Habitat Conservation Plan for the Upper Etowah River Watershed:

Road Crossings – Effects and Recommendations

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I. Introduction

Habitat destruction and subsequent habitat fragmentation are conditions that put endangered and threatened fishes of streams and rivers at risk. Ninety percent, or greater of flowing water in the United States is greatly impacted by man-made alterations of channels (e.g. dams, water diversion) that fragment these networks, and as a result, 47 percent of all federally listed endangered animals in the United States are freshwater species (Jackson et al. 2001).

It has become impossible to deny the strong relationship between streams and the lands through which they flow (Hynes 1975, Vannote et al. 1980, Minshall et al. 1985, Junk et al. 1989), and watersheds are sometimes viewed as a more appropriate ecosystem unit (Lotspeich 1980). With this in mind, it must be acknowledged that terrestrially occurring activities have great influence upon streams (May et al. 1997, Meyer and Wallace 2001) and the biota that live in them.

With the intent of protecting endangered species and their habitat, the United States Congress passed the Endangered Species Act (ESA, 1973), which prohibits the harassment, harm, pursuit, hunting, shooting, wounding, killing, trapping, capture, collection of any protected species, or any attempt to engage in any of the aforementioned behaviors. Concern over the extent of the ESA's ability to restrict landowners' rights to engage in lawful activities on their own lands led to the amendment of the ESA in 1982.

The ESA amendment, Section 10, authorizes non-intentional harm of endangered species within a specified context. It is now possible to obtain permits to engage in (legal) activities, such as construction, or other land development, that could lead to the 'incidental take' of federally listed species. To obtain such a permit, a Habitat Conservation Plan (HCP) must be submitted with the request for the permit. An HCP must make a statement about the activity's potential harm to the federally listed wildlife present in the area of the proposed activity and demonstrate that appropriate measures will be taken to minimize the activity's effects on the livelihood of the listed species.

The construction of a region-wide HCP requires the synthesis of a large amount of scientific knowledge into practical ideas of how to discuss, assess, treat, and monitor the effects of general development in a watershed. To provide such a framework, it is necessary to separate the larger issue of land development into its component activities.

The purpose of this paper is to: 1) discuss legal aspects regarding Habitat Conservation Planning, under the ESA, 2) discuss the effects of culverts on stream habitat, and provide recommendations for their use, and 3) identify problems presented to stream habitat by bridges, and provide recommendations for their use.

In most instances, the effects that road crossing structures have on streams are extensions of, or are exacerbated by conditions caused by general land development. For this reason, the physical effects of urbanization on watershed hydrology and stream channel morphology are summarized. To provide a biological context in which to interpret the effects of road crossings on streams, a cursory treatment of the utilization of stream habitats by fishes is also given. These treatments are included in appendices to this paper.

Upper Etowah River Watershed-Wide Incidental Take Permit

The Georgia Department of Natural Resources has requested that The University of Georgia work together with local governments of the Upper Etowah River Watershed to develop a basin-wide (which includes parts of Cherokee Co., Dawson Co., Forsyth Co., Lumpkin Co., and Pickens Co.) Habitat Conservation Plan for the protection of endangered, threatened, and candidate aquatic species of the area.

As human population growth continues at a rapid-pace in the Etowah basin, the small-stream habitats of tributaries to the Etowah River are experiencing increased levels of habitat fragmentation and degradation. The major threats to aquatic communities in this system are associated with upland land uses brought about by change as development within the watershed takes place.

Due to the presence of endangered species in the area, it is imperative that many major land disturbing activities (such as altering land for the construction of houses, or road building) be cleared by obtaining a biological opinion from the U.S. Fish & Wildlife Service, or be accompanied by an incidental take permit. These are cumbersome processes that could be made less burdensome by obtaining one incidental take permit for a large area. The HCP for the application of this permit would cover many common, land-disturbing activities associated with land-use changes in the area.

If approved, a single, region-wide incidental take permit would be issued to all governments contained within the Etowah watershed. By the issuance of this permit, the authority to grant permission for parties to engage in those activities covered under the HCP is conferred to local governments of the Etowah basin. For these activities, separate biological opinions, or HCPs would no longer be required.

Regional HCP and Habitat of Endangered Species

Because streams and rivers are exist as a network and they are greatly affected by the lands they drain, habitat quality for the endangered aquatic fishes of the Etowah integrates the characteristics of all areas within the Etowah basin. It is necessary, therefore, to take steps towards protecting the habitat of the drainage network of the Upper Etowah River Watershed as one entity. The development of a watershed-wide HCP promotes a regional perspective on environmental protection and resource management.

The initiative to form a regional HCP for the Etowah basin is also significant because it gives recognition to the idea that human activities have an additive impact on the environment and that the effects of these activities cannot be considered as separate from one another.

II. The Endangered Species Act

The Endangered Species Act § 10 addresses incidental take permits and habitat conservation plans. § 10(a)(1)(B) provides for incidental take permits, stating that "the Secretary may permit, under such terms and conditions as he shall prescribe any taking otherwise prohibited by §9(a)(1)(B) of this title if such taking is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity." § 9(a)(1)(B) makes it unlawful to "take any such species within the United States or the territorial sea of the United States." §10(a)(1)(B) is subjected to the following subsection, (a)(2)(A) which addresses habitat conservation plans. This section states that:

> No permit may be issued by the Secretary authorizing any taking referred to in paragraph (1)(B) unless the applicant therefore submits to the Secretary a conservation plan that specifies –
>
> (i) the impact which will likely result from such taking;
>
> (ii) what steps the applicant will take to minimize and mitigate such impacts, and the funding that will be available to implement such steps;
>
> (iii) what alternative actions to such taking the applicant considered and the reasons why such alternatives are not being utilized; and
>
> (iv) such other measures that the Secretary may require as being necessary or appropriate for purposes of the plan.

In identifying the likely impacts on the species, the potential permittee must determine "(a) delineation of the HCP boundaries; (b) collection and synthesis of biological data for the species to be covered by the HCP (c) identifying activities proposed in the plan area that are likely to result in incidental take; and (d)quantifying anticipated take levels"(Habitat Conservation Plan Handbook). Under §10(a)(2)(A)(iii), the permittee must also specify what mitigation occur. This can include "avoiding the impact, minimizing the impact, rectifying the impact, reducing or eliminating the impact over time, or compensating for the impact"(Habitat Conservation Handbook). Types of mitigation steps may be acquisition of existing habitat, conservation easements, enhancement of former habitats or creation of new habitats. Monitoring should also be implemented to analyze and adjust mitigation strategies if needed. The potential permittee must also demonstrate that adequate funding is available for planned mitigation measures. If all of these requirements have been met the Secretary will issue the permit. An Implementation Agreement may be developed if the Fish and Wildlife Service requests one. An IA is a signed contract that "defines the obligations, benefits, rights, authorities, liabilities, and privileges of all …parties to the HCP." (Stanford Environmental Law Society 2001) If the permittee does not comply with the terms and agreements of the permit it may be revoked by the Fish and Wildlife Service.

In the early stages of the HCP program, progress was very slow and number of problems arose. From 1982 to 1991, only 11 HCPs were approved by the Fish and Wildlife Service. HCPs that were developed were on a small scale, usually covering less than 1,000 acres. These small HCPs were often done in isolation, causing a "piecemeal" application which only sporatically protected the species in a given area. The length of the planning process as well as economic uncertainty were also constraints on the plans. Landowners were reluctant to commit land and resources to an HCP without assurances that additional protective measures would not be required in the future. In 1994, Secretary of the Interior Babbitt redesigned the program, implementing his "No Surprises Policy." This promises that "if, in the course of development or land use, a landowner invests money and land into saving endangered, threatened, or unlisted species covered in an HCP, the government will not later require that the landowner pay more or provide additional land even if the needs of the species change over time"(Fisher 1996). The policy gave landowners the certainty they desired to fully participate in developing HCPs. The burden shifted to the government and the public to act if any additional funds or lands were needed to protect a certain species if unforeseen circumstances were to arrive. The economic certainty that this policy creates also encourages lenders to make financial commitments for funding that is required before the HCP is approved.

As of 1999, 300 HCPs have been developed, covering 30 million acres and 200 endangered species. These HCPs are taking on a more regional application, increasing in size. While early HCPs usually covered 1,000 acres or less, today there are 13 HCPs of 10,000-100,000 acres, 10 covering 100,000 to 500,000 acres, and two covering over 1,000,000 acres.

III. Legal Ramifications of the Endangered Species Act

While most case law in the environmental sector involves environmentalists challenging the government to do more to protect endangered species, the government can also incur liability by requiring landowners to do much, or by not adhering to there acts and duties under the Endangered Species Act. In addition, if a permittee violates the Endangered Species Act, liability is shifted to the issuing agencies and away from private parties. The Endangered Species Act § 11(g) provides a means for private citizens and organizations to bring a civil suit against governmental agencies and private parties.

§11(g)states:

> (1) …any person may commence as civil suit on his own behalf –
>
> (A) to enjoin any person, including the United States and any other governmental instrumentality or agency, who is alleged to be in violation of any provision of this chapter…
>
> © against the Secretary where there is alleged a failure of the Secretary to perform any act or duty under § 1533 of this title which is not discretionary with the Secretary.

In 1997 the United States Supreme Court addressed this provision and its applicability in actions against the Secretary of the Interior for "overdetterence" and failure to perform his duties in Bennett v. Spear. Plaintiffs in this case were Oregon ranch operators and irrigation districts that depended upon water from the Klamath Project which released water from lakes and reservoirs in the area. The Fish and Wildlife Service issued a biological opinion which stated that the operation of the project would have adverse effects on two endangered fish species. The Service believed that the maintenance of minimum water levels in the lakes and reservoirs would keep these species out of jeopardy. The Plaintiffs filed suit claiming they had an economic interest in the water and that the Secretary had violated the Endangered Species Act by not taking economic considerations into account.

The court first addressed whether the Plaintiffs had standing to sue under the ESA. It found that the applicable standing requirement was "whether the interest sought to be protected by the complaintant is arguably within the zone of interests to be protected or regulated by the statute…" The court found that the ESA citizen suit provision expanded the zone of interests test, and that persons who allege overenforcement of the Act are entitled to suit, not environmentalists alone. The court also found that while the Plaintiff's claims were not reviewable under §(A) of the citizen suit provision, their claims were reviewable under §(C). Due to the fact that they alleged that the Secretary did not take into account economic impact or use scientific data as required under § 4 of the Act, they could file a citizen suit alleging that they Secretary did not perform an act or duty specified by the Act.

While Plaintiffs claim that the Secretary did not take into account economic impact and scientific data in issuing the Incidental Take Permit are not reviewable under the civil suit provision, they may be brought under the Administrative Procedure Act which authorizes the court to "set aside agency action, findings, and conclusions found to be…arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law." The court noted that the purpose of the requirement in §7 that each agency "use the best scientific and commercial data available" is to ensure that the ESA not be implemented haphazardly, on the basis of speculation or surmise." Therefore, without using the best scientific data, the agency was acting arbitrarily and capriciously in its decision to implement the incidental take permit. This case illustrates the need for the Fish and Wildlife Service to review adequate data and findings before granting an incidental take permit that is not grounded on a rational basis. Bennett v. Spear also set the precedent that those alleging overenforcement may have standing to sue if they can allege an actual injury, such as economic loss.

HCPs have also been overturned for reasons of underdetterence. In National Wildlife Federation v. Babbitt, the United States District Court for the Eastern District of California found that the Fish and Wildlife Service's issuance of an incidental take permit was arbitrary and capricious on a number of counts. The National Wildlife Federation alleged that the permit allowing the development of the Natomas Basin in Northern California violated provisions in §10 and § 7 of the ESA pertaining to HCPs. Like the proposed HCP for the Etowah Watershed, this plan was regional in scope, allowing resources to be pooled to acquire conservation land. Plaintiffs argued that the finding that the "plan will minimize and mitigate taking to the maximum extent practicable, is arbitrary and capricious because the Service failed to consider any alternatives involving greater mitigation measures." The court first looked at the HCP's mitigation measures which were to conserve land at a ratio of .5 acres conserved to 1 acre developed and a set fee for developing on land in the plan area of $2000-2500/acre. The court found that these measures were arbitrary and capricious because there was no showing that a higher ratio or fee would be impracticable. Also, these measures were the minimum possible, not satisfying the statutory language that required mitigation and minimization "to the maximum extent possible." The HCP also precluded rice farmers in the region from using any conservation measures at all without giving support for why this would not effect mitigation and minimization measures.

The court also upheld the plaintiff's claim that the approval of the HCP for the city of Sacramento was arbitrary and capricious because it lacked necessary funding. The City refused to fund the plan in the event that there was a "shortfall." The court read the ESA statute to require that the applicant must guarantee funding before approval, which this HCP did not do. The Service also did not adequately consider how the City's permit, which will include the bulk of development in the area, will affect the endangered species. There was relatively little analysis on the record of how the permit on its own will impact the species, therefore the approval of the permit was arbitrary and capricious. The court did however, uphold the Service's use of the 'best scientific and commercial data" with respect to ESA § 7, although the Plaintiff's claimed the data relied upon was incomplete. The court concluded that the requirement does not imply that the data must be perfect, but instead must be the best available.

In a similar case, Sierra Club v. Babbitt, the United States District Court for the Southern District of Alabama found that the issuance of an incidental take permit was arbitrary and capricious because the level of funding assured was not adequate and did not have any support in the Administrative Record. The incidental Take Permit and Habitat Conservation Plan in question was developed to protect the endangered Alabama Beach Mouse against habitat destruction along the Alabama Coast. The HCP provided for a total of $210,000 to be collected from the major developer in the plan, Aronov Realty Management. The HCP also called for funding from "speculative unknown sources." Sierra Club challenged the HCP on the grounds that funding was not adequate to protect the species, and that there was no rational basis in the record to support the plan. The court found for Sierra Club, stating that there was no "clearly articulated analysis demonstrating whether the amount of funding is rationally based on the relevant facts.," and therefore the issuance of the permit was arbitrary and capricious. The court also noted the discrepancy between the Fish and Wildlife Field Office, who criticized the proposed HCP, and the regional office, that apparently ignored the field office's reservations about the plan.

National Wildlife Federation and Sierra Club stress the importance of the Fish and Wildlife Service to go to the maximum extent available to protect listed species and having adequate data on record to uphold their findings. Service action under § 7 and § 10 of the ESA needs to pass the arbitrary and capricious standard to be upheld in court, therefore, it is imperative to have a rational basis behind all Service decisions that is documented on the record.

Although there are no cases on record alleging a "taking" of property by the government through an HCP, it is important to note the implications of the takings doctrine. The Fifth Amendment of the Constitution states: "Private property [shall not] be taken for public use without just compensation." Due to the fact that an HCP is entered into voluntarily, the permittee can not usually allege a taking of property for conservation uses because it is agreed upon by both parties. A taking may occur if an HCP is altered by the government, requiring additional lands that the government would be required to pay for. This is an unlikely situation, however, due to the "No Suprises" Policy which precludes the government from taking any additional property in the event of unforeseen circumstances.

IV. Habitat of the Imperiled Aquatic Species of the Etowah Watershed

Burkhead et al. (1997) summarized the ecological correlates of fish imperilment in the Etowah River Watershed. They found the following to be important in predicting whether fishes were imperiled, or not (listed in order of importance, determined by Burkhead et al. (1997)):

- Range size was found to be the most important correlate of imperilment. Most imperiled species of the area are found only in local areas, or are geographically isolated.

- Specialization for living in contact with the stream bottom (benthic habits). Benthic fishes are imperiled at five times the rate of fishes that do not rely on the stream bottom habitat. Sedimentation is largely responsible for this type of habitat degredation.

- Fishes with small body sizes are more likely to be imperiled. Smaller fish may have lower dispersal abilities, shorter lives, lower reproductive potential, and many are benthic in habit. In the Etowah watershed, 15 of 17 imperiled fishes are of very-small and small sizes.

Effects of Road-Stream Crossings on Habitat

Road-stream crossings are indispensable when there is no alternative to crossing water. However, these features of our landscape are far from benign in respect to natural systems. Bridges and culverts have direct impacts on stream channels. They influence erosion patterns by changing the way that water flows within the stream channel, on stream banks, and on the floodplain. Their impacts to streams are often exacerbated by increased runoff associated with the altered hydrologic regimes of urbized areas.

Bridges and interact directly with riparian vegetation, bank structure of the stream, and the bed of the stream. Physical changes to the stream channel affected by road crossings (during construction and after) include:

- Removal of riparian vegetation.
- Drastic disturbance of land surrounding the stream channel, such as grading of riparian areas, placement of fill in riparian areas, excavation of stream bed, and alteration of stream banks (especially when structures are being placed into existing banks).
- Constriction of stream channel (both vertically and horizontally).
- Placement of structures into the stream bank and channel that interfere with flow patterns of the water.

Riparian Vegetation

Riparian vegetation performs many biological and physical functions important to the stream channel (e.g. food supply for stream organisms, temperature regulation through shading, provision of physical habitat). Riparian vegetation also affects erosion processes through various mechanisms and in many cases can help to alleviate some erosion problems. Riparian vegetation can allay erosive actions by:

- Intercepting rainfall and slowing the movement of water towards the stream channel.
- Root structure of riparian vegetation can stabilize stream banks and help to prevent their collapse.
- By providing physical structure on land and stream banks, riparian

vegetation can trap sediments that are being mobilized from the upland areas by water runoff.

Removal of riparian and floodplain vegetation leads to increased levels of erosion. Erosion originates within the stream channel from the delivery of greater amounts of water caused by decreased absorption and slowing of water by vegetation, falling of stream banks as support structure is lost, and increased upland erosion due to loss of physical structure on disturbed land surfaces.

Land Disturbance

Any major change in terrain of the area immediately adjacent to the stream channel, or alteration of the stream channel itself, exposes a great amount of material that can be deposited directly to the stream channel, or carried into the stream channel with runoff unless diligent efforts are made to prevent this from happening.

Channel Constriction

Channel constriction can lead to severe changes to stream form by limiting the area available for water to expand into during high water flow events, such as floods. If road crossing structures are placed onto banks and have little vertical clearance, water may routinely be funneled into narrow areas. When water is forced through channels in this way:

- There is often a widening of the channel upstream of the constricting structure, made by the erosive action of water backing up behind the structure before it is able to pass through.

- As water pushes through the constricting structure, its velocity increases and often there is a deepening of the channel downstream of the constriction.

Channel constriction therefore leads to a number of channel changes, such as:

- Increased levels of sediments within the channel.

- Scour of the channel bed, removing biota with the passage of high velocity water and sediments.

- Unstable bank structure.

- Destabilization of road crossing structures as erosion occurs around them.

Safety hazards for vehicles, or pedestrians that may be attempting to use the road above the channel during high flow events.

Disturbance of Water Flow

Road crossing structures that are placed within the stream channel (e.g. bridge piers, culvert footings) interrupt the flow of water and cause turbulent patterns in water flow. As water passes, vortices erode material surrounding road crossing structures (e.g. piers, bridge abutments) (Hilmes and Vaill 1996). Scour around bridge foundations had caused failure of more than 487,000 U.S. bridges that span water (Kotun et al. 1997).

Animal Range Size and Road-Stream Crossings

Road-stream crossings can block the movement of fishes by creating excessive water velocities during high flows, by changing stream morphology so that there is inadequate water depth in the channel during low flow, or by creating excessive drops at the outlets of structures, such as culverts (Furniss et al. 2000). When species' range is already small, any loss of habitat can be highly detrimental to their survival (Appendix I). By altering hydrology, and erosion processes, road-stream crossings causes habitat degradation that leads to fragmentation of large habitat patches into smaller habitat patches divided by degraded areas (Appendix II).

Benthic Habitat and Road-Stream Crossings

Benthic fishes have specific sediment requirement for the completion of their life cycles (see review Waters 1995). The eroded material that results from the kinds of intensified erosion mentioned above is deposited within the stream channel before it moves downstream (Knighton 1998). This deposition changes the composition of the natural stream bed sediments, making it difficult, or impossible for fishes to complete their life-cycles in these areas.

V. An Overview of Culverts: Various Types, Their Effects, and Recommendations on How to Install

Introduction

"Culverts are the most commonly used method for providing access over a watercourse, particularly for small and medium sized streams" (Dept. Fisheries and Oceans 1999). In the past, culverts were designed with the primary focus on safety, hydraulic efficiency, and initial construction costs (Kosicki 2000). Many of the traditional culverts were too narrow to allow adequate fish passage or would speed the flow of the water which interfered with the fish's swimming pattern. The Washington Department of Fish and Wildlife "estimates that up to 3000 miles of stream habitat are blocked due to impassable conditions at 2400 culverts at public and private road crossings" (Essential Fish Habitat 1999). Usually the traditional culvert not only impeded fish passage, but also resulted in scour in the streambed. Now, culverts are designed taking the old factors into account along with the consideration of fish passage. There are many more culvert designs today than were traditionally used that minimize impact on the natural stream channel. This section of the paper will explore the problems encountered using a traditional culvert, the various new models available, their advantages and disadvantages, and general guidelines concerning culvert installation.

Problems With Traditional Culverts

A traditional culvert typically refers to a smooth, round metal pipe, but is applicable to any model improperly installed with no concern of fish passage. This pipe usually forms a small hole in an embankment, and has no superstructure, substructure, or deck. The most common problems concerning fish passage encountered with traditional culverts are "high water velocity, shallow water depth within the culvert, excessive vertical drop at the culvert outlet, and debris blockages" (Oregon Department of Fish and Wildlife 1999). A field survey in Virginia found that "outfall heights and shallow flow depths contributed most to impeding fish passage in the culverts studied" (U.S. Roads 1999). An Arkansas study revealed “evidence that increased water velocity through culverts is part of the mechanism by which these crossings restrict fish passage” (Warren and Pardew 1998). Hence, all these impediments need to be recognized and eliminated.

Traditional culverts primarily posed problems to the upstream migration of anadromous fish. Thus, the majority of culvert research has been done in states such as Washington and Oregon, which have large anadromous fish populations. Often a culvert was simply placed in a stream which, as previously mentioned, constricted the flow and caused high water velocities. Also, during a dry season when the water level dropped, a hydraulic drop would occur at the end of the culvert, impeding upstream fish passage. This led to the isolation of subpopulations of fish upstream and downstream from the culvert, making them vulnerable to extirpation from catastrophic events. (Essential Fish Habitat 1999).

In Georgia, large dams block diadromous fishes (American Shad, American Eel, etc.) from access to many upstream portions of our river basins. However, we have many concerns about migrating fishes (Redhorse sucker, etc.) that may be affected by the improper installation of culverts, as well. Culverts may inhibit dispersal and interpopulation movements by many stream fishes. A hydraulic drop at the culvert outlet not only leads to channel scour and subsequent sedimentation, but also may hinder a fish’s swimming pattern. It is thought that hydraulic drops, such as those at the mouth of a culvert, may interfere with a fish’s buoyancy, resulting in an inability to swim. The fast flow of water funneled through a small culvert causes turbulence, which may also have the same effect.

There are many types of culverts. Only those that span the stream or simulate the streambed should be used. Streambed simulation means that the “substrate and flow conditions in the crossing structure mimic the natural streambed for fish passage flows” (Oregon Department of Fish and Wildlife 1999). Embedded culverts simulate the streambed, and bottomless (or open bottomed) culverts span the stream.

Bottomless Culverts

Bottomless culverts are similar to bridges. They span the streambed and allow for natural flow of the stream. Bottomless culverts, like bridges, retain the natural morphological features of "stream width, stream bed composition, slope, and cross-sectional area" (Fish Passage in Streams 2001). Bottomless culverts come in concrete or metal arch top and flat top styles. The installation of bottomless culverts typically does not entail excavation in the stream, only in the bank for the footings. However, this excavation can cause substantial disturbance to the stream bed and banks (Fish Passage in Streams 2001). The Georgia Department of Transportation experienced many difficulties with the installation of the footings for an open bottom arch culvert at Shoal Creek, a tributary of the Etowah. If there are enough problems and costs associated with these culverts, then bridges should be used instead (Will Griffin 2001). Besides installation concerns, foundation substrate is another primary consideration when deciding between a bottomless or an embedded culvert (Oregon Department of Fish and Wildlife 1999). If deep unconsolidated gravel is present at the site, failure of the bottomless culvert is a major concern. However, if bedrock is present, a bottomless culvert should be used because embedding a culvert would entail extensive excavation (Oregon Department of Fish and Wildlife 1999).

Corrugated Metal Steel Pipe Culvert

The corrugated metal steel pipe culvert is similar in design to the traditional culvert, except its surface is corrugated, while traditional culverts have a smooth surface. This type of culvert is a simple round shape constructed of galvanized corrugated steel. For the purpose of fish passage, the deeper the corrugations, the better (Oregon Department Fish and Wildlife 1999), because they slow the flow of the water. These structures are prone to corrosion and leaks, and it is often difficult to construct the backfill. For these structures, the "rustline that forms in the bottom may provide a quick field assessment tool. Preliminary observations have shown rusting heights in excess of one third the pipe diameter indicate that it is hydraulically undersized" (Furniss 1996). While the deep corrugations are good at slowing down the water speed, it may result in turbulence. It is thought that turbulent water can cause a fish to fail to recognize the primary flow direction, resulting in the fish losing its orientation and failure to negotiate the crossing (Fish Passage in Streams 2001).

Box Culverts

The box culvert is typically made of concrete, which allows for greater hydraulic efficiency than the corrugated metal structures. These structures are relatively maintenance free; however, they are prone to leaking. Box culverts can come in spans up to 18 feet. This culvert can also come in aluminum, which is more durable than the steel culvert because it does not rely on the thin galvanized coating to protect the parent metal and it is not as prone to improper backfill. This structure can be lifted into the excavation site in one piece. However, the stream must be excavated and strip footers must be poured into the streambed prior to installation.

Multiple Culverts

Multiple culverts, two or more culverts placed side by side in the stream channel, are not recommended. These may form a barrier to fish at the spaces between each culvert. If the stream is so wide as to need more than one culvert, then a bridge should be used. (Comfort 1996).

Embedded Culverts

Culvert embedding is usually done with the corrugated metal steel pipe culvert; however, embedding is possible with any round or four sided culvert. If properly embedded, the culvert can retain the natural flow of the stream. The embedding allows the bottom of the culvert to be covered with natural streambed materials, which makes the object less intrusive on the stream environment. All embedded culverts should be embedded at least 20% of its height or one foot, which ever is greater (Oregon Department of Fish and Wildlife 1999). Further guidelines are discussed below.

General Guidelines Concerning Culvert Installation

Bridges should be preferred to any culvert model (Scottish Executive 1999). However, because of their costs, bridges are often not feasible. When that is the case, culverts that simulate the stream (embedded culverts), or those that span the stream (bottomless culverts) should be used (Oregon Department of Fish Wildlife 1999). If the culvert is properly installed, "it can reduce the adverse effects on fish while maintaining hydraulic efficiency" (U.S. Roads 1999).

Many sources suggest that if road crossings that simulate the stream can not be used, then nonembedded culverts or baffled culverts should be used (Oregon Department of Fish and Wildlife 1999). These structures should only be an option of last resort. As previously noted, a nonembedded culvert often increases the velocity of the water, and results in turbulence and scour. A baffled culvert includes many concrete protrusions inside the culvert aimed at slowing the water's velocity. Baffles are typically used in culverts with steeper gradients (Oregon Department of Fish and Wildlife 1999) to slow the flow of the water. However, a baffle may impede fish passage by providing a barrier inside the culvert. Also, baffled culverts tend to accumulate debris, forming another barrier to fish movement and requiring more frequent maintenance. A literature review of primarily western states recommended not using a baffled culvert to control flow speeds under normal circumstances, but instead "increasing the roughness coefficient of the culvert's bottom," (U.S. Roads 1999), for example, by embedding the culvert. On the other hand, a study in Wisconsin revealed habitat enhancement baffles used in long box culverts (45.7 and 117 meters long) "can increase habitat heterogeneity and resident stream fish abundance and species diversity" (Slawski and Ehlingder 1998). This process placed alternating limestone baffles along the interior of the culvert, which slowed the water and simulated the natural stream flow. However, if the culvert is properly installed, there is no need to slow the velocity of the water, and thus, no need for a baffle. Therefore, if it is impractical to replace a problem culvert, using a habitat enhancement baffling process may be a good alternative.

The road crossing should be placed in an area with minimal to 0% slope, and the culvert should be placed at the same slope as the streambed. "Bottomless arches and all styles of embedded culverts shall be placed at or near the same gradient as the natural streambed and shall be at least as wide as the active stream channel" (Oregon Department of Fish Wildlife 1999). Field surveys in Virginia found that "a culvert installed deeper than the streambed can increase flow and decrease depth of flow below minimum values. A culvert installed at a gradient less than the streambed can cause a hydraulic jump at the barrel's inlet, which in turn can cause turbulence and reduce a fish's buoyancy" (U.S. Roads 1999). The culvert must also be placed in line with the natural course of the stream in order for it to have the least amount of impact. "Alignment with the stream channel is critical for the stream channel to function properly. Culverts set at an angle to the channel can cause bank erosion and can develop debris problems. Culvert alignment must fit the natural stream channel" (Comfort 1996). With respect to a culvert's length, some experts recommend that none should exceed six meters. Although not proven, "preliminary research shows that some native fish will not enter darkened passages, although the amount of light required has not yet been quantified" (Fish Passage in Streams 2001). Until further research is completed, it is suggested that the culverts remain short, or provide some inlet for sunshine. The length should also remain shorter if the velocity inside is too fast, since fish cannot maintain burst speeds to swim then entire length of a long culvert (Fish Passage in Streams 2001).

During installation of the culvert, disturbance to the stream bank and bed should be limited "to that necessary to place the culvert, embankment protection, and any required channel modification associated with the installation" (Oregon Department of Fish and Wildlife 1999). Approved structures shall be constructed in the dry before installed (Oregon Department of Fish and Wildlife 1999). Due to the relatively unknown effects of the newer culverts, each structure should be monitored during and after installation.

Culverts should be checked for blockages and any other problems after all major rain events, and any problems shall be promptly remedied (Essential Fish Habitats 1999).

There is no set formula to decide which road crossing structure is appropriate for a particular site;

"consideration must be given to biological, physical and hydrological factors" (Forrest Practices Code 1997).

<u>Recommendations For Road Crossings</u>

1. Use a bridge, where practicable
2. Use a bottomless culvert or embedded culvert if a bridge is not practicable
3. Install the culvert at same slope as the stream
4. The slope of the stream should be as close to 0% as possible
5. Align the culvert with the natural stream channel
6. Monitor the culvert during and after construction, especially after all major rain events

<u>Attributes of Properly Installed Culverts</u>

1. No hydraulic jumps at the inlet of the culvert
2. No hydraulic drops at the outlet of the culvert
3. Natural stream bottom in place
4. No impeded fish passage
5. No turbulence inside the culvert
6. Velocity of the water inside the culvert should match that of the stream

VI. Recommendation for Planning of Future Bridge Projects

Bridges represent the best hope for minimizing the impacts of road crossings on stream ecosystems. It is therefore of great importance that the problems they present to these systems be identified and mitigated. If we are successful in designing bridges that maintain the integrity of the systems in which they are placed, then we have only to make sure that these are used as often as possible as road crossing structures. Culverts, no matter how greatly improved, will always be an intrusive structure within the stream channel that eventually results in the degradation of stream habitat. It should be recognized that bridges should always be used in stream crossings if impacts to habitat are to be minimized.

- It is important to realize that the kinds of changes imposed on stream habitats by bridges greatly impact the biota largely through the aspects of hydrology and geomorphology. A great effort should be made to educate workers involved with bridge planning projects in this aspect of bridge structures.

- Keep all bridge support structures out of the channel. This precaution will prevent elevated levels of erosion associated with turbulent water flow caused by placing these structures in water. There will also be a decrease in the level of maintenance required to keep the bridge structure in safe, working condition.

- Make every attempt to understand the channel in terms of its hydrology, using historical data when possible, and always making current field measurements. This will help to calculate adequate clearances, both horizontally, and vertically. Every attempt should be made to avoid constructing an unnaturally narrow structure.

- Bridge structures should not only span the floodprone area of the channel (i.e. floodway, active floodplain), but should be set as far apart as possible. This will lessen the amount of impervious surface introduced to the land adjacent to the channel (e.g. fill, pavement) and decrease erosion.

- Riparian vegetation should not be unnecessarily disturbed, and should be replaced as soon as possible. Vegetation should include only appropriate native vegetation.

- Construction plans should be made to take place during times when spawning of endangered fishes does not occur.

- To prevent sedimentation during construction, Best Management Practices (State of Georgia) regarding bridge construction activities should be followed.

Bridge Construction Recommendations

1. Educate bridge designers in the consequences of bridge structures to stream morphology and hydrology and how these aspects tie into biological impacts.

2. Keep all bridge support structures out of the channel, off of the banks, and off of the active floodplain.

3. Make every attempt to understand natural hydrology of channel before making changes: use historical data and current field measurements for any modeling.

4. Preserve natural qualities of land adjacent to stream banks by not placing impervious grounds in these areas.

5. Re-vegetate disturbed areas as soon as possible with native vegetation.

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Appendix I. Habitat Conservation

"…the major task of conservation efforts is to reverse previous and minimize future human impacts on natural

systems."

-Helfman et al. 1997

There exists more than one approach to protecting endangered species. Some species are preserved outside of their natural environment (*ex situ* conservation), in places such as zoos, and gardens. However, these methods of preservation are not desirable, or practical for many species. The alternative to *ex situ* conservation is to conserve species within their natural environment (*in situ* conservation, habitat conservation). Many species become endangered through the destruction of their habitat—in these cases, the most appropriate way to conserve the species is to preserve their natural habitats (together with the imperiled species).

The land upon which we live is not discreetly divided into patches, which do not influence one another. Rather, the surface of the Earth is continuous, and there exist not only physical connections between landscapes, but biological connections as well. Besides landscape connectivity, there are also connections between organisms on many levels. This infinite web of connections makes habitat conservation a complex matter. The objective of conserving habitat is actually the aim to preserve intact ecosystems. In order to successfully preserve an ecosystem, many issues on various levels must be addressed. Speight et al. (1999) presented four major ecological aspects to consider for the habitat conservation of insects, but they apply to habitat conservation of other species as well:

1) All habitats important to the organism should be retained.

2) Habitat areas should be large enough to sustain organism populations.

3) There should be enough areas of a number of habitat types. These areas should be arranged in a way that allows the movement of individuals between different habitat areas, so that the long-term survival of the species is assured.

4) Appropriate habitat management strategies must be formulated and adopted.

Each topic mentioned above can be subdivided into smaller questions that are still complex enough to have espoused a multitude of studies.

Although the task of conservation may seem daunting, it is important that we engage in attempting it now—while there is still diversity of the natural world to preserve. Habitat conservation is ultimately about regulating human growth and activity.

Appendix II. Effects of Development on Watershed Hydrology and Stream Form

"Rivers are essentially agents of erosion and transportation, removing the water and sediment supplied to them from the land surface to the oceans. They provide the routeways that carry excess precipitation to the oceanic store, thereby completing the global hydrological cycle."
-David Knighton 1998

"When precipitation falls on a continent, it separates into that which infiltrates the ground, that which immediately evaporates, and that which runs off the ground surface. The runoff carves or maintains the challs of rill, stream, and river."
-Luna B. Leopold 1994

Streams drain the Earth's surface and their physical characteristics (as well as biological attributes) are directly influenced by catchment hydrology and erosion rates (Knighton 1998). Streams are influenced by downstream, local, and upstream factors, such as: climate, geology, and basin physiography (Knighton 1998). These controls act to influence streams by impacting watershed hydrology, erosion processes, and mineral materials entering the channel.

Climate influences streamflow patterns through its supply of stream ecosystems with energy and water (Gordon et al. 1992). Climate also influences landforms, and determines the nature of vegetation.

Geology influences the patterns in which water drains, determines the erodibility of lands over which waters run, the kind of sediments that are supplied to streams, and the chemical matters supplied to the water column. Vegetation found in an area is also influenced by the local geology.

Vegetation contributes biological energy to the stream channel, influences the stability of soils, and has an effect on the amount of water that becomes runoff.

Alteration of Hydrology and Erosion Processes

> *"Hydrology is the study of the interrelationships and interactions between water and its environment in the hydrological cycle."*
> *-Gordon et al.1992*

When considering individual watersheds, in addition to natural controls, such as those previously listed, anthropogenic land use also has a great influence on stream channels and stream network qualities (Leopold 1994). That is, by altering landscape attributes, humans change hydrology, erosion rates, and water constituents (e.g. toxic substances deposited on land are washed into the stream with runoff water) within a given watershed.

Human projects on land often involve the conversion of rural areas into urban and residential landscapes. As this conversion takes place, the hydrology and erosion processes of a watershed are altered through the disturbance of vegetation, the disturbance of soils, and the creation of "impervious surfaces," or land surfaces that do not allow the penetration of water into the ground. Roads, fill, paved parking lots, storm drains, and rooftops are examples of impervious surfaces.

During rain events, impervious surfaces and the loss of vegetation leads to an increased amount of water running over land (runoff), a faster rate of water delivery to channels (Hollis 1975), and elevated sediment loading in channels by increasing overland erosion as well as erosion within the channel itself (Leopold 1994).

Unnaturally high levels of runoff and erosion have large impacts on channel form. Under the influence of increased runoff, erosion within a stream channel increases through:

- Downcutting (incision within channels by altered water flow), which leads to deeper channels (Trimble 1997).

- Greater erosive force of water (due to increased volume) pushing against banks (Leopold 1994).

- Elevated, rapid peaks and declines in water volume within channels in quick succession, which causes slumping of banks (Leopold 1994).

Increased erosive actions eventually lead to:

- Wider, straighter, and smoother channels (Pizzuto 2000).

- Increased amounts of fine, inorganic materials within the stream channel that either change the composition bed sediments (through deposition), or remain suspended in the water column.

These changes to streams have profound effects on stream organisms, which rely upon local conditions to provide them with suitable habitat for living, feeding, and propagating.

Appendix III. Utilization of Stream Habitats by Fishes

Streams are dynamic assemblages of local hydraulic and physical conditions. Moving water and its interactions with sediments present organisms with an array of habitat choices. Each habitat, however, is similar in that physical structures and water join to create locally mediated conditions. For example, within the same stream reach, directly adjacent to one another, may be: a wide area full of large bed materials that causes water to flow swiftly over the area (i.e. riffles); and a more narrow, deeper area where the water slows down and the bed sediment is distinctly smaller (i.e. pools). These local conditions create different habitats. Major habitats for fishes in streams may be considered according to the vertical water column (e.g. habitat just above the stream bottom, or near the surface of the water), geomorphic forms (e.g. pools, riffles, bedrock outcrops), or water flow (e.g. rapidly flowing water, slowly flowing water).

It is more than likely that:

- Fishes engage in choosing their habitat.

- That habitat choices are specific to fish species.

- That habitat choices may change with varying life stages (Helfman et al. 1997).

- Some behaviors of fishes, upon which completion of their life cycles depend, are greatly influenced by habitat quality.

Fishes display ecological flexibility, exploiting habitats and food sources that change over time (Gorman 1988). This flexibility of fishes allows them to persist in the uncertain environments of streams. This does not mean, however, that these animals can adapt to any and all changes to their habitat. In an undisturbed stream network, it is likely that the patchiness and changeability of habitat distributions are offset by their abundance. If these habitats are reduced in number, in frequency of occurrence, and in quality, it could mean that areas once used as refugia by fishes in times of change are likewise reduced and that the fishes will not be able to persist during times of change.

If heterogenous habitats that support a diversity of fishes are allowed to become simplified and isolated, it could lead to destabilization and simplification of fish assemblages. Because choices made by fishes with regard to the habitat they occupy are specific, long-term and dramatic changes to habitats may affect fishes' ability to remain in areas where changes have occurred. When habitat of endangered and threatened species has already been marginalized, further loss of habitat can lead to extirpation.