Appendix 2B
Stream Crossing Analysis

Stream Crossing Analysis

Simplot's Proposed Mining at Panels F & G
Technical Memo

1.0 Introduction

Ecological connectivity refers to the capacity of a landscape to support the movement of organisms, materials, and energy (Peck 1998 *as cited in* Porior 2003). In terms of stream crossing design, connectivity is the linkage of organisms and processes between upstream and downstream channel reaches. The health of aquatic populations ultimately depends on the health of their ecosystem, which in large part depends on such connections. Biotic linkage within an aquatic system includes the upstream-downstream movement of fishes, amphibians, insects, debris, sediment, and migration of channel patterns (Porior 2003). Stream crossings, when designed correctly, can provide good passage for aquatic species and debris. Stream crossing structures can be divided into four general types: bridge, circular culvert, pipe arch culvert, and open bottom structures. Descriptions of each crossing type are provided in the following sections.

Ecological functions such as biotic linkage may be blocked by undersized or improperly designed stream crossings. In terms of fish passage, the most common reasons for crossing structure ineffectiveness involve alterations to stream flow, such as insufficient water depths, increased water velocities, and vertical drops (Zwirn 2002). For each structure type, specific features can be designed to accommodate characteristics of the site as well as passage goals of the structure. Goals may include the passage of all fish species and size classes at any time of the year, passage of adult fishes during the spawning period, passage of all fish and other aquatic species, etc. The primary goal for stream crossings associated with Simplot's proposed Panels F&G Mine Expansion Project is to allow for passage of spawning cutthroat trout and to maintain up- and down-stream channel stability by maintaining the ability to accommodate 100-year flood events. The stream crossings associated with the Project would be temporary (approximately 16 years) and designed to support loaded haul trucks (approximately 1200 tons).

2.0 Crossing Types

2.1 Bridge

Description
Bridges are structures erected over a depression or obstruction (such as a stream) that have a floor for carrying traffic and other loads (WCT 2002). Bridges crossing streams are generally designed to have abutments and/or piers located outside the stream, so that the stream flows unobstructed below (Porior 2003). Large bridges needing to support loads such as haul trucks typically require bank armoring (Bates 2003) and other additional structural measures to ensure strength.

Pros
- high level of channel retention and stability (Bates 2003, QDPIF 2005)
- minimal impact on fish passage (BCMF 2002)

- no inherent dimensional limitations (Bates 2003)
- minimal debris problems (Porior 2003)

Cons

- may be most expensive option available (ODFW 2005, Baggett et al. 2001, Salmon Nation 1999, Gibson et al. 2005)
- elaborate design requirements needed to support heavy loads (Blair 2005)
- requires civil engineering or geotechnical expertise (Salmon Nation 1999)

2.2 Circular Culvert

Description

A culvert is a conduit or passageway under a road, trail, or other obstruction, which is generally used to divert a stream or rainfall runoff to prevent erosion or flooding of the obstruction (WCT 2002). A circular culvert is the traditional culvert shape, consisting of a simple rounded pipe either smooth or corrugated (White 2003), unbroken (entire) in cross-section, and made of metal, concrete, plastic, or clay (WCT 2002). Circular culverts are typically covered with embankment around their entire perimeter, and the lower portion may or may not be buried in stream substrate. For this Project, it is assumed that circular culverts would be designed, using the best available technology and information, to simulate a natural stream bottom and to pass fish.

Pros

- low risk of foundation failure (Porior 2003)
- may be least expensive option (Porior 2003, Gibson et al. 2005)
- easiest assembly, installation, and removal (Porior 2003)
- materials widely available (Zwirn 2002)
- strongest of any pipe material (Gibson et al. 2005)

Cons

- can't be built on rock foundations (Porior 2003)
- "stream simulation" requires extra designing effort (Porior 2003)
- may constrict stream flow if not properly designed (Baggett et al. 2001)
- flows inside tend to accelerate if not properly designed; turbulence common (Warren and Pardew 1998, Baggett et al. 2001)
- baffles may not be as effective on rounded bottoms (Zwirn 2002)

2.3 Pipe Arch Culvert

Description

Pipe arch culverts are pipes that have been factory deformed from a circular shape, such that the width (span) is larger than the rise. Pipe arch culverts have a continuous circumference and take the shape of a rounded triangle, the lower portion of which may or may not be buried (WCT 2002). Like circular culverts, pipe arch culverts are typically covered in embankment around their entire perimeter. The wider bottom of a pipe arch allows the culvert to better fit the lower portion of the stream cross-section, allocating more water through the culvert without creating a substantial change in hydraulics (Zwirn 2002).

Pros

- low risk of foundation failure (Porior 2003)
- slightly better "stream simulation" potential than circular culverts (Porior 2003)
- doesn't need to be embedded as deeply as circular culverts (Porior 2003)
- flat bottom retains backwater influence and reduces water velocity (Zwirn 2002)
- lower profile advantageous for low-clearance situations or where upstream water stage must be minimized (Zwirn 2002)
- may require less road fill than circular culvert (Comfort 2001)

Cons

- can't be built on rock foundations (Porior 2003)
- more difficult to install than circular culvert (NLDEL 1992)
- may require concrete footings (Gibson et al. 2005)
- more expensive than circular culvert (Gibson et al. 2005)
- eight percent less capacity than equivalent circular culvert (Comfort 2001)
- must be deformed at 30-foot intervals, so long culverts must be assembled on-site, ideally the sections match each other, but in practice, it seldom happens (Porior 2003)
- limited in high traffic loads, relative to circular culvert, due to non-concentric shape (QDPIF 2005, Gibson et al. 2005)

2.4 Open Bottom Culvert

Description

Unlike circular or pipe-arch culverts, open-bottom culverts are discontinuous in profile. Like bridges, open-bottom culverts span the stream channel with supports and allow natural stream features to be retained (Zwirn 2002, Baggett et al. 2001). Like closed culverts, fill must be placed over and around the structure (BCMF 2002). The widths of open-bottom culvert footings increase as load bearing needs increase; the stability of footings is essential to the effectiveness of the structure and is the primary cause of failure (Salmon Nation 1999). Profiles of open-bottom culverts may be square, rectangular, or arched; made of corrugated metal pipe, metal plate, pre-cast concrete, cast-in-place concrete, wood, or clay (WCT 2002).

Pros

- retains natural streambed substrate and channel conditions (Lang et al. 2004, Zwirn 2002)
- minimal impact on fish passage (Zwirn 2002)
- practical for steeper sites or when bedrock is near the surface (Porior 2003, Baggett et al. 2001)

Cons

- high risk of foundation failure if not built on rock or concrete (Salmon Nation 1999, Porior 2003)
- foundations need to be erosion-resistant; sensitive to scour damage (Porior 2003).
- relatively expensive (Salmon Nation 1999, Porior 2003, Gibson et al. 2005).
- requires substantial initial disturbance for culvert footings excavation (Zwirn 2002)

- relatively difficult installation (Salmon Nation 1999)
- requires civil engineering or geotechnical expertise (Salmon Nation 1999)

3.0 Summary of the Analysis for the Existing Sage Creek Haul Road Crossing

The following information can be found in the Mine and Reclamation Plan for Panel E (BLM and USFS 1997), located approximately two miles northeast of Proposed Panel F.

Four crossing designs were considered for the Sage Creek haul road: 1) steel plate arch, 2) bridge, 3) an elliptical culvert, and 4) a circular culvert. An engineering review concluded that the steel plate arch and elliptical culvert were impractical for a structure needing a 50-foot depth of fill to support haul trucks. The bridge option was rejected for similar reasons, in that a large amount of surface disturbance from construction equipment would be necessary to construct footings and a bridge span large enough to support 150-ton haul trucks. In addition, the cost of such a large bridge was estimated at $2.3 million, approximately 100 times more than an equivalent circular culvert.

The final fish passage structure chosen for the Sage Creek haul road crossing was selected from two circular culvert designs proposed by a BLM engineer. The first design proposed a 266-foot long corrugated metal pipe eight feet in diameter. The second design proposed a shorter culvert (200 feet) that included an embankment retaining structure. Both proposed culverts were designed to accommodate a 200-year flood event, and were modified by installing fish passage structures (24-inch high stainless steel weirs) to allow passage of all age classes of fish. In addition, a plunge pool at the outlets of each culvert were designed in order to dissipate the energy of the water flowing through the pipe, thus allowing fish to enter the culverts more easily from the downstream end. Both culverts were designed to function for a minimum of 20-30 years.

The shorter culvert design alternative was eventually rejected in favor of the longer culvert. Although the shorter design alternative involved fewer impacts to the streambed (66 fewer feet of stream channel disturbance) and riparian habitat (0.1 fewer acres of wetland disturbed), additional construction costs were required to build the retaining walls needed to stabilize the channel. It was determined that reducing the culvert length would have only slightly lessened the sediment impacts associated with the second crossing design. This degree of change in sediment impacts was deemed immeasurable between design alternatives in terms of water quality.

4.0 Case Studies

According to surveys in Oregon and California, thousands of existing culverts are total or partial barriers to fish migration (Mirati 1999, SCC 2004). Most are corrugated metal pipes (circular culverts). A 2002 survey of 47 culverts along 210 km of the Trans Labrador Highway (Labrador, Canada) found that 53% posed problems to fish passage (Gibson et al. 2005). All but two of the culverts surveyed were corrugated metal pipes.

Older, circular culverts are largely ineffective for fish passage (Furniss et al. 1991) because culverts were traditionally designed for passing water only (Porior 2003). Fish biologists frequently recommend open-bottom culverts or bridges for stream crossings because fish passage through open structures is generally guaranteed (e.g., Bates 2003, Porior 2003, ODFW 2005). Relative to closed culverts, however, bridges and open-bottom structures are relatively expensive (ODFW 2005, Baggett et al. 2001) and involve complex installations (Salmon Nation 1999, Labrador Métis Nation 2002). Baggett et al. (2001) report that the Georgia Department of Transportation experienced many difficulties with the installation of the footings for an open bottom arch culvert. Browning's (1990) survey of culverts in Oregon reported that open-bottom culverts, more often than not, had serious undermining which threatened the stability of the fill around the structure (Browning 1990 *as cited in* Salmon Nation 1999). Bridges have a relatively low risk of failure, but in terms of materials and construction costs, bridges are typically the most expensive crossing structure type (Baggett et al. 2001).

The most frequent causes of impasse at circular culverts are a drop (perch) at the culvert inlet or outlet and excessive water velocity inside the culvert. The dynamic nature of stream channels (as well as erosion from culvert installation) has caused perched inlets or outlets to develop around closed culverts that prevent fish from entering (Lang et al. 2004). In addition, narrow inlets and smooth bottoms of many closed culverts causes an increase in water velocities. Several studies document these problems in terms of culvert design.

Lang et al. (2004) studied leaping performance of anadromous salmonids in four "perched" culverts, and found that although leaping ability was site-specific, it was generally proportional to drop height. Adult fish successfully entered culverts that were 2-3 feet high less than 15% of the time, and less than 1% of attempts were successful at a culvert 5 feet high. A widely-cited laboratory study by Stuart (1962) concluded that a pool depth of at least 1.25 times the leap height is needed to reach swim speeds fast enough to make a successful leap.

Warren and Pardew (1998) found fish passage through closed culvert types in Arkansas was an order of magnitude lower than through open bottom structures and natural reaches, and that the difference could be attributed to faster water velocities in closed culverts. Velocities in closed culverts ranged from 1-4 feet per second, whereas velocities in open structures and natural reaches were consistently below one foot per second. Belford and Gould (1996) tested six relatively long circular culverts (>140 feet) in Montana for trout passage effectiveness and concluded that velocity must be inversely proportional to culvert length for fish to successfully pass through. Anadromous salmonids can only sustain heightened swimming speeds, needed to pass some culverts, for limited periods (Furniss et al. 1991). Belford and Gould (1996) found cutthroat trout could pass through a 295-foot circular culvert as long as mean water velocity inside was less than 2.0 feet/second. The longest two culverts surveyed along the Trans Labrador Highway (132.5 and 133 feet) were both observed to successfully pass young trout (Gibson et al. 2005).

Consideration of fish passage during the planning and design of stream crossings can greatly reduce or eliminate the barrier affect that crossing structures can have (Furniss et al. 1991). Published design requirements for closed culverts that accommodate fish passage are now widespread (e.g., NMFS 2001, Porior 2003, ODFW 2005). Culvert design criteria documents prescribe ways to avoid the problems most commonly associated with improperly designed closed culverts. Most list minimum speeds for water velocities that decrease with culvert length (NMFS 2001, CDFG 2002, Bates 2003, Porior 2003, Scottish Executive Consultants 2005, ODFW 2005). The design of longer culverts (>200 feet), therefore, depends largely on controlling water velocity (Scottish Executive 2005), although adding illumination may also be necessary (ODFW 2005).

QDPIF (2005) concedes that fish may be affected by light conditions in culverts but that more research is needed; Scottish Executive (2005) claims light inside culverts is not an issue. Water volume, velocity, and depth are generally considered the most important elements of culvert design. To reduce water velocities, baffles and weirs are frequently installed to provide pools and resting areas for fish, particularly if the culvert is on a slope (Porior 2003). The practice of embedding culverts, a measure to prevent the development of hydraulic drops, increase water depth, and improve "stream simulation," is also a prescribed standard (BCMF 2002, Porior 2003).

Barnard (2003) found that stream simulation culverts, whether round, pipe arch, or bottomless, are reliable and create similar passage conditions compared to the adjoining channel. All culverts in his study with a width ratio of >1.3 (culvert bed width to channel width) and slope ratio of <1.3 (slope of culvert to channel slope) were not significantly different than natural reaches, regardless of culvert type, demonstrating the importance of site choice and design over culvert type per se. In some cases, conditions inside open and closed culverts may differ, but the differences do not necessarily affect fish passage. Another study by Wellman et al. (2000) compared bridges and (box) culverts in 41 Tennessee streams, and found that although sediment conditions differed between streams with culverts and streams with bridges, no differences in fish diversity, abundance, or richness were evident.

In 2004, NewFields (2005) conducted electrofish surveys in Sage Creek, above and below the circular culvert built in 1998, and recorded the presence of cutthroat trout both below and above the crossing. However, since resident cutthroat populations can exist upstream of barriers, these data alone do not answer the question, "does the crossing allow for passage of spawning cutthroat trout?" Thus, to better understand and document the effectiveness of this culvert, additional monitoring data will be collected during early 2005. These data will be included in this technical memo when available. This 266-foot culvert contains weirs to slow water velocity inside the channel, a surge basin at the outlet for fish to rest, and has been designed to accommodate a 200-year flood event (BLM and USFS 1997).

5.0 Summary

In terms of stream crossings associated with this Project, it has been determined that bridges are not feasible due to cost and extensive disturbance in the uplands during construction and removal. Pipe arch and open bottom culverts were determined to be impractical given the amount of fill and weight of haul trucks that the structure would need to support. It has been decided that circular culverts designed to simulate natural stream bottom and to allow for the passage of spawning cutthroat trout would be used at all fish-bearing stream crossings.

6.0 References

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