Assessment of Embedded Box Culverts for Aquatic Organism Passage

by

Matt Blank, PhD, PE
Assistant Teaching Professor/Research Scientist

Western Transportation Institute
College of Engineering
Montana State University – Bozeman
P.O. Box 174250
Bozeman, MT 59717

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Montana Department of Transportation
2701 Prospect Avenue
P.O. Box 201001
Helena, MT 59620-1001

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PROBLEM STATEMENT

Montana Department of Transportation (MDT) designs, operates, and maintains many of the transportation systems throughout Montana. When roads intersect rivers, streams, wetlands or other water features, MDT utilizes hydraulic structures, either bridges or culverts, to pass over them. And, in situations where the waterbody has aquatic organisms, such as fish or amphibians, MDT designs the structures to not only convey water, sediment, and woody debris through them, but also to provide connectivity for aquatic species.

In some settings, MDT designs and constructs crossings using embedded box structures with a "two" layer approach. The bottom layer in this design consists of larger rock designed to be stable and an upper layer designed to match a river channels mobile sediment regime. The upper layer is often thought of as the "active" layer as it can move with natural sediment movements in the stream or river system.

Some state and federal agencies that review MDT projects and issue permits for them, have expressed concern with the "two" layer approach and, specifically, the use of concrete box culverts instead of open-bottom arches or bridges, in some settings. MDT also wants to ensure their designs are functioning properly by providing river and stream continuity, aquatic organism passage, and a safe, resilient road infrastructure, but at the same time not overdesign them.

Therefore, there is a need to assess how existing box culverts designed using the "two" layer approach are functioning in terms of maintaining their sediment beds while also providing aquatic organism passage.

BACKGROUND SUMMARY

MDT designs, operates, and maintains many of the transportation systems throughout Montana. When roads intersect rivers, streams, wetlands or other water features, MDT utilizes hydraulic structures, either bridges or culverts, to pass over them. And, in situations where the waterbody has aquatic organisms, such as fish or amphibians, MDT designs the structures to not only convey water and sediment through them, but also to provide connectivity for aquatic species. Given the complexity of the road system in Montana, and the large variety of aquatic habitats crossed by the system, it can be challenging to design crossings to accommodate aquatic organism passage and river functions in all settings. Thus, investigating a range of possible structure designs is often necessary to address the objectives for different settings.

Culverts are a common and often cost-effective means of providing transportation intersections with naturally occurring streams or rivers but have been identified as potential barriers to fish mobility. Bridges, as compared to culverts, are typically used to cross larger waterways and generally do not impede fish or other aquatic species' movements.

Aquatic organism passage presents a complex challenge to engineers, hydrologists, and biologists due in part to the dynamic nature of streams and rivers, both physically and biologically. The interactions between physical and biological elements further complicate the problem. There are many physical factors that determine whether a fish can or cannot pass through a culvert; insufficient water depth, large outlet drop height, and excessive water velocity comprise the most common physical factors limiting passage (Baker and Votapka 1990; Votapka 1991; Fitch 1995; Burford et al. 2009). Biological factors such as a species swimming ability, motivation, and behavior play an equally important role in passage.

Although no comprehensive inventory of the number of culverts on fish-bearing streams in North America is available, there are an estimated 5+ million stream-road crossings in the United States. Examples of the number of culvert barriers from various parts of North America highlight the problem that improperly designed, constructed, or maintained culverts can pose to aquatic species movement. Sixty-one percent of culvert crossings in the Notikewin watershed and 74% of culvert crossings in the Swan River watershed, both in Alberta, likely impede fish movement (Tchir, Hvenegaard, and Scrimgeour 2004). In Whatcom County, Washington, researchers assessed the passage status of culvert crossings on 1,673 crossings; they believe 837 (50%) are barriers to fish passage (Whatcom County Public Works 2006). An analysis of fish passage across road-stream crossings identified 2,900 culverts on 50,000 miles of forest roads in Montana, northern Idaho, and western North and South Dakota. The analysis showed that about 80% of the culverts are barriers to Westslope or Yellowstone cutthroat trout at some life stage. Of the total surveyed, 576 (about 20%) were classified as total barriers that completely isolate upstream fish populations (USDA National Technology Development Program 2008). An evaluation of four bridges and 47 culverts along a 210-km segment of the Trans Labrador Highway in Canada identified that 53% of the culverts posed fish passage problems due to poor design or construction (Gibson et al. 2005). In Alberta's Kakwa River watershed, 57% of culvert crossings are perched, thus blocking fish access to an estimated 98 km of upstream habitats (Johns and Ernst 2007).

There are many different methods to analyze the barrier status of culverts, each with distinct advantages and disadvantages. For this discussion, these methods are split into direct and indirect assessments. Direct assessments measure the amount of movement by fish or aquatic species in the field with an experiment such as a mark-recapture study (Burford et al. 2009; Belford and Gould 1989; Warren Jr and Pardew 1998; Burford et al. 2009). Another method that can directly measure passage and also allows for the ability to analyze fish movement through a range of flow conditions is the use of passive integrated transponder (PIT) tags and antennae placed at the upstream and downstream ends of a culvert (Cahoon et al. 2005). These approaches can provide detailed information concerning both the passage status of a culvert and the hydraulic environment within and adjacent to the culvert that allows or prevents passage; however, they can be labor-intensive and are only practical for assessing a smaller number of culverts.

Indirect methods generally approximate aquatic species movement potential by comparing the culvert's physical conditions to those the species are known to be able to overcome. This approach has been used for fish passage assessments for years. FishXing is a software program that combines culvert characteristics (slope, length, roughness, etc.) and stream hydrology to model the hydraulic conditions in and near the culvert (Six Rivers National Forest 2012). These hydraulic conditions are then compared to the swimming ability of the fish species of interest to determine a passage status. Although this method of analysis may be useful for assessing a large number of culverts with a relatively small amount of field data collection, caution must be used when interpreting the results, as research shows that this method can provide a conservative (i.e. more barriers to movement are predicted when compared to direct assessment results) estimate of the barrier status of culverts (Cahoon et al. 2005; Karle 2005). HEC 26, developed by the Federal Highway Administration, also provides guidance on passage assessment, inventory, and design of culverts for fish and aquatic organism passage (Kilgore et al. 2010).

A common indirect approach to provide an initial assessment of how well a culvert allows, limits, or impedes upstream passage is to evaluate the culvert slope, outlet drop, and level of continuous substrate in the bottom. As the culvert slope increases, upstream passage becomes more challenging for fish and other species because water velocity increases with increasing culvert slope. Outlet drop is the difference in vertical elevation between the water surface in the culvert outlet (downstream end) and the water surface in the pool downstream. Some species do not jump, and in all cases, aquatic organisms of a given size and species can only leap a certain height. Thus, outlet drops may present a barrier to upstream movement. Finally, a culvert may impede passage by having a somewhat steep slope combined with an outlet drop. This condition can be viewed as a combination barrier where slope or outlet drop alone may not create issues; yet the combined effect of higher slopes with an outlet drop makes for a challenging passage.

Species abundance, size structure, and genetic differentiation can also be used as an indirect approach to evaluate passage. Typically, such studies compare the results of biological samples taken from locations upstream and downstream of a culvert. For example, population surveys performed upstream and downstream of a perched culvert indicated that cutthroat trout density was 64% lower upstream than downstream, and size structure was skewed to a higher proportion of large fish downstream of the culvert, suggesting the culvert was functioning at least as a partial barrier to upstream movement (US Fish and Wildlife Service 2002). This upstream and downstream approach can provide valuable information about how culverts affect the abundance, size structure, and distribution of fish or other aquatic species populations; however, results from these types of studies may be inconclusive regarding the barrier status of a culvert. There may not be significant differences between upstream and downstream samples, even when a culvert is a barrier. Inconclusive results may indicate either recent genetic isolation or that a culvert allows partial movement of a species of interest (Knaepkens et al. 2004).

MDT uses methods in HEC-26, Culvert Design for Aquatic Organism Passage, Hydraulic Engineering Circular Number 26, to design new crossings when aquatic organism passage (AOP) design procedures are required (Kilgore et al, 2010). Two overarching methods commonly used for AOP passage are to either: (1) design the crossing using a stream simulation approach, or (2) design the crossing using a hydraulic design approach with embedded structures. Both methods can use either bridges or culverts, or some combination of them.

Stream simulation in simple terms means a natural channel is constructed through the crossing that matches the stream geomorphology. The idea being that if the river or stream is continuous through the crossing, then all aquatic species in that system should be able to pass unimpeded through it. A study in Washington evaluated 50 stream simulation culverts with the goal of comparing the stream characteristics within them to the adjacent stream channels (Barnard et al. 2014). The researchers found most of the structures, except one, had maintained a functioning streambed within them.

Hydraulic design matches the hydraulics, especially water depth and velocity, in the structures at design flows to those of the aquatic species requiring passage through them. Design following HEC 26 includes sediment stability/mobility analyses to determine the material used to embed the structure. Embedded structures can be either full stream-simulation designs, hydraulic designs, or some combination of them.

In some settings, MDT designs and constructs crossings using embedded box structures with a “two” layer approach. The bottom layer in this design consists of larger rock designed to be stable and an upper layer designed to match a river channels mobile sediment regime. The upper layer is often thought of as the “active” layer as it can move with natural sediment movements in the stream or river system.

Some state and federal agencies that review MDT projects and issue permits for them, have expressed concern with the “two” layer approach and, specifically, the use of concrete box culverts instead of open-bottom arches or bridges, in some settings. MDT also wants to ensure their designs are functioning properly by providing river and stream continuity, aquatic organism passage, and a safe, resilient road infrastructure, but at the same time not overdesign for the stated objectives.

BENEFITS AND BUSINESS CASE

MDT manages a road system with thousands of crossings over rivers, streams, and other water features. Montana is also renowned for its scenic waterways and plentiful fish species, with recreational fishing bringing in millions of dollars annually to the economy. MDT needs a range of different hydraulic design options for crossing waterbodies, and it needs to ensure the designs provide not only safe, reliable, and cost-effective transportation but also are not adversely affecting the environment or fish and aquatic organism passage.

Given that a single road-stream crossing can cost hundreds of thousands to millions of dollars to design, construct, and maintain, there is a benefit to investing in research to assess existing culvert designs to ensure they are functioning properly. In addition, this project will help MDT engineers with future designs, enhance communication with resource agencies, and help streamline the review and permitting process.

OBJECTIVE

The primary objectives for this project are to evaluate existing road stream crossings that were designed with the "two" layer approach, with a focus on concrete box structures, and to determine:
(1) how well the substrate/sediment within the design is functioning, and (2) if the structures provide passable conditions for resident aquatic species.

RESEARCH PLAN

The project will address the objectives by performing an assessment of existing structures designed following the “two” layer approach. This assessment will involve reviewing, collecting, and analyzing stream geomorphology, structure substrate, hydrologic and hydraulic data. It will not include any active fish or other aquatic species movement or monitoring efforts; but rather will evaluate measured conditions relative to published swimming characteristics and criteria for resident species. In addition, geomorphic comparisons will be made between the substate within and near the culverts to the adjacent stream channels.

During previous conversations about this project, MDT estimated there are between 12 and 20 existing crossings designed and constructed using a “two” layer or similar approach. Figure 1 includes a map of some of MDT’s road-stream crossings, including AOP crossings. Table 1 includes a prioritized list of ten sites, provided by MDT, that will be evaluated for this study.

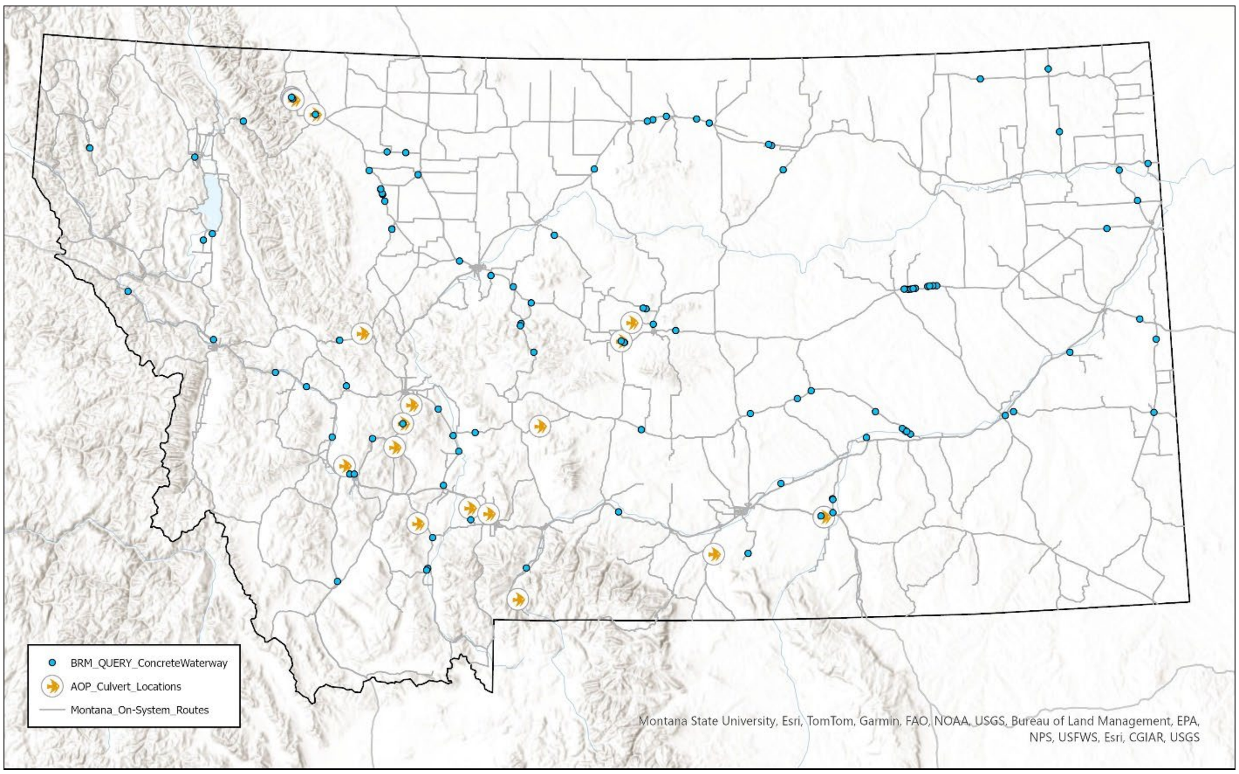

Figure 1 – Map of MDT road stream crossings including AOP culvert locations.

Table 1: Prioritized List of Sites

Priority	UPN	Project Name	Year Installed or Year to be Installed	Description	2-Layer Bottom?
1	4577000	Cedar Creek	2014	2 Layer system with habitat rocks	YES
2	6097000	South of Boulder-South	2020	14x8 RCB on Little Boulder River. Class I with Streambed 6-in layer. Alternating riprap high piles.	YES
3	7726000	Judith River Slide Repair	,	Single 12' x 12' RCB culvert. 2' thick streambed material oversized over 1' thick streambed material (salvaged). Large rocks along meandering alignment. See link to plans.	YES
4	9684000	S-282 Culvert - Prickly Pear Crk	2024	South of Helena	YES
5	9380000	SF 169 S288 Curves	2024	On Camp Creek near Churchill	YES
6	7209000	SF 099 E of Pony	2016	96-IN CMP embeded 2-ft	YES
7	4368001	Eddies Corner - E & W	2021	14x8 RCB at Olsen Creek w/ Class I riprap w/ alternating benches and 2" streambed material (see Sheet 27)	YES
8	7896000	North of Rocker Interchange-N	2024	Browns Gulch	YES
9	4322000	NH 24-3125-76	2014	MT 200, Hardscrabble Creek, RP 81.75	YES
10	7776000	Bozeman Frk Cr-SW Lennep/MT11-1	2012	10 x 10 RCB Bozeman Fk Musselshell R	YES

The following tasks will be accomplished as part of this project:

<u>Task 1: Existing Data</u>

- MDT will provide WTI with project locations and as-built drawings for each location. At times, MDT uses final design plans and specifications as as-builts; a practice that is relatively common.

- WTI will gather other information with MDT related to the designs, such as techniques used to estimate sediment size, gradation, and related hydraulic features. This will help in understanding the design process as well as on-the-ground projects.

- MDT will provide any existing hydraulic models used to design the culverts and any other relevant hydrologic data such as flood frequencies.

- In addition, using existing data sources, such as the MFISH database, WTI will summarize which fish and other aquatic species are thought to reside in each waterbody. This information will then be used to identify available fish and aquatic movement data. In terms of fish specifically, hydraulic conditions are usually evaluated relative to the prolonged swimming speeds of resident species, with attention paid towards the weaker swimmers. Fish locomotion is typically categorized into three modes: (1) sustained, (2) prolonged, and (3) burst or sprint swimming (Hoar and Randall, 1979). During the design process, velocity and depth are estimated in and near the proposed structure using hydraulic computations and modeling. The proposed water velocities, and depths, are then compared to the swimming abilities of resident species.

Task 2: Data Collection

WTI will collect a consistent set of field measurements at each crossing to evaluate sediment conditions, geomorphic conditions, basic structure dimensions (length, width, and slope, etc.), hydrologic conditions, and hydraulic conditions. Each location will only be visited one time. Data collection points will be marked with wood stakes (or equivalent) in case there is a desire to monitor them in the future. Data will include, at a minimum, the following:

- Photographs of the conditions of each crossing, the waterbody, and related features.
- Collection of hydraulic data including flow, water depths, and velocities.
  - Flow will be measured using a Hach flow meter or equivalent following the USGS mid-section technique.
  - Velocities will be measured using a Hach flow meter or equivalent throughout the culvert, and in the adjacent waterbody both up- and downstream. Please note this will be done only if conditions are deemed safe for measurements, and in culverts large enough to permit entry. WTI typically uses the "rule of 6" for identifying safe conditions. The "rule of 6" means the combination (through multiplication) of water velocity and depth shall not exceed 6. For example, if the water depth is 3 ft and the water velocity is 2 ft/s, the combined number is 6. If a structure is too small to safely enter or the conditions are unsafe, a smaller set of data will be collected to aid in estimating hydraulic conditions in the culvert.
  - Water depths will be measured throughout the culvert, and in the adjacent waterbody both up- and downstream; typically in concert with the velocity measurements. However, additional depth data may be collected.
- WTI will collect a data set consistent with the Aquatic Organism Passage Monitoring and Assessment Protocol (AOPMAP).
- WTI will collect a suite of sediment/substrate data in the culverts and adjacent to them in the natural channel both up- and downstream. The depth of sediment (embedded depth) within the culvert will be measured at various locations, with a minimum of three focus areas: (1) the inlet, (2) the middle of the barrel, and (3) the outlet. The particle size distribution within the active layer of the culvert will also be measured using a modified Wolman pebble count approach.
- Sediment distribution, using a modified Wolman pebble count, will be collected in the adjacent channel at three locations upstream and three downstream.

- The outlet and inlet configuration will be measured in the field, with attention paid to the outlet region. Outlet drops have been identified as one of the more common passage barriers in culverts; therefore, measurements of this region will be important for evaluating the effectiveness of these designs and providing passage (Warren and Pardew, 1998; Burford et al. 2009).

- Basic river geomorphology measurements will be characterized including bankfull widths. This geomorphic characteristic is often used to estimate culvert width in design. A minimum of 10 bankfull width measurements will be collected both up- and downstream.

Task 3: Data Entry, Summary and Analysis

The AOPMAP data will be entered into the Survey 1, 2, 3, aopMAP Field Monitoring Tool. Survey 1, 2, 3, aopMAP in an approved MDT application, and it is free and available for download by anyone. Other field data will be entered into Microsoft Excel. Field data will be checked for accuracy and completeness while data collection is ongoing and post field work. Data will be summarized into appropriate tables and graphs to best display it and for comparative purposes.

The analysis will compare current sediment conditions relative to as-builts; and may help in understanding whether designs are at least maintaining an embedded condition and not experiencing significant scour or fill. In addition, the data will allow for some comparisons between culvert conditions and stream channel characteristics both up- and downstream of it. Part of this comparison will consider recommendations from Barnard et al. (2014). They proposed a set of criteria for what it means to simulate stream-like conditions: (1) the median particle size should be within 18% of that found in the representative reach, (2) predicted velocity during flood should be plus or minus 9% of the prevailing stream velocity, and (3) the mean thalweg depth can be within 10% and still be said to simulate the natural channel. If the physical environment within the crossing is similar to adjacent channels, then the crossing is assumed to provide passage for resident aquatic species, including non-fish aquatic species.

Lastly, measured and/or modeled hydraulic conditions, specifically depths and velocities near and through the structures, will be compared to published fish swimming characteristics to aid in assessing passage.

Task 4: Draft and Final Report Preparation, and Final Presentation

A draft report will be prepared summarizing all tasks and data collected as detailed above. The report will include site maps, field data, analyses, results, and a summary of findings. After review by MDT and other stakeholders, WTI will prepare a final report organized in the same fashion.

WTI will also prepare a presentation of the research and present it to MDT and the Technical Panel.

INTELLECTUAL PROPERTY

We anticipate no intellectual property issues.

MDT AND TECHNICAL PANEL INVOLVEMENT

The researchers will coordinate a project kickoff meeting with MDT to discuss methods, identify or refine project sites, and related topics. There will also need to be coordination between WTI and MDT during the project at times through phone or video conferences.

MDT will need to provide design information for existing crossing structures, including site locations, site maps, as-built drawings, hydraulic models, and related information.

MDT will also need to provide a review of the draft report.

In addition, WTI will present the research to MDT and the Technical Panel.

OTHER COLLABORATORS, PARTNERS, AND STAKEHOLDERS

The research team will utilize their network of contacts with expertise in culvert design and fish passage, including Katey Plymesser with the Civil Engineering department at MSU and potentially others.

PRODUCTS

As described in the research plan, the following deliverables are proposed:

- Field data summarized into Microsoft Excel sheets.
- A draft report.
- A final report.
- Final presentation.

RISKS

We anticipate the risks in conducting this project to be relatively low. The biggest concern is safely accessing the streams and culverts to measure field data. The WTI team is experienced in working in rivers and streams. There may be some sites where the team will have to collect a reduced data set because conditions are unsafe to practically collect full data sets.

WTI will have two people collecting data for field data activities where people enter the culverts for safety reasons.

IMPLEMENTATION

We anticipate the final report will aid MDT in future crossing designs that utilize the embedded culvert approach or similar hydraulic structures. This project will enhance communication between MDT and resource agencies and help streamline the review and permitting process for new crossings.

SCHEDULE

The exact dates for the project depend on when a final contract is signed and the project start date is known. The project will be completed within one year of the start date barring any unforeseen challenges. Ideally, the start date will be no later than June 1, 2025, allowing for sufficient time for planning and field activities. Assuming a June 1 start date, data collection will be completed in summer or early fall 2025. Data compilation and analyses will be done in winter of 2025/2026. A draft report will be submitted for review to MDT and other stakeholders in winter 2025/2026. Reviewers will have 60 days for review of the draft report. A final report will be completed once final comments on the draft report are received and edits have been made to the draft report. In addition, a final presentation of the research will be presented at the end of the project.

BUDGET

The total project budget is $49,982.74. The following table provides details of the budget.

Table 2: Budget

Task		**Unit**	**Cost/Unit**	**Number of Units**	**Total Cost**
Task 1: Site Selection and Existing Data					
				Total Task	$ 1,680.31
Task 2: Data Collection					
				Total Task	$ 15,154.52
Task 3: Data Entry, Summary and Analyses					
				Total Task	$ 3,835.52
Task 4: Draft and Final Report					
				Total Task	$ 11,531.84
				Labor Total All Tasks	$ 32,202.19
				IDCs	$ 8,050.55
Direct Cost/Expenses					
Vehicle Rental		day	$ 180.00	16	$ 2,880.00
Gas		gallon	$ 3.50	600	$ 2,100.00
Per Diem		day	$ 33.50	24	$ 804.00
Hotel		night	$ 150.00	12	$ 1,800.00
Supplies		lump	$ 200.00	1	$ 200.00
				Total Direct Expenses	$ 7,784.00
				IDCs	$ 1,946.00
				Total without IDC	$ 39,986.19
				Total with IDC	$ 49,982.74

STAFFING

Matt Blank will serve as principal investigator (PI) for this project. He will be involved in all aspects of the project, including meetings with MDT, site selection, and field data collection efforts. Matt will analyze the data and prepare the final report.

Matt Bell will support this effort by collecting data, summarizing data, and participating in data analyses and report preparation efforts.

Marcel Huijser will provide review of the final report.

WTI may engage other personnel to assist with data collection efforts, if necessary.

Short CVs are included for the three primary staffing members at the end of this document.

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MATTHEW BLANK, PHD, P.E.

Research Scientist and Teaching Professor
Western Transportation Institute and Civil Engineering Department
Montana State University

PROFESSIONAL SUMMARY

Dr. Blank has over 25 years of experience conducting both academic studies and consulting activities on water resources issues. He is currently a research scientist and assistant teaching professor at the Western Transportation Institute and the Civil Engineering Department at Montana State University and performs water resources consulting as a partner with Restoration Engineering, LLC, a private consulting firm. He is principal investigator of a fish passage and swimming research facility formed through a partnership with the United States Fish and Wildlife Service and has been investigating fish passage and aquatic connectivity issues both in the lab and in rivers and streams for over 20 years. He teaches applied fluid mechanics and water resources engineering at MSU. Through both research and consulting activities, Dr. Blank has been involved with the assessment, design, or review of over a hundred hydraulic structures, most of which incorporate fish passage, in rivers and streams across the country and in Canada. This work spans the range of structures from small culverts on gravel roads, to irrigation diversions, to large hydropower dams on major rivers.

EDUCATION

Ph.D.	Civil Engineering, Montana State University (2008)
M.Sc.	Civil Engineering, Montana State University (2002)
B.Sc.	Geological Engineering, University of Wisconsin (1994)

PROFESSIONAL REGISTRATIONS

Professional Engineer	Montana #20179

RECENT EMPLOYMENT

2007-present	*Research Engineer*, Western Transportation Institute, Montana State University, Bozeman, MT
	Assistant Teaching Professor, Montana State University
	Partner/Owner, Restoration Engineering, LLC

ACTIVE GRANTS

Evaluating Swimming and Leaping Performance and Restoring Connectivity for Native and Priority Fish Species in the West, from US Fish and Wildlife Service (USFWS).

Fish Passage Research, from US Fish and Wildlife Service (USFWS).

RECENT PUBLICATIONS

Plymesser, K., Blue, T., Kappenman, K., **Blank, M**., Cahoon, J., Dockery, D. (2023). Flow Control Plates to Manage Denil Fishways in Irrigation Diversions for Upstream Passage of Arctic Grayling. *Journal of Fish and Wildlife Management.*

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MATTHEW A. BELL, MSC

SHORT BIO

Research Engineer
Road Ecology Program
Western Transportation Institute (WTI)
Montana State University (MSU), Bozeman, MT 59717
Phone: 406-994-6126
Email: matthew.bell8@montana.edu

Matthew Bell has over 10 years of experience with wildlife analyses, modeling, mapping, data collection, scientific testing, and management. He has mapped wildlife-vehicle collisions to create risk maps to increase driver awareness along Montana's road network, identify priority areas where WVCs are most common, and layering wildlife data to map suitable habitats and corridors. In addition to analytical skills, he also has mechanical intelligence and is researching new designs for wildlife crossing infrastructure using composite materials. The results from these research areas were presented at international conferences and workshops. Mat strives to understand WVC to identify priority areas for both transportation safety and wildlife conservation perspectives. He hopes to aid in the decision-making process made by resource managers, engineers, and planners – to increase public safety, reduce wildlife-vehicle collisions along roadways, and participate in the design of wildlife infrastructure. He has been involved with research and conservation issues pertaining to a wide variety of species and ecological landscapes.

EDUCATION

2014: BSc, Wildlife Biology, University of Montana, Missoula, Montana

2019: MSc, Civil Engineering, Montana State University, Bozeman, Montana

EXPERIENCE

2019-present: Research Engineer, Western Transportation Institute, Montana State University

2014-2016: Wildlife Technician, multiple agencies, Montana and Alaska

PUBLICATIONS

Bell, M., Wang, Y., & Ament, R. (2023). Risk Mapping of Wildlife-Vehicle Collisions across the State of Montana, USA: A Machine Learning Approach for Imbalanced Data along Rural Roads. *Transportation Safety and Environment*.

Paul, K., Faselt, J., **Bell, M.**, Huijser, M. P., Theobald, D., Keeley, A., & Ament, R. (2023). *West-Wide Study to Identify Important Highway Locations for Wildlife Crossings*. Western Transportation Institute.

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Bell, M., Fick, D., Ament, R., & Lister, N. M. (2020). The use of fiber-reinforced polymers in wildlife crossing infrastructure. *Sustainability*, *12*(4), 1557.

Ament, R., Hall, K., **Bell, M.**, & Wittie, M. (2019). Federal Lands Wildlife-Vehicle Collision Data Coordination Project Phase 2.

Marcel Huijser, PhD

Research Ecologist

Qualifications Overview

Marcel Huijser is a senior research ecologist with 32 years of experience. Specializing in road ecology since 1995, he has conducted research in Europe, North America, South America and Asia. His focus is on the ecological impacts of transportation infrastructure as well as mitigation measures aimed at reducing these impacts. Most of his research relates to reducing large mammal-vehicle collisions, providing safe crossing opportunities for wildlife, and cost-benefit analyses regarding the implementation of mitigation measures. Marcel advises students and has taught road ecology courses for MSc and PhD students, and a course on wildlife habitat, conservation, and management.

Marcel Huijser has led several dozens of road ecology projects, **including a report to U.S. Congress** on reducing wildlife-vehicle collisions (2008), and several handbooks containing practical suggestions on implementing effective mitigation measures aimed at reducing wildlife-vehicle collisions (2008, 2022) and providing safe crossing opportunities for wildlife (2011, 2022). While mitigation measures may be required based on human safety and biological conservation parameters alone, Marcel also developed a cost-benefit model (2009, 2022) that serves as a decision support tool based on economics. While Marcel is an applied research ecologist he also values publishing in peer-reviewed journals.

Project Experience and Publications:

https://www.mphetc.com/publications

Years of Experience: 31

Primary current affiliations

- Senior research ecologist, Western Transportation Institute – Montana State University (since 2002)
- Visiting professor, University of São Paulo, Brazil (since 2014)
- MPH:ETC consulting
- Instructor Wildlife Biology Program, University of Montana (since 2021)

Past affiliations

- Research Ecologist (1999-2002), Institute for Animal Husbandry, The Netherlands.
- Researcher (1995-1998), Dutch Mammal Society
- Research ecologist (1992-1995), Dutch Ministry of Transportation and Waterworks.

Subject area expertise

- Road ecology
- Ecological impacts infrastructure
- Mitigation measures aimed at reducing large mammal-vehicle collisions and providing safe crossing opportunities for wildlife
- Cost-benefit analyses for wildlife mitigation measures

Education

- PhD, road ecology, Wageningen University, Netherlands (2000)
- MSc, ecology, Wageningen University, Netherlands (1992)

Key Skills

- Ecology
- Data analyses
- Writing and presentation
- Project management

Contact:

- mhuijser@montana.edu
- 406-543-2377