock is the major unknown. Without specific foundation data, bidders will have difficulty assembling their proposals. One way to approach this issue is to specify a toe-down depth based on conjecture, and adjust the toe-down depth during construction once the rock configuration is exposed by excavation. This could lead to a costly modification since critical activities such as excavation, dewatering, diversion, concrete, rebar, and anchor bars would be impacted. Instead, we are considering placing a stack of gabion baskets upstream and downstream of the structure. If scour undermines alluvium deeper than the concrete toe-downs, the gabions will fall into the scour hole, preventing flows from passing under the structure. This allows the structure to be constructed as designed and bid on, without a costly modification during construction. Two wing walls will be necessary to direct normal flows and small runoff events over the main drop structure. These walls will overtop during runoff events exceeding 13 cfs (assuming the wing walls are 0.4 feet higher than the main structure). The walls are located near the top of natural rock drop-offs, and should perform adequately as fish barriers themselves.

6. Access - There is not an existing road for vehicular access all the way to the fish barrier site. The road from Patagonia breaks away from the stream 0.7 miles before the barrier site, at a parking area. Contractor employees will access the site on foot from this parking area. Vehicles are physically prevented from continuing up the steam channel by a rock outcrop about 200 yards beyond where the road breaks away from the stream.

The Coronado National Forest has indicated a strong preference to have concrete flown in and placed by helicopter. The only equipment that will be allowed to be driven to the site will be a backhoe/excavator, a drill rig for the dewatering system, and one pickup truck for ambulance use. The downstream rock outcrop will need to be ramped over. All materials, such as steel, concrete, gabions, and gabion rock will need to be flown into the site.

The helicopter will likely be a Bell Long Ranger. These are readily available and have a payload capacity of 800 to 1,000 pounds, about 0.25 cubic yards of concrete.

7. Laydown area - Two contractor laydown areas have been identified; one on the right terrace at the barrier site, and the other 1/3 mile downstream where the road leaves the stream. There will be specific fuel storage restrictions at each of these sites.

A separate helicopter loading area will be coordinated by the contractor.

8. List of construction equipment - To assist with NEPA documentation, a list of anticipated construction equipment is provided. This list is intended to develop a general understanding of the project and may change depending on the contractor's approach to the work.

Drill rig for installing welllpoints	Backhoe or excavator
Pumps for dewatering	Drill for anchor bars
Trash pump for minor dewatering	Hand power tools
Generators	Pick-up truck for supplies and ambulance

9. Concrete suppliers - There are two concrete suppliers in the Nogales area; CPC Southwest Materials, Inc. and Rinker Materials. These are reputable firms, and they should be able to provide good quality concrete for this job.

10. Lodging - The contractor will be allowed to have a camp at the site, primarily for security. There are ample lodging accommodations at Patagonia, Sonoita, and Nogales.

D. Cost Estimate

Assumptions: 1) materials will be brought in by helicopter or by hand; 2) Concrete will batched at on off-site location, slung to the site, and placed using a helicopter 3) weights of construction materials are approximately:

(16 $yds^3$of concrete)(4,000 lb/yd^3) = 72,000 lbs
2,000 lbs rebar and anchor bars
1,000 lbs forming materials
(8 yds^3 gabions and rock)(3,300 lb/yd^3) = 26,400 lbs
4,000 lbs miscellaneous tools, tool boxes, generators, pumps, etc.
Total weight = 105,400 lbs

- Heli mat'ls to site [(105,400 lb)/(500 lb/load)/(8 loads/hr)]($1,400/hr) -	$36,890
- Diversion of stream	$ 5,000
- Dewatering	$15,000
- Form and place concrete ($1,600/yd³)(16 cy)	$25,600
- Rebar ($0.70/lb)(2,000 lb)	$ 1,400
- Drill and grout anchor bars (30 bars)($250/bar)	$ 7,500
- Gabions (8 yds³)($250/yd³)	$ 2,000
- Excavation (62 yds³)($30/yd³)	$ 1,860
- Backfill (42 yds³)($10/yd³)	$ 420
- Helicopter demob [(8,000 lb)/(500 lb/load)/(8 loads/hr)]($1,400/hr) -	$ 2,800
SUBTOTAL 1	$98,470
Mobilization 95% of Subtotal 1	$ 4,924
SUBTOTAL 2	$103,394
Contingencies (20% of Subtotal 2)	$20,679
TOTAL COST	$124,072

V. Environmental Compliance

Consideration of a Redrock Canyon fish barrier beyond the feasibility stage must include provisions for compliance with National Environmental Policy Act (NEPA), Endangered Species Act (ESA), and Clean Water Act (CWA). The NEPA process entails writing draft and final Environmental Assessments of the preferred project and its considered alternatives, and potentially presenting the preferred and alternative projects at public meetings. The NEPA process can take 6-12 months to complete. Reclamation's cost to perform this work is estimated at approximately $50,000.

ESA compliance will involve writing a Biological Assessment that determines effects of the project to federally-listed species and designated critical habitat for species. The Fish and Wildlife Service (FWS) is expected to determine in the biological opinion that a fish barrier project at Redrock Canyon does not adversely affect designated critical habitat, but project impacts to listed species likely must undergo formal consultation. As the project is for the benefit of native fishes, consultation with FWS should proceed smoothly, as it did with Reclamation's Aravaipa Creek and Fossil Creek fish barrier projects. Reclamation estimates that ESA compliance activities should not take more than 3-6 months, depending on the priority it receives from FWS. Estimated costs for ESA compliance is approximately $20,000.

The acquisition process for a 404 permit under requirements of CWA includes determining the impact footprint of the barriers (flooding, sedimentation, and construction zones), receiving a jurisdictional delineation from U.S. Army Corps of Engineers, and further processing of a 404 permit application. Identification of mitigation for impacts to "waters of the US" for this barrier has already been completed through Reclamation acquisition of stream/riparian habitat along the San Pedro River. Processing time for CWA compliance will be 3-6 months. Reclamation estimates that compliance costs associated with CWA regulations would be approximately $10,000.

VI. Recommendations

The importance of Redrock Canyon as habitat for Gila topminnow, combined with the quality fish barrier site, leads Reclamation to recommend continuing forward toward an eventual fish barrier. The proposed site offers a good, solid foundation for an extremely stable structure. Maintenance on the fish barrier should be minimal.