Department of Fish and Wildlife

DESIGN GUIDELINES APPROVED FOR USE IN DESIGNING WATER CROSSINGS OVER FISH-BEARING WATERS IN WASHINGTON STATE

FHWA HDS 6 – River Engineering for Highway Encroachments[1]

Notes for appropriate use to comply with WAC 220-660-190

November 9, 2015

This document contains a wealth of information and tools useful for the hydraulic design of bridge waterways. This document does not contain criteria or design elements that explicitly provide for the movement of fish or the protection of their habitat. It cannot, therefore, be used by itself to design a water crossing (bridge or culvert) in fish-bearing waters of Washington State. The comments below can be used to comply with Washington state Hydraulic Code rules for water crossings WAC 220-660-190.

Chapter 1: INTRODUCTION.

Section 1.1 – Classification of River Crossings and Encroachments

This objective of the document, as described in this section, is consistent with that of the Water Crossing Design Guidelines, when specifically applied to the design of channels that provide for fish passage, continuity of geomorphic processes and properly functioning fish habitat.

Section 1.2 – Dynamics of Natural Rivers and their Tributaries

This section describes how hydraulic engineers frequently view rivers as static (that is, unchanging in shape, dimensions, and pattern), when, in fact, alluvial rivers are constantly changing position and shape, and that human induced changes can be propagated upstream and downstream for long distances.

[1] FHWA (2001). **River Engineering for Highway Encroachments**. Hydraulic Design Series Number 6. Federal Highway Administration – National Highway Institute. Washington DC.

Chapter 2: OPEN CHANNEL FLOW

Section 2.10.1 – Hydraulics of Bridge Waterways: Introduction

A properly designed bridge should have an opening sufficiently large enough to prevent excessive constriction of flows and upstream backwater rise during floods. Aside from potential flooding impacts, flow constriction and backwater can cause scour of the channel through the bridge, and sediment deposition and lateral shifting of the upstream channel. These consequences may result in the need for bank armoring and scour countermeasures, with their associated impacts to fish and fish habitat.

Section 2.10.2 – Hydraulics of Bridge Waterways: Backwater Effects on Waterway Openings

Use of guide banks to improve hydraulic efficiency of the bridge opening (in lieu of widening the opening) is likely to increase velocities through the opening in excess of Water Crossing Design Guidelines[2] recommendations (see WCDG pp. 85-89) and WAC 220-660-190(4)c.

Section 2.10.3 – Hydraulics of Bridge Waterways: Effects of Submerged Superstructure

If the water surface reaches the bottom of the superstructure at any point over the range of design flows (typically up to a 100- or 500-year event), the structure may be unable to pass expected debris (see WCDG pg. 81). The minimum required clearance specified in WAC 220-660-190 (4)f is 3 feet, unless engineering justification shows a lower clearance will allow the free passage on anticipated debris.

Section 2.10.4 – Hydraulics of Bridge Waterways: Effects of Supercritical Flow

Supercritical flow occurring at any point within the range of fish passage flows generally produces a barrier condition (high velocity/low depth). In addition, a hydraulic jump occurring within the waterway may create sufficient turbulence to create a barrier condition. At higher discharges, supercritical flow and hydraulic jumps may result in increased scour of the bed and banks of the waterway. See WCDG p. 88)

Section 2.10.5 – Hydraulics of Bridge Waterways: Types of Flow in Bridge Openings

All 4 types of flow described in Figure 2.40 create backwater above the normal water surface. The Washington Administrative Code for water crossings previous to the current version (1994 updated in 2014) limited the backwater above the N.W.S of 0.2 ft. The intention of this provision was to limit the effect of floodplain encroachment to a degree that minimized the impacts to fish and their habitat. In the current WAC 220-660-190(4)c the scale of impacts are measured by the difference in velocity between the main channel in the bridge cross section and the channel outside the bridge's influence (this relation is called the velocity ratio - also see WCDG pp.86-87). In general, Type I flow will protect fish habitat when the velocity in the main channel under the bridge is similar to the natural main channel velocity. Type II and Type III flows will create conditions that will interfere with natural stream processes as required by WAC 220-660-190(2). This provision goes on to say that "Water crossings that are too small in

[2] Barnard RJ, Johnson J, Brooks P, Bates KM, Heiner B, Klavas JP, Ponder DC, Smith PD, Powers PD. 2013. **Water Crossings Design Guidelines**. Washington Department of Fish and Wildlife: Olympia, Washington.

relation to the stream can block or alter these processes, although some encroachment of the flood plain and channel migration zone will be approved when it can be shown that such encroachment has minimal impacts to fish life and habitat that supports fish life." It is through the velocity ratio that these impacts are measured.

Section 2.12 – Hydraulics of Bridge Waterways: Hydraulics of Culvert Flow

Design methods described in HDS 5 are appropriate for culverts that function primarily for flow conveyance (for instance, road drainage), and are generally not appropriate for fish bearing streams. For the design of culverts in fish-bearing streams, see WAC 220-660-190 and Water Crossing Design Guidelines Chapters 1-3 , or other approved alternative guidelines found on the WDFW website :

http://wdfw.wa.gov/conservation/habitat/fish_passage/guidance_standards.html

Chapter 5: RIVER MORPHOLOGY AND RIVER RESPONSE

Section 5.4.2 – Fluvial Cycles and Processes: Straight River Channels

Straight river channels with natural, erodible banks seldom exceed ten (bankfull) channel widths in length.[3]

Section 5.7.1 – Highway Problems Related to Gradation Changes: Changes Due to Human Activities

(1) Changes in hydrology due to urbanization are often not represented in regression equations commonly used to estimate design flows. In many urbanized areas, detailed hydrologic modeling has been conducted which explicitly represents the degree of urbanization at the time the model was assembled, and often at some point in the future (e.g. assumed "build-out" conditions). Use of these models is generally preferable where they exist.

(2) Incised channels in urban areas usually represent a geomorphic response to changes in hydrology, sediment load, and constraints on channel geometry (e.g. straightening, bank hardening) imposed by urban land development and infrastructure. While "recovery" to a pre-development channel condition may be difficult or impossible, the expected trajectory to a new, more ecologically functional equilibrium condition is generally predictable (see channel evolution models by by Schumm, et al[4] and Cluer and Thorne (2013).[5] Where a reasonable potential for achieving this condition exists, channel designs for water crossing structures are encouraged to accommodate, or at least not preclude, expected channel changes.

[3] Langbein, WB and LB Leopold. 1966. River Meanders – Theory of Minimum Variance. Professional Paper 422H. US Geological Survey.

[4] Schumm SA, Harvey MD, and Watson CC. 1984. *Incised Channels: Morphology, Dynamics,and Control*. Water Resources Publications: Littleton, CO.

[5] Cluer B, and C Thorne. 2013. *A Stream Evolution Model Integrating Habitat and Ecosystem Benefits*. River Research and Applications. (2013). Wileyonlinelibrary.com. DOI: 10.1002/rra.2631.

Section 5.7.2 – Highway Problems Related to Gradation Changes: Natural Causes

Bridges regulated by WDFW in Washington State are required to provide three feet of clearance between the bottom (low chord) of the bridge structure and the water surface at the 100-year peak flow, unless engineering justification shows a lower clearance will allow the free passage of anticipated debris.

Chapter 6 : RIVER STABILIZATION AND BANK PROTECTION

Section 6.3.4 River Training and Stabilization: Countermeasure Design Guidelines

Use of hard armoring (riprap, concrete blocks, articulated mattresses, etc) should be limited to the absolute minimum necessary to protect the water crossing structure and associated infrastructure. Additional bank protection, if necessary, should utilize bioengineering methods (see section 6.6.2 of this document and the Integrated Streambank Protection Guidelines[6]).

Section 6.4.11 Flow Control Structures: Drop Structures

Drop structures which span the entire channel are generally discouraged, except where absolutely necessary to protect public infrastructure or private property. These structures are classified as fishways, and are subject to applicable hydraulic criteria for velocity, flow depth, and hydraulic drop, monitoring and maintenance requirements, and corrective measures if they fall out of compliance. See the requirements in WAC 22-660-200, Fish Passage Improvement Structures.

Chapter 7: SCOUR AT BRIDGES

Section 7.7.1 Local Scour at Piers: Introduction

If piers are required to support the bridge deck, place them outside of the main channel where possible to reduce maintenance and scour issues. If they cannot be placed outside the channel, they should be designed to minimize scour and limit debris accumulation.

Section 7.8.1 Local Scour at Abutments: Introduction

With respect to impacts to fish and fish habitat, pile foundations or drilled shafts often do not require scour protection and are preferred over spread footings requiring heavy riprap protection.

[6] WA State Aquatic Habitat Guidelines Committee. 2003. *Integrated Streambank Protection Guidelines*. Available at: http://wdfw.wa.gov/publications/00046/.

Chapter 9: DESIGN CONSIDERATIONS FOR HIGHWAY ENCROACHMENTS AND RIVER CROSSINGS

Section 9.2 Principle Factors to be Considered in Design

Factors described in this section may be evaluated as part of a reach assessment *(see ISPG Ch.3 and WCDG Ch. 4).*

Section 9.3 Procedure for Evaluation and Design of River Crossings and Encroachments

This section describes a procedure which incorporates reach assessment (Levels 1/2), along with more detailed assessment, analysis, and modeling (Levels 2/3) into the initial scoping and conceptual design of a river crossing.