Fish Passage Status of Road-Stream Crossings on Selected National Forests in the Southern Region, 2007

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Background

There are more than 50,000 road-stream crossings on National Forest managed lands in the eastern United States. (M. Hudy, Forest Service U.S. Department of Agriculture, unpublished data). Each of these crossings represents a potential impediment or barrier to fish movement among stream reaches and watersheds. The Forest Service recognizes the importance of modifying or removing those crossings identified as barriers to meet its objective of restoring and maintaining native species diversity (Forest Service, U.S. Department of Agriculture 2004). In alignment with the Forest Service National Strategic Plan, the Southern Region has also listed the removal of barriers to movement by fish and other aquatic organisms as a key strategy for meeting its critical objective of improving watershed condition (Southern Region Forest Service, U.S. Department of Agriculture *Draft*).

In 2003 and 2004 the U.S. Forest Service Southern and Eastern Regions and the San Dimas Technology and Development Center (SDTDC) hosted several fish passage assessment and remediation workshops. The National Inventory and Assessment Procedure (NIAP) (Clarkin et al. 2003) presented at these workshops provided a framework for collecting field data, but the assessment models, designed for western U.S. fish species, were not directly applicable to most species in the eastern U.S. The southeastern U.S. has over 660 freshwater fish species in 27 families encompassing a wide range of swimming and leaping abilities (Warren et al. 2000). Development of species-specific passage models was considered impractical and lack of data on leaping and swimming ability for most eastern fish species limited the usefulness of previously developed passage assessment software such as FishXing (Love et al. 1999).

In 2003, graduate students and biologists of the U.S. Forest Service Aquatic Ecology Unit – East at James Madison University began to develop models that would allow managers to quickly assess the passage status of a crossing. These 'coarse screening filters' were developed based on the leaping and swimming abilities of three groups of fish: Filter A strong abilities; Filter B moderate abilities; and Filter C weak abilities. Model validation using data collected with the NAIP, combined with knowledge of affected fishes, showed that the coarse filters were effective tools for predicting fish passage (Coffman 2005).

In 2005 the USFS Southern Region, pursuing its critical priority of improving watershed condition partnered with the Southern Research Station, Center for Aquatic Technology Transfer (CATT) to design and execute an inventory and assessment program for road-stream crossings. The CATT developed an inventory protocol based on the NIAP, deployed field crews to collect data, and then classified each crossing as passable, impassable or indeterminate for each of the three coarse filters described above. The CATT completed inventories on several Forests in 2005-2006 (Coffman et al. 2005, Coffman et al. 2006) (Figure 1). Between April and August 2007, we conducted surveys on the

Daniel Boone National Forest, Ozark National Forest, George Washington- Jefferson National Forest and Uwharrie National Forest. We contracted with TEAMS Enterprise to complete additional surveys on Kisatchie National Forest, Sam Houston National Forest, and Land Between the Lakes National Recreation Area between August and November 2007 (Figure 1). This report summarizes the results of road-stream crossing inventories performed by the CATT and TEAMS Enterprise between April and November 2007.

Methods

Site Selection

In early March 2007, the Regional office reviewed work requests, selected Forests for site visits, and forwarded their selections to the CATT. The CATT contacted selected Forests in mid-March to request lists of road-stream crossings for survey. Forests non-randomly selected crossings for survey based on Forest-specific priorities.

Data Collection

Dimensions, characteristics, shape (Figure 2), and condition of road-stream crossing structures and data pertaining to the adjacent stream channel were recorded for each site following the National Inventory and Assessment Procedure (NIAP) for road-stream crossings (Clarkin et al. 2003). A CST/berger SAL series automatic level with 32x magnification mounted on a tripod and a 25-foot stadia rod graduated in tenths of feet were used to measure the elevation of the crossing structure inlet and outlet, tailwater control, and the water surface (Figure 3). A measuring tape marked in hundredths of a foot was used to measure the distance between the crossing inlet and outlet. Bankfull channel width was measured at three locations upstream of the crossing and three downstream where natural channel geometry was intact (i.e. outside of the influence of the crossing structure). Photographs of the inlet and outlet were taken and each site was sketched on paper. Condition of the crossing structure was recorded and any natural barriers (e.g. waterfalls) immediately upstream or downstream were documented. Natural stream substrate covering the bottom of the crossing structure was recorded as continuous throughout the structure or not present within the structure. Substrate had to cover 100% of the structure bottom for a crossing to receive a continuous throughout the structure designation.

Data Analysis

The elevation and distance measurements for the crossing inlet, crossing outlet, tailwater control, and water surface were used to calculate residual inlet depth, outlet drop, outlet perch, slope, and slope x length values for each crossing (Figure 3).

Residual inlet depth is calculated as

$$P_3 - P_1,$$

where P_3 is the tailwater control elevation of the outlet pool and P_1 is the crossing inlet elevation. Residual inlet depth values greater than zero indicate the structure is completely backwatered, allowing fish passage.

Outlet drop is calculated as

$$P_2 - P_3,$$

where P_2 is the crossing outlet elevation and P_3 is the tailwater control elevation of the outlet pool.

Outlet perch is calculated as

$$P_2 - Ws,$$

where P_2 is the crossing outlet elevation and Ws is the water surface elevation immediately downstream of the outlet. Outlet perch is used in place of outlet drop when a tailwater control is not present and outlet drop cannot be calculated. Excessive outlet drop or outlet perch values indicate the presence of jump barriers.

Slope is calculated as

$$(P_{1elev} - P_{2elev}) / (P_{1dist} - P_{2dist}) * 100,$$

where P_{1elev} is the crossing inlet elevation, P_{2elev} is the crossing outlet elevation, P_{1dist} is the crossing inlet distance, and P_{2dist} is the crossing outlet distance. Steep slope is an indicator of velocity barriers.

Slope x length is calculated as

$$[(P_{1elev} - P_{2elev}) / (P_{1dist} - P_{2dist}) * 100] * (P_{1dist} - P_{2dist}),$$

where P_{1elev} is the crossing inlet elevation, P_{2elev} is the crossing outlet elevation, P_{1dist} is the crossing inlet distance, and P_{2dist} is the crossing outlet distance. High slope x length values indicate an exhaustion barrier.

Percent of crossing structure bottom with natural substrate, residual inlet depth, outlet drop, outlet perch, slope, and slope x length values for each crossing were applied to each of three regional coarse filters (Figures 4– 6) to determine upstream passage status. Threshold values for each parameter differ by filter and were set according to published swimming and leaping abilities of representative species in each filter group, and relationships among crossing dimensions, species presence/absence data, and movement data (Coffman 2005). Filter A (Figure 4) classifies crossings for species with strong swimming and leaping abilities, such as the adult brook trout (*Salvelinus fontinalis*). Filter B (Figure 5) classifies crossings for species with moderate swimming and leaping abilities such as juvenile trout or species in the minnow family (Cyprinidae). Filter C (Figure 6) classifies crossings for weak swimmers and leapers, such as species in the darter (Percidae) and sculpin (Cottidae) families. Crossings are classified as passable, impassable, or indeterminate for each of the three filters. Biological sampling or computer modeling is required to determine passage status for crossings classified as indeterminate.

The ratio of culvert width to bankfull channel width was also calculated for each site. The ratio is calculated as

$$CW / BCW,$$

where CW is the maximum width or diameter of the crossing structure and BCW is the average of all six (three upstream and three downstream) bankfull channel width measurements. A ratio of 1.0 or greater indicates that the crossing structure is equal to or greater than the width of the bankfull channel. Fords, vented fords, and sites with more than one crossing structure (e.g., culverted site with multiple pipes) were eliminated from this analysis.

Special Cases

Sites with more than one crossing structure (e.g. culverted site with multiple pipes) were occasionally encountered during the surveys. At these sites each individual structure was numbered sequentially from left to right when facing downstream. Each individual structure was then surveyed and classified, which could result in a single site having multiple classifications for a given filter. Under those circumstances the location was classified based on the structure that received the best passage rating. For example, in a crossing location with two circular culverts where one was classified as impassable and one indeterminate by Filter B, the location would receive an overall classification of indeterminate rather than impassable.

By definition open bottom arches receive a natural substrate continuous throughout structure designation, thus these structures receive a passable classification by default for each coarse filter. Full surveys were still completed at open bottom arches to capture channel conditions and crossing structure dimensions.

Crossing location was documented but the structure was not surveyed if there was inadequate habitat upstream of the crossing to support fish, or if the crossing structure was a bridge or natural ford. Bridges and natural fords were assumed to always provide adequate upstream fish passage. Crossing locations that could not be reached because of inaccessible or closed roads, private property issues, or locked gates were also documented, but not surveyed.

Results

We completed surveys at 273 of 1504 documented road-stream crossings in 2007 (Table 1). The majority of surveyed crossings were either impassable or indeterminate for all filters. Only 50%, 28%, and 20% of these crossings were rated passable by Filters A, B, and C respectively (Figures 7-9, Table 2). The percentage of crossings rated impassable, passable, and indeterminate by each Filter varied among

Forests surveyed in 2007 (Figures 7-9). Excessive outlet drops accounted for 60%, 69%, and 83% of the impassable sites for Filters A, B, and C respectively (Table 3).

The majority of crossings surveyed were either circular culvert (56%, n=153) or concrete slab fords (21%, n=57). Box culverts (9%, n=24), vented fords (4%, n=10), pipe arches (10%, n=28), and bottomless arches (1%, n=1) were less frequently encountered. Filter A classified 15% of circular culverts and 18% of ford crossings as impassable (Figure 9, Table 4). The proportion of circular culverts and fords classified impassable increased from Filter A to Filters B and C. Filter B classified 43% of circular culverts and 60% of ford crossings as impassable (Figure 9, Table 4). Filter C classified 59% of circular culverts and 86% of fords as impassable (Figure 9, Table 4).

Crossing width was less than the bankfull channel width at 94% of all surveyed crossings (excluding fords, vented fords, and multiple structure crossings). The crossing width to channel width ratio was 0.44 ± 0.23 (mean ± SD) (n=128) (Figure 10). Only 8 crossings were greater than or equal to the mean bankfull channel width (i.e. crossing width to channel width ratio was greater than or equal to 1.0).

Discussion

Regional Analysis

Crossings that prevent upstream fish passage are a common feature of stream networks on southern Forests: 50% or less of the crossings surveyed on each Forest were rated as passable for all three filters. Outlet drop triggered passage failure at the majority of impassable sites, but it was not the only factor that would have prevented movement. Over 13% of sites classified as impassable due to excessive outlet drop by Filter C would also have failed due to either excessive slope or slope x length values. Even if fish had managed to find a way to leap into these crossing structures they likely would have faced water velocities that exceeded their swimming abilities or a combination of water velocity and pipe length that would have exhausted them before they could exit the upstream end of the structure. These conditions are created when crossing structures do not mimic natural channel characteristics such as bankfull channel width, slope, and substrate. Impassable crossing structures typically concentrate water into a steeper, narrower channel profile with less resistance to flow. The result is increased water velocity within the structure and scouring immediately downstream creating an outlet drop, or perch (Castro 2003).

The vast majority of crossings structures surveyed were narrower than the natural bankfull channel. Undersized crossing structures disrupt natural stream processes such as transport of sediment and large woody debris, leading to blocked inlets or blowouts during storm events. Changes in stream flow and water velocities caused by undersized structures can lead to the development of passage barriers as discussed previously. The average width ratio of impassable sites was much less than the average width ratio of passable sites, however some sites with low width ratios were still classified as passable,

which precludes this metric from being a reliable indicator of passage status. One possible explanation for this could be varying ages of crossing structures. Installation of undersized culverts may not immediately result in passage barriers, but over time the combined effect of varying flows and the unnatural characteristics/dimensions of the crossings can lead to the creation of barriers. The width ratio is unlikely to change dramatically over time, but the filter classification could due to events such as downstream scour and uneven settling of culverts.

The high proportion of impassable crossings for Filters B and C is particularly troubling. Minnow and darter species, many of which are represented by Filters B and C, constitute roughly 66% of the freshwater fish diversity in the Southeast and the majority of the 28% that are threatened, endangered, or vulnerable to extinction (Warren et al. 2000). Our results suggest that these moderate and weak swimming species face barriers to movement at 47-64% of the crossings we surveyed. The habitat fragmentation associated with these crossings likely contributes to continued species imperilment, and adds to the challenge of restoring connectivity.

All crossing types blocked upstream fish passage to some degree with the exception of open bottom arches, which are classified passable by default as discussed in the 'Special Cases' section of this report. However, open bottom arches can be expensive and installation complicated compared to other crossing types (Murphy and Pyles 1989), which may explain why we encountered relatively few of these structures. Fords and circular culverts were the most frequently encountered crossing type. Fords and circular culverts dominate the road-stream crossing landscape, but they can create passage problems when stream hydrology and biological factors are not carefully considered prior to installation (Baker and Votapka 1990).

Current Limitations and Future Improvements

The coarse filters presented here apply to several general categories of fish including strong swimmers and leapers (Filter A), moderate swimmers and leapers (Filter B), and weak swimmers and leapers (Filter C). We assigned adult trout to represent Filter A, minnows and young trout to represent Filter B, and darters and sculpins to represent Filter C, however there are a range of swimming and leaping abilities represented within each family. For example some minnow species are strong swimmers and therefore may be most appropriately assessed by Filter A, whereas other weak swimming minnows may be candidates for Filter C. Still other families or species, such as those that are strong swimmers but weak to moderate leapers may require the creation of additional filters. Currently, few data are available regarding swimming and leaping abilities of non-game fish species in the Southeast making it difficult to refine or expand the existing set of filters. Members of the sucker (Catostomidae), catfish (Ictuluridae) and sunfish (Centrarchidae) families may fit into such filters, but clearly more research is needed.

Results provided by the existing filters include a sometimes large area of indeterminate passage status. Crossings enter this "gray area" when they pass for outlet drop and slope but do not pass or fail for slope x length. The range of values that leads to an indeterminate classification for slope x length can be quite large, particularly for Filter A leaving a large portion of sites essentially unclassified. The slope x length value represents the relative level of exhaustion a fish would experience by trying to swim through a pipe of a certain slope for a given distance. Because few empirical data exist for species exhaustion rates the filters were designed to be conservative. Biological sampling can provide important information for evaluating fish passage at sites classified indeterminate and generally with little expense relative to the cost of replacing a crossing structure. Mark-recapture sampling designs can vary in complexity and effort depending on project goals (Warren and Pardew 1998) and provide direct evidence of fish passage without the assumptions of fish passage models. The mark recapture design can be as simple as marking and releasing a sample of fish downstream of a crossing, and then sampling for marked fish above the crossing on subsequent sampling trips. Collection of marked fish above the crossing would indicate that crossing is passable for the species in question. More elaborate designs to detect if movement through the crossing is the same or similar to movement through the unobstructed natural stream channel can also be implemented (Coffman 2005). The use of mark-recapture studies at indeterminate sites would not only allow Forests to classify these sites as passable or impassable, but would also provide data necessary to refine the filter thresholds and shrink the gray areas.

The Forests have opportunities to improve fish passage at road-stream crossings both during routine maintenance, when crossing structures reach the end of their serviceable life, and when funding becomes available to replace crossings outside of the regular maintenance schedule. Managers should always consult with their biologists and hydrologists to determine whether routine replacements should include aquatic organism passage considerations. Selection of sites for replacement outside of the routine maintenance schedule can be more challenging. Currently, Forests can use the information from our surveys to locate impassable crossings that are candidates for replacement; however the number of impassable crossings per Forest makes selecting sites an overwhelming task. Survey results only provide passage status and exclude many other factors that should be considered when prioritizing crossings for replacement. Information such as miles of habitat upstream of a crossing, proximity to other barriers, cost of replacement, species presence, and species status (i.e. threatened, endangered, exotic invasive) need to be included in the decision process. Given the large number of impassable sites, using criteria such as these to prioritize sites for remediation can be time consuming and overwhelming.

In 2005, CATT proposed the development of a decision support system (DSS) to assist managers in prioritization of crossing remediation projects (Coffman et al. 2005). The DSS would allow managers to (1) prioritize watersheds for assessment based on selected watershed characteristics; and (2) after

assessments are complete prioritize impassable crossings for replacement based on factors such as quantity and quality of habitat (Coffman et al. 2005). The CATT estimates that a working prototype DSS could be developed for 20% of the expense of replacing a single culverted crossing (based on the installation of a 12 foot open bottom arch, 80 feet long with a 20 foot high road embankment that allows fish passage costs roughly $108,000 (USDA Forest Service 2006)). The DSS would help to ensure replacement crossing installations result in the most cost-effective benefit for the resource. A fully operational DSS would be a powerful tool for selecting from the large number of impassable crossings within each Forest.

The results of culvert inventories performed in the Southern Region in summer 2007 demonstrate the effects of road-stream crossings on aquatic organism passage in southern streams. Future inventories in the Region will expand the baseline data necessary to meet national and regional strategic goals, prioritize crossings for replacements, and compete for remediation funds.

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Acknowledgements

We would like to thank the CATT field crew for collecting all of the data presented in this report. The field crew included Colin Krause, Ross Andrew, Brandon Copeland, Kirk Dunn, Jennifer Dvorsky, Mark Galatowitsch, Tom Ivasauskas, Chas Kyger, Mike O'Melia, Nicholas Redifer, John Saxton, Julie Wolfe and Jonathan Wrenn. We would also like to thank the TEAMS Enterprise Aquatic Habitat, Hydrology & Hydraulics Branch for assisting in the collection of data on National Forests in Texas, Kentucky and Louisiana. In addition, we thank Leigh McDougal, Jim Kozik, and the Southern Region for providing assistance and funding for the surveys, along with Dawn Kirk, Dave Peterson, David Byrd, Pam Martin, Keith Whalen, Sheryl Bryan and Judy Hallisey for their assistance with field logistics.

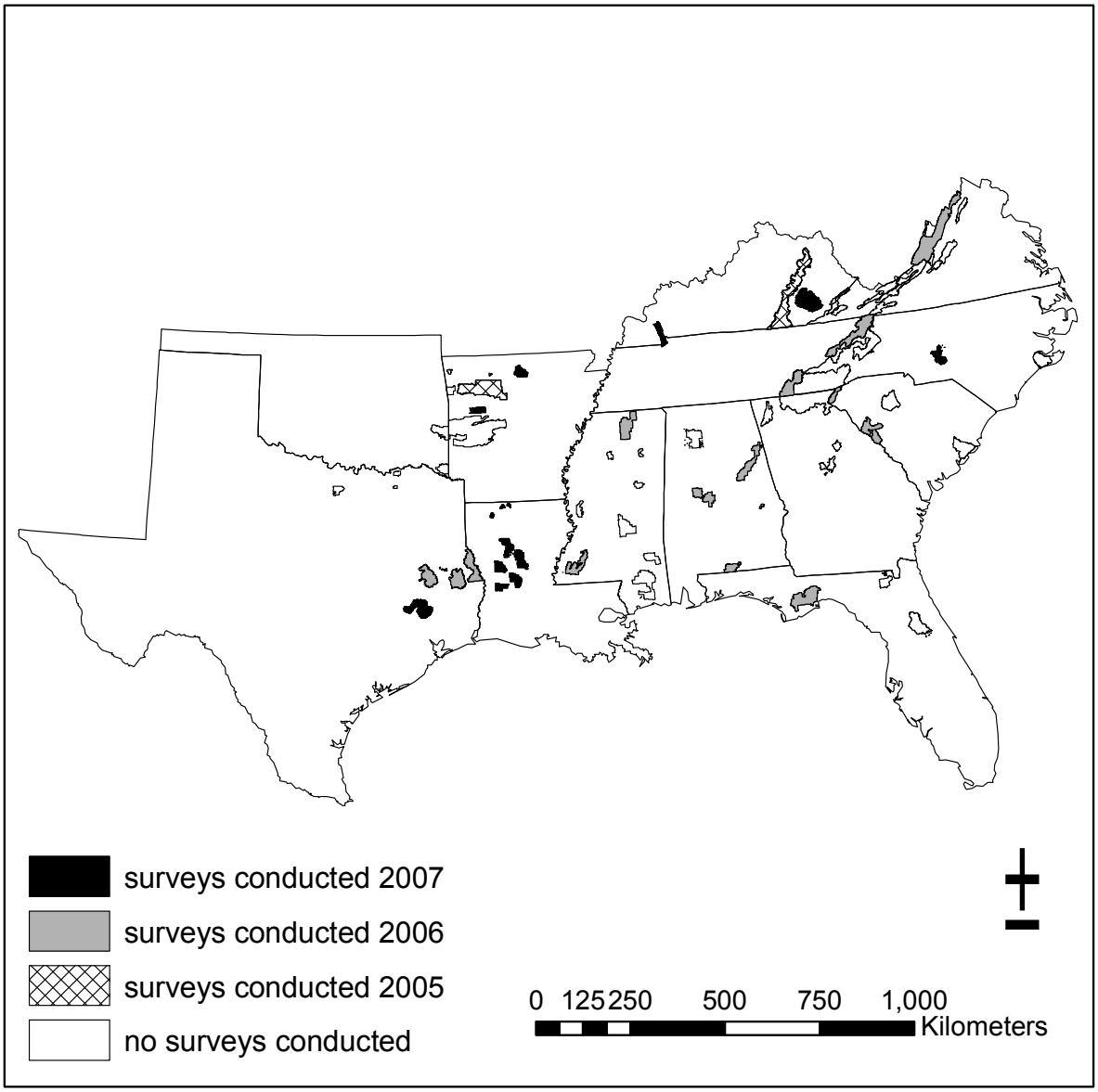

Figure 1. National Forest managed lands in the Southern Region. Crossing assessments were conducted between May and October 2007 in areas shaded black. Crossing assessments were conducted in 2006 for National Forests shaded in gray (Coffman et al. 2006). Crossing assessments were conducted in 2005 for crosshatched National Forests (Coffman et al. 2005).

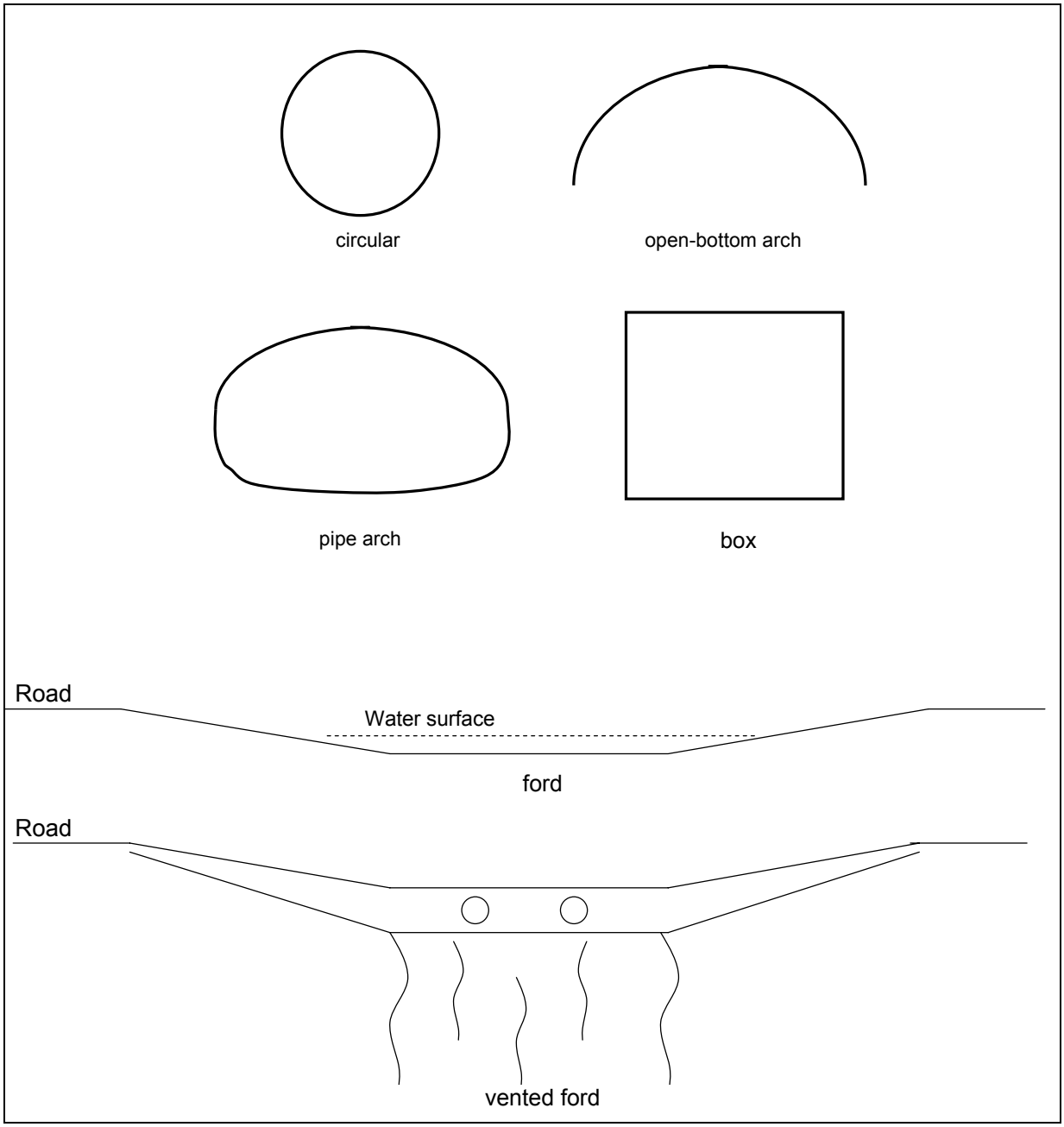

Figure 2. Common crossing shapes encountered during road-stream crossing inventories conducted in the Southern Region, summer 2007.

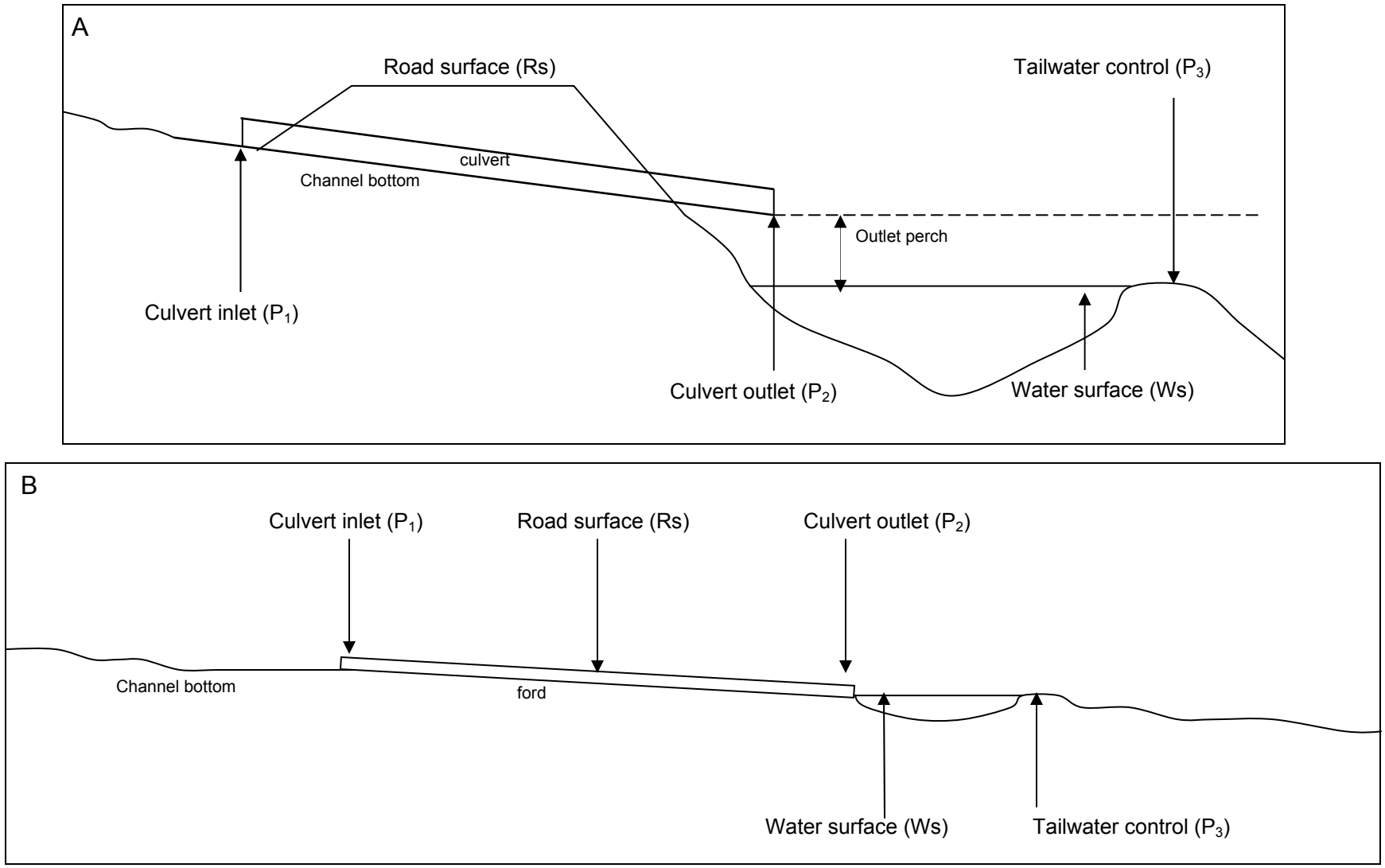

Figure 3. Survey points measured on culverts (A) and unvented fords (B) to calculate parameters used in coarse filters for upstream fish passage Adapted from Clarkin et al. 2003. Parameters are calculated as follows: Residual inlet depth= $P_3 - P_1$; Outlet drop= $P_2 - P_3$; Outlet perch= $P_2 - Ws$; Slope= $(P_{1elev} - P_{2elev}) / (P_{1dist} - P_{2dist}) * 100$; Slope x Length= $[(P_{1elev} - P_{2elev}) / (P_{1dist} - P_{2dist}) * 100] * (P_{1dist} - P_{2dist})$.

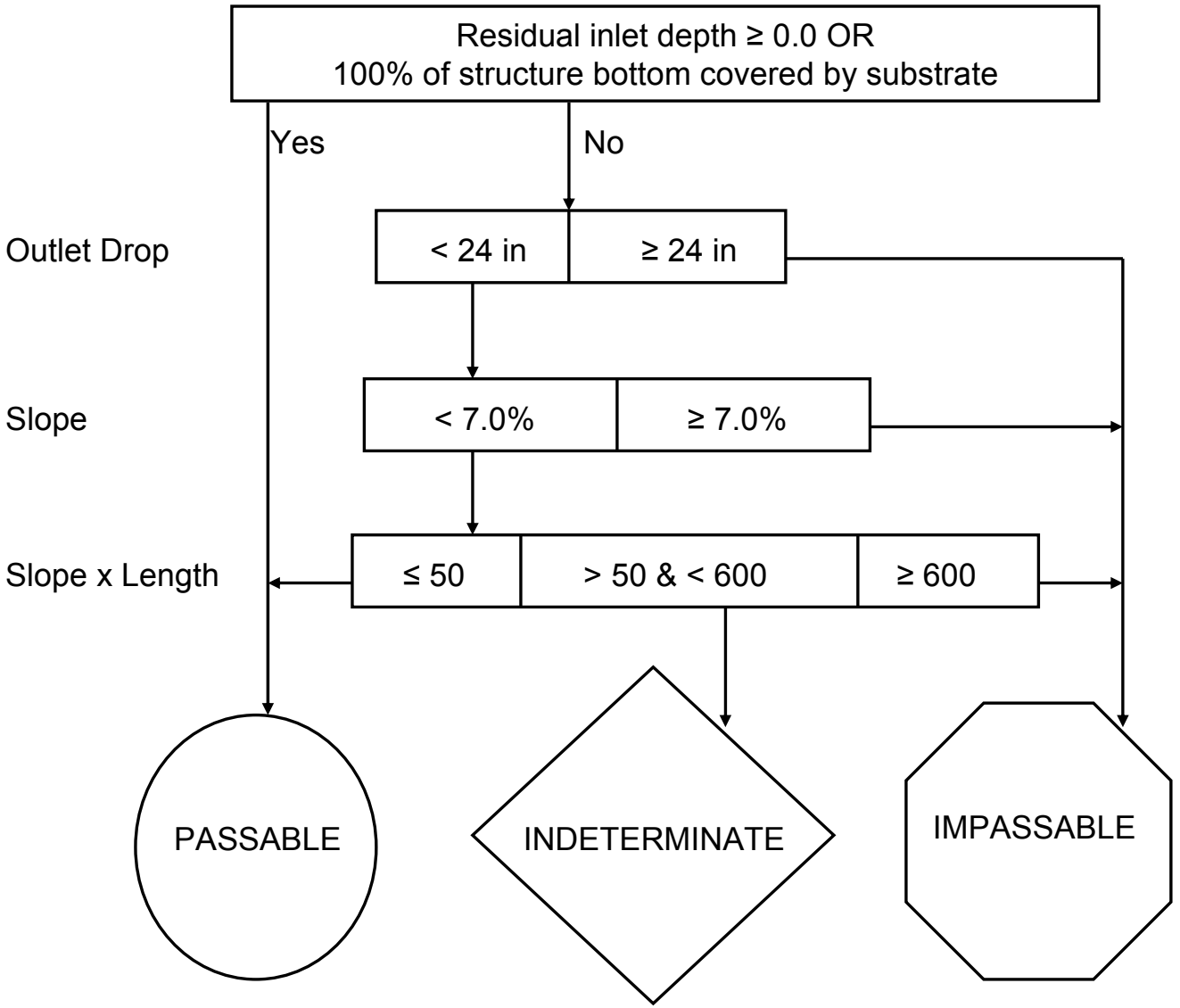

Figure 4. Coarse Filter A: Predictive model used to determine upstream passage for fish with swimming and leaping abilities similar to adult trout. A residual inlet depth ≥ 0.0 (Figure 2) indicates structure is fully backwatered. An outlet perch of 14 in is used when outlet drop could not be calculated (Coffman 2005).

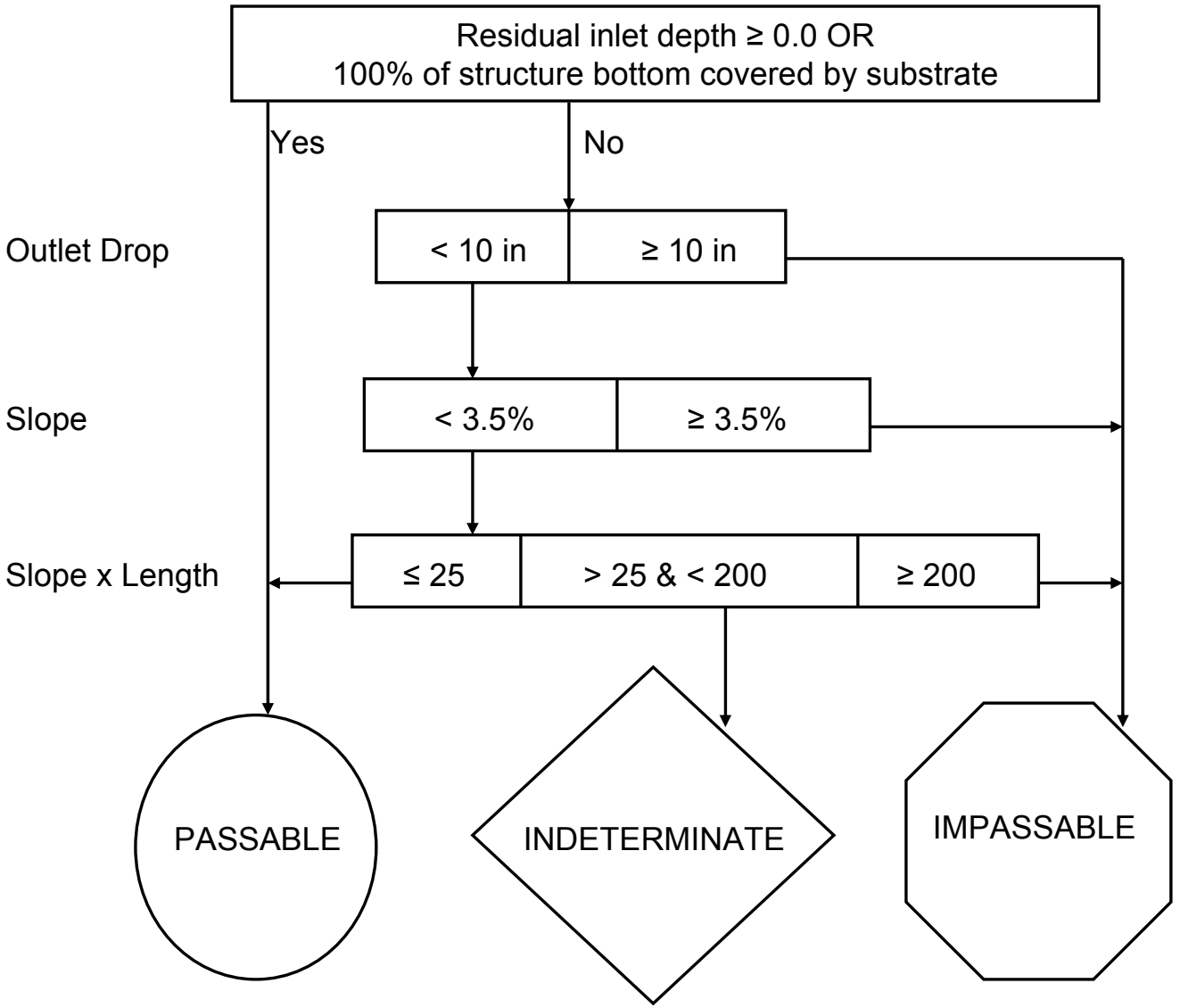

Figure 5. Coarse Filter B: Predictive model used to determine upstream passage for fish with swimming and leaping abilities similar to minnows and juvenile trout. A residual inlet depth ≥ 0.0 (Figure 2) indicates pipe is fully backwatered. An outlet perch of 5 in is used when outlet drop could not be calculated (Coffman 2005).

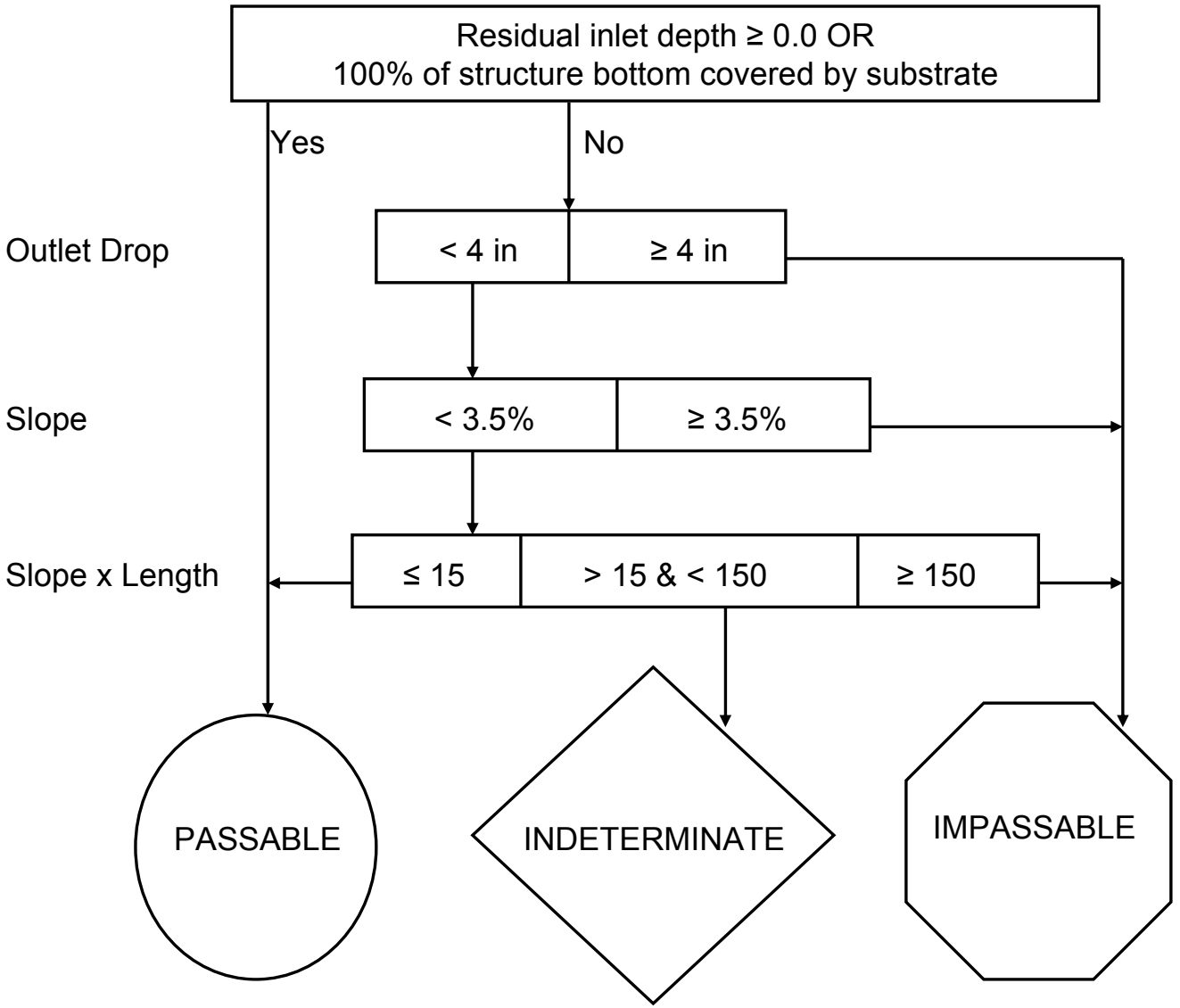

Figure 6. Coarse Filter C: Predictive model used to determine upstream passage for fish with swimming and leaping abilities similar to darters and sculpins. A residual inlet depth ≥ 0.0 (Figure 2) indicates pipe is fully backwatered. An outlet perch of 2 in is used when outlet drop could not be calculated (Coffman 2005).

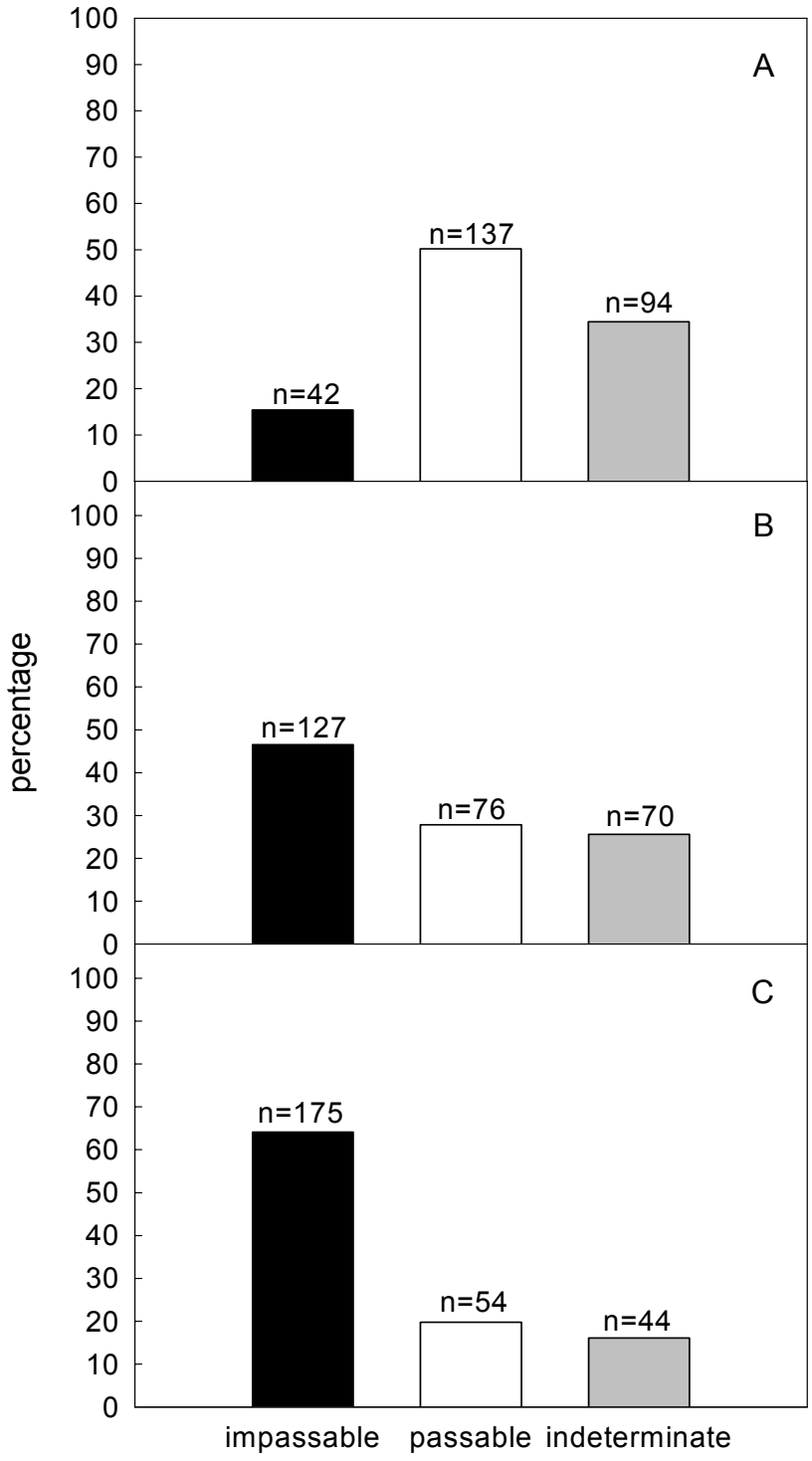

Figure 7. Percentage of crossings classified as impassable, passable, or indeterminate for Filters A, B, and C on Forests surveyed within Region 8, summer 2007 (N=273).

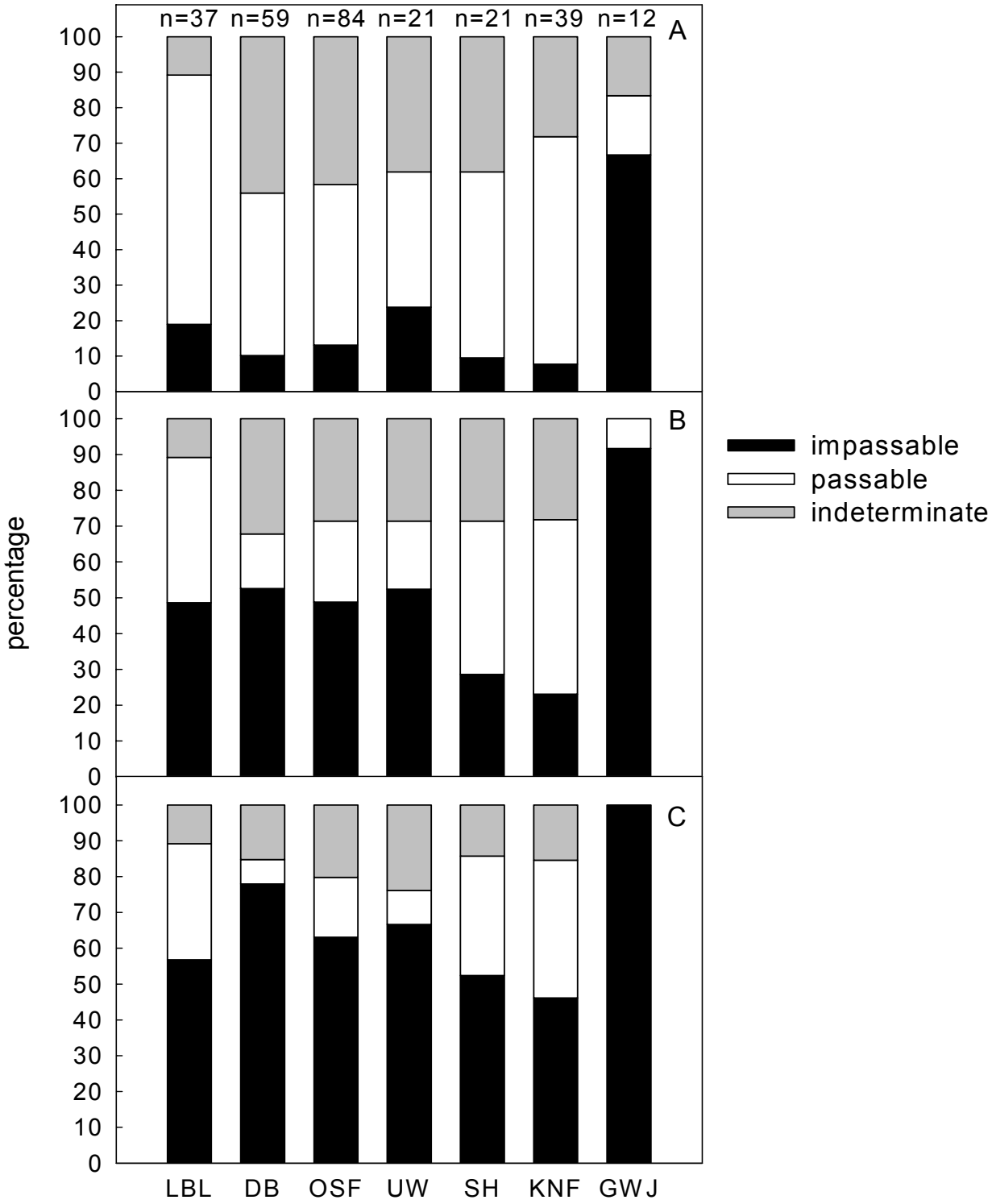

Figure 8. Percentage of crossings classified as impassable, passable, or indeterminate for Filter A, B, and C on Forests surveyed within Region 8, summer 2007 (N=273). (LBL= Land Between the Lakes National Recreation Area, DB= Daniel Boone National Forest, OSF= Ozark-St. Francis National Forest, UW= Uwharrie National Forest, KNF= Kisatchie National Forest, SH= Sam Houston National Forest, GWJ= George Washington- Jefferson National Forest).

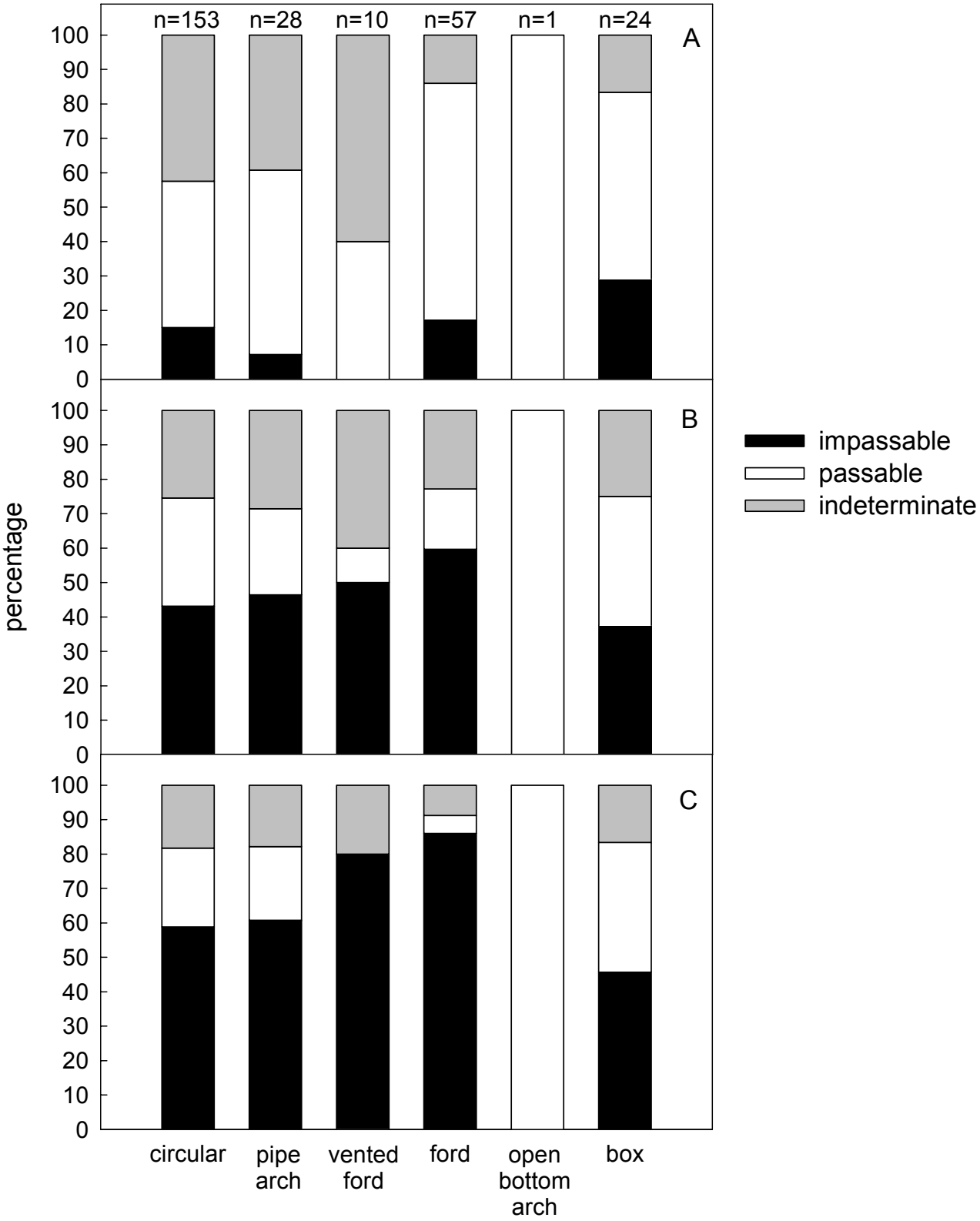

Figure 9. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter A, B, and C on Forests surveyed within Region 8, summer 2007 (N=273).

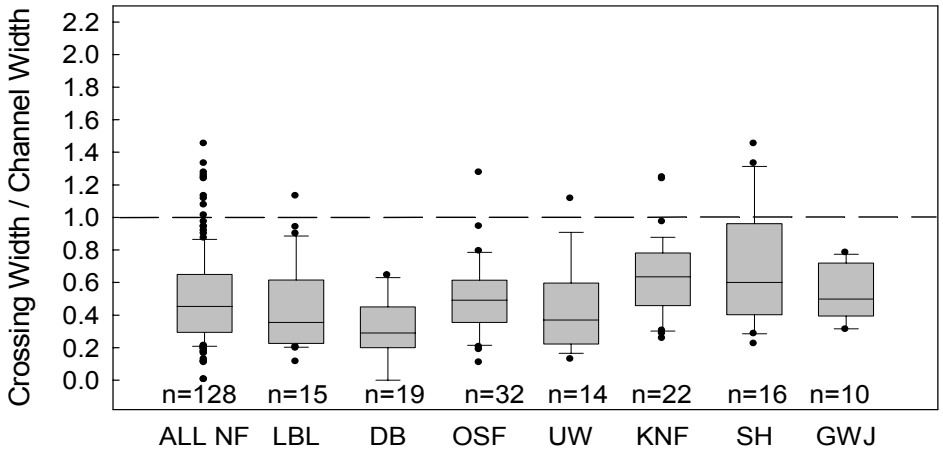

Figure 10. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2007 (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. ALL NF=Forests combined, LBL= Land Between the Lakes National Recreation Area, DB= Daniel Boone, OSF= Ozark- St. Francis, UW= Uwharrie, KNF= Kisatchie, SH= Sam Houston, and GWJ= George Washington- Jefferson. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

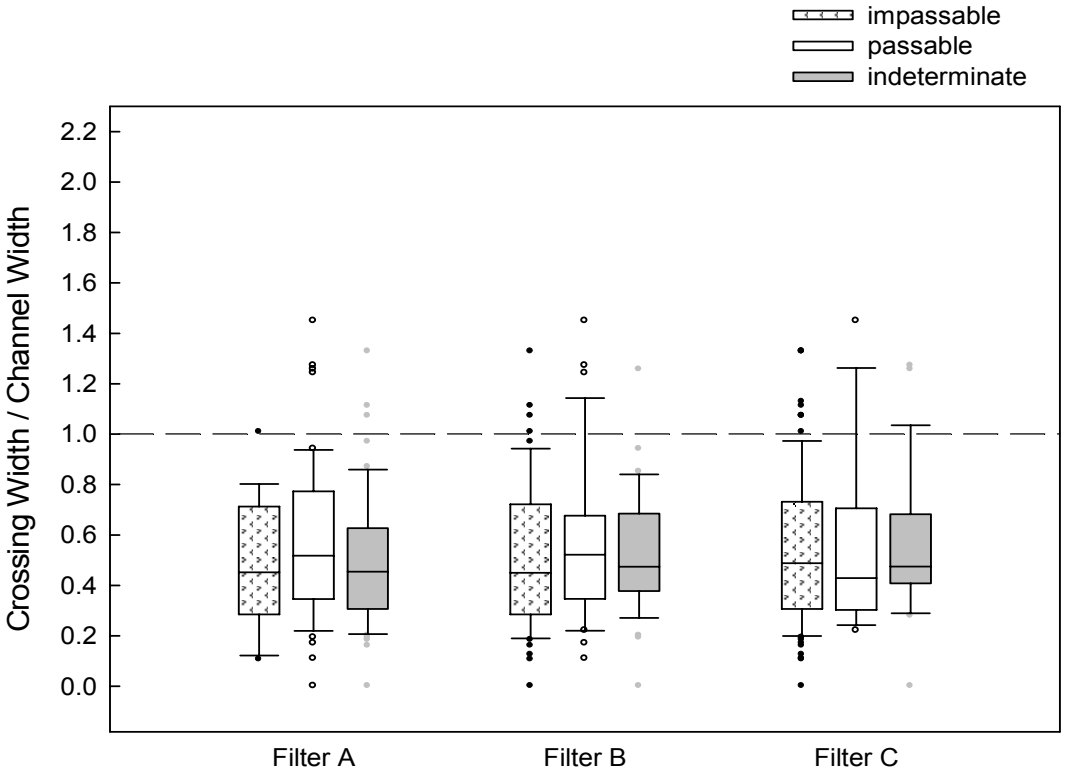

Figure 11. Crossing width to bankfull channel width ratio for crossings classified as impassable, passable, or indeterminate (all Forests combined) in summer 2007 (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

Table 1. Number of crossings documented (Total crossings documented) and number not surveyed (Crossings not surveyed) on Forests visited in summer 2007. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossings documented	Crossing not surveyed (n,[%])				
		NH	NA	NF	BR	Total not surveyed
Land Between the Lakes	150	41 (27)	2 (1)	58 (39)	12 (8)	113 (75)
Daniel Boone	196	15 (8)	104 (53)	13 (7)	5 (3)	137 (70)
Ozark-St. Francis	903	106 (12)	357 (40)	322 (36)	34 (4)	819 (91)
Uwharrie	37	4 (11)	2 (5)	1 (3)	9 (24)	16 (43)
Sam Houston	25	3 (12)	1 (4)	0 (0)	0 (0)	4 (16)
Kisatchie	181	75 (41)	65 (36)	2 (1)	0 (0)	142 (78)
George Washington-Jefferson	12	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Total	1504	244 (16)	531 (35)	396 (26)	60 (4)	1231 (82)

Table 2. Number of crossings surveyed (Total surveyed) with coarse filter results for Forests visited in summer 2007. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse filter results								
		Impassable (n,[%])			Passable (n,[%])			Indeterminate (n,[%])		
		A	B	C	A	B	C	A	B	C
Land Between the Lakes	37	7 (19)	18 (49)	21 (57)	26 (70)	15 (41)	12 (32)	4 (11)	4 (11)	4 (11)
Daniel Boone	59	6 (10)	31 (53)	46 (78)	27 (46)	9 (15)	4 (7)	26 (44)	19 (32)	9 (15)
Ozark-St. Francis	84	11 (13)	41 (49)	53 (63)	38 (45)	19 (23)	14 (17)	35 (42)	24 (29)	17 (20)
Uwharrie	21	5 (24)	11 (52)	14 (67)	8 (38)	4 (19)	2 (10)	8 (38)	6 (29)	5 (24)
Sam Houston	21	2 (10)	6 (29)	11 (52)	11 (52)	9 (43)	7 (33)	8 (38)	6 (29)	3 (14)
Kisatchie	39	3 (8)	9 (23)	18 (46)	25 (64)	19 (49)	15 (38)	11 (28)	11 (28)	6 (15)
George Washington-Jefferson	12	8 (67)	11 (92)	12 (100)	2 (17)	1 (8)	0 (0)	2 (17)	0 (0)	0 (0)
Total	273	42 (15)	127 (47)	175 (64)	137 (50)	76 (28)	54 (20)	94 (34)	70 (26)	44 (16)

Table 3. Number of crossings (percentage in parentheses) classified as impassable due to excessive outlet drop, excessive slope, or excessive slope x length values for each coarse filter; Southern Region (all Forests combined), summer 2007. Note: a crossing must pass for outlet drop to be considered for slope and it must pass for outlet drop and slope to be considered for slope*length.

	Filter A	Filter B	Filter C
Outlet drop	25 (60)	88 (69)	145 (83)
Slope	17 (40)	38 (30)	27 (15)
Slope*Length	0 (0)	1 (1)	3 (2)
Total	42	127	175

Table 4. Number of each crossing type (percentage in parentheses) classified as impassable, passable, or indeterminate for each coarse filter; Southern Region (all Forests combined) during summer 2007.

Classification	Crossing type	Filter A	Filter B	Filter C
Impassable	circular	23 (15)	66 (43)	90 (59)
	pipe arch	2 (7)	13 (46)	17 (61)
	vented ford	0 (0)	5 (50)	8 (80)
	ford	10 (18)	34 (60)	49 (86)
	open bottom arch	0 (0)	0 (0)	0 (0)
	box	7 (29)	9 (38)	11 (46)
Passable	circular	65 (42)	48 (31)	35 (23)
	pipe arch	15 (54)	7 (25)	6 (21)
	vented ford	4 (40)	1 (10)	0 (0)
	ford	39 (68)	10 (18)	3 (5)
	open bottom arch	1 (100)	1 (100)	1 (100)
	box	13 (54)	9 (38)	9 (38)
Indeterminate	circular	65 (42)	39 (25)	28 (18)
	pipe arch	11 (39)	8 (29)	5 (18)
	vented ford	6 (60)	4 (40)	2 (20)
	ford	8 (14)	13 (23)	5 (9)
	open bottom arch	0 (0)	0 (0)	0 (0)
	box	4 (17)	6 (25)	4 (17)

Appendix A: Results for the Land Between the Lakes National Recreation Area

We completed surveys at 37 (25%) of 150 documented crossings on the Land Between the Lakes National Recreation Area in 2007 (Figure A1, Tables A1 and A2). Filter A (strong swimmers and leapers) classified 19% (n=7) of crossings as impassable, 70% (n=26) as passable, and 11% (n=4) as indeterminate (Figure A2, Table A2). Filter B (moderate swimmers and leapers) classified 49% (n=18) of crossings as impassable, 41% (n=15) as passable, and 11% (n=4) as indeterminate (Figure A3, Table A2). Filter C (weak swimmers and leapers) classified 57% (n=21) of crossings as impassable, 32% (n=12) as passable, and 11% (n=4) as indeterminate (Figure A4, Table A2). Characteristics and filter classifications for each crossing are presented in Tables A3-A5.

All of the crossings surveyed were either circular culverts (43%, n=16), pipe arches (11%, n=4), fords (16%, n=6), or box culverts (30%, n=11). No open-bottom arches or vented fords were surveyed. Filter A classified 6% of circular culverts, 0% of pipe arch crossings, 50% of fords, and 36% of box culverts as impassable (Figure A3). Filter B classified 31% of circular culverts, 50% of pipe arch crossings, 100% of fords, and 45% of box culverts as impassable (Figure A3). Filter C classified 38% of circular culvert, 75% of pipe arch crossings, 100% of fords, and 55% of box culverts as impassable (Figure A3). The mean crossing width to channel width ratio for surveyed crossings (excluding fords and multiple structure crossings) was 0.46 ± 0.25 (mean ±SD) (n=15) (Figure A4). The sample size was too low to calculate mean crossing with for surveyed crossings classified impassable by Filter A. The mean ratio for crossings classified impassable by Filter B was 0.48 ± 0.33 (n=6), and was 0.48 ± 0.36 (n=9) for Filter C (Figure A5). The mean crossing to channel width ratio for surveyed crossings classified passable by Filter A was 0.51± 0.29 (n=10). The mean ratio for crossings classified as passable by Filter B was 0.39± 0.19 (n=6), and was 0.38± 0.16 (n=4) for Filter C (Figure A5).

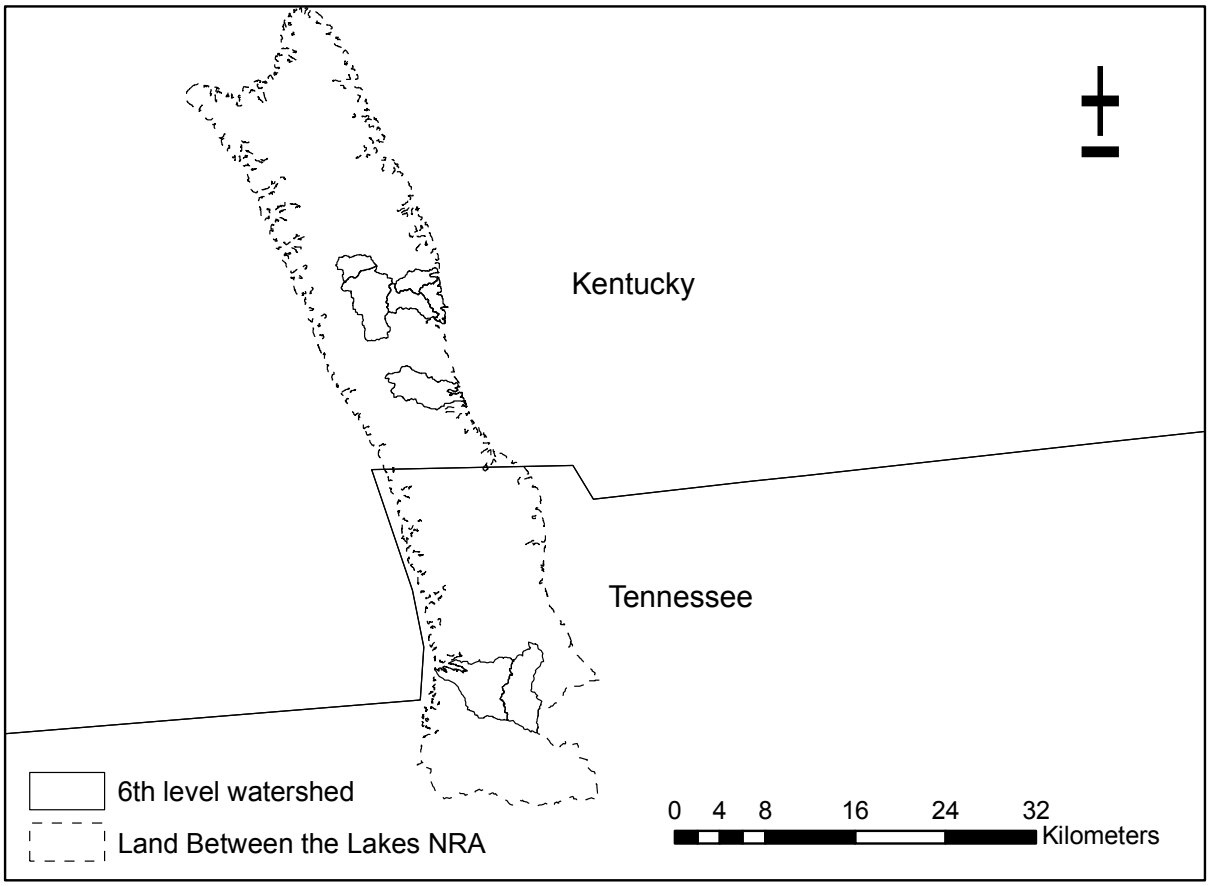

Figure A1. Watersheds on the Land Between the Lakes National Recreation Area where road-stream crossing surveys were conducted in 2007.

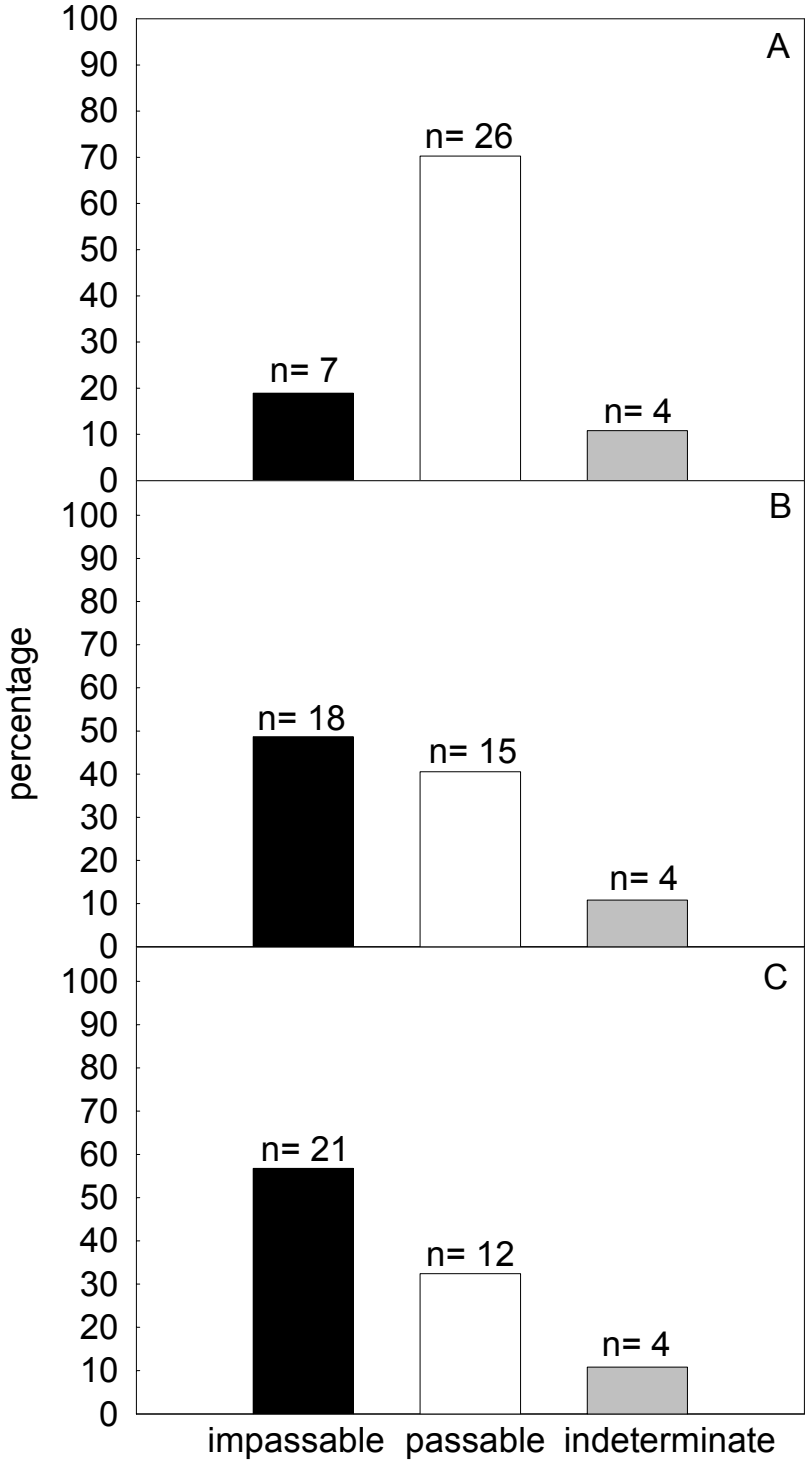

Figure A2. Percentage of crossings classified as impassable, passable, or indeterminate for Filters A, B, and C; Land Between the Lakes National Recreation Area, Kentucky, summer 2007 (N= 37).

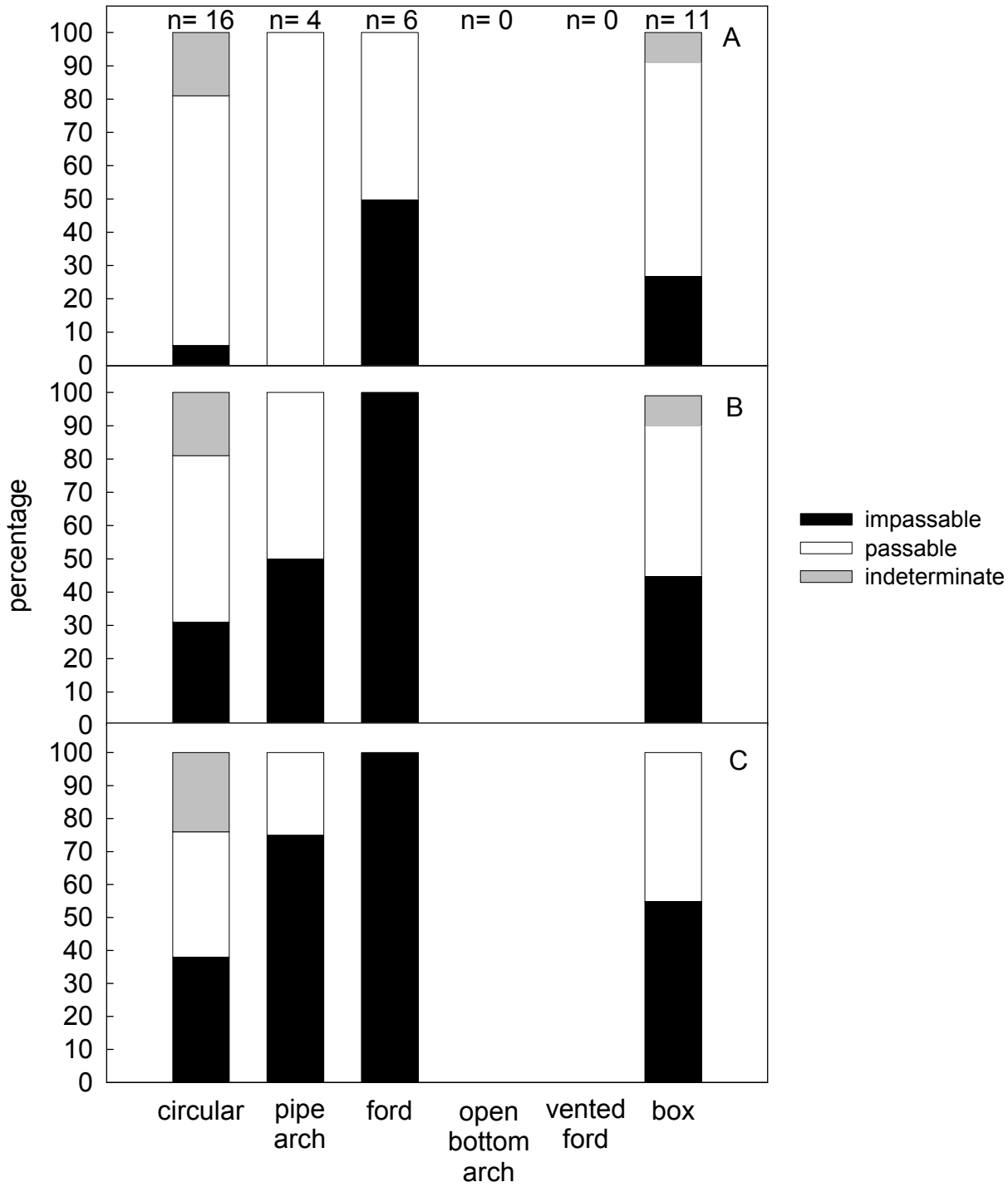

Figure A3. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter A, B, and C; Land Between the Lakes National Recreation Area, Kentucky, summer 2007 (N= 37).

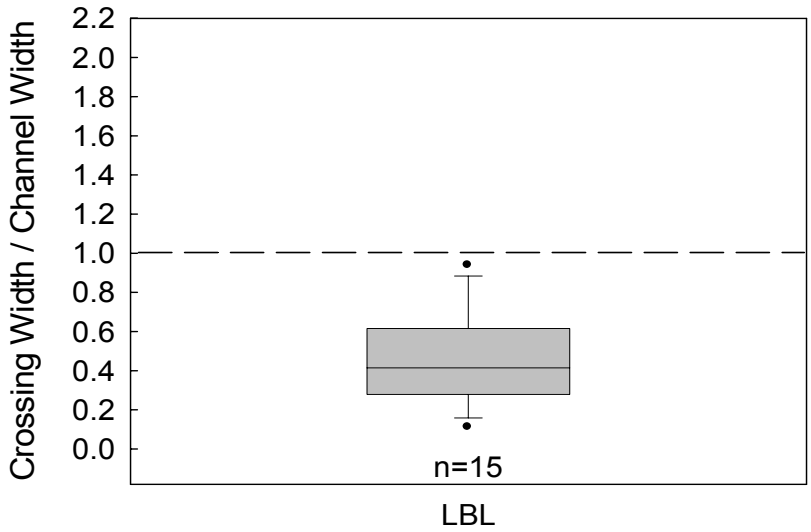

Figure A4. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2007 on the Land Between the Lakes National Recreation Area (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

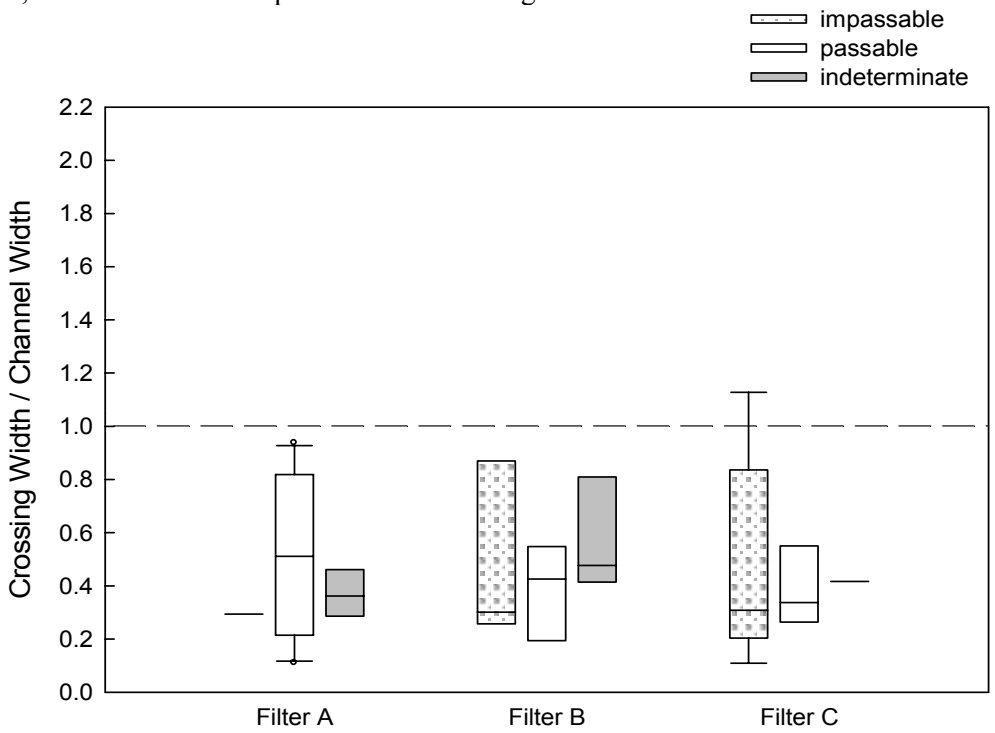

Figure A5. Crossing width to bankfull channel width ratio for crossings classified as impassable, passable, or indeterminate in summer 2007 on Land Between the Lakes National Recreation Area (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

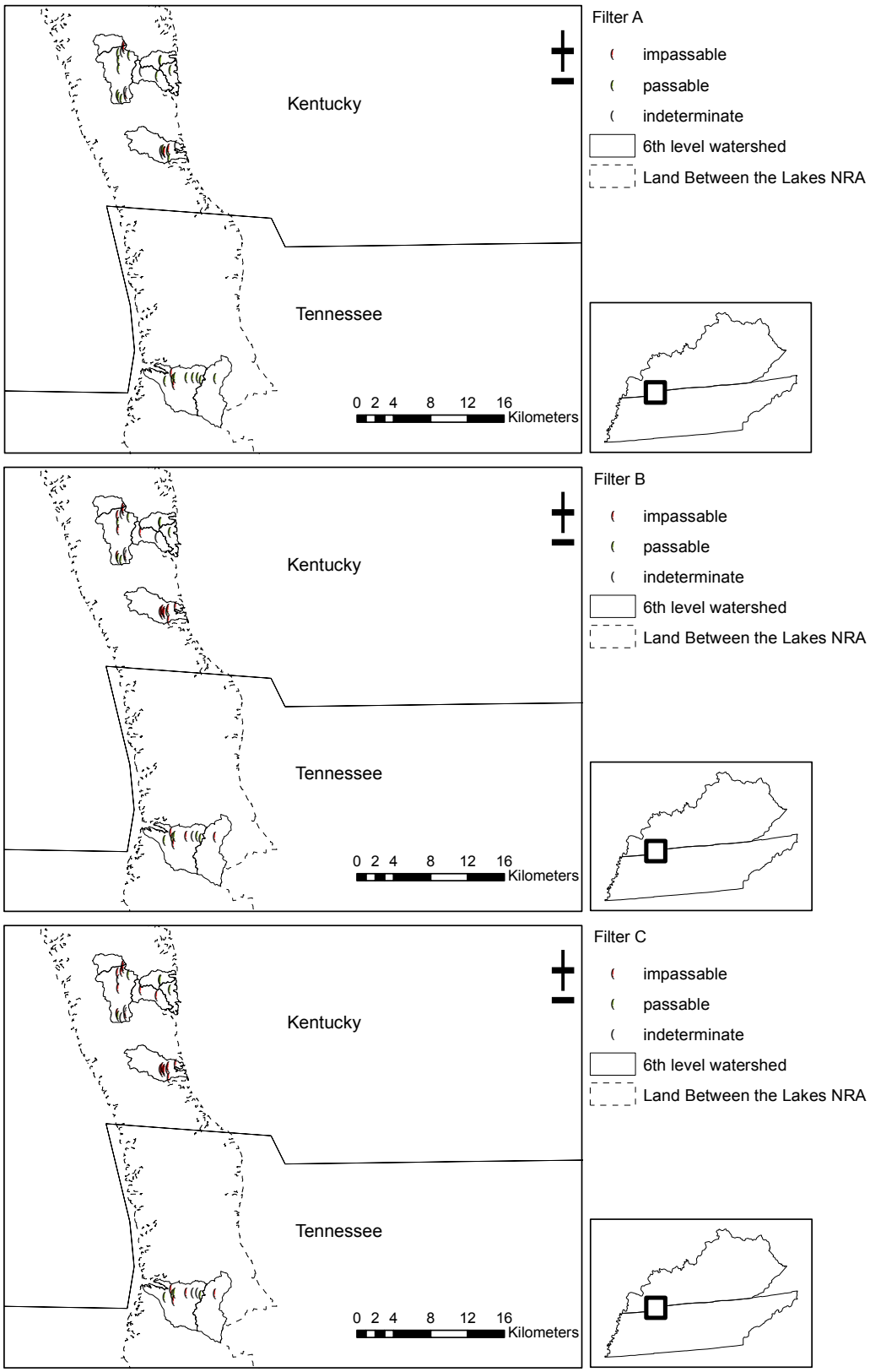

Figure A6. Location of crossings classified for fish passage by coarse filters A, B and C within 6th level watersheds on the Land Between the Lakes National Recreation Area, summer 2007.

Table A1. Number of crossings documented (Total crossings documented) and not surveyed (Crossings not surveyed) on the Land Between the Lakes National Recreation Area in summer 2007. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossings documented	Crossings not surveyed (n,[%])				
		NH	NA	NF	BR	Total not surveyed
LBLNRA	150	41 (27)	2 (1)	58 (39)	12 (8)	113 (75)*

* A pre-survey reconnaissance team visited an additional 139 non-surveyed sites. The sits were not surveyed due to: (1) the team could not locate a crossing structure, or (2) the sites were not visited by the survey crew because they were outside of the highest priority watersheds, as designated by LBL.

Table A2. Number of crossings surveyed (Total surveyed) with coarse filter results for the Land Between the Lakes National Recreation Area in summer 2007. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse Filter Results								
		Impassable (n,[%])			Passable (n,[%])			Indeterminate (n,[%])		
		A	B	C	A	B	C	A	B	C
LBLNRA	37	7 (19)	18 (49)	21 (57)	26 (70)	15 (41)	12 (32)	4 (11)	4 (11)	4 (11)

Table A3. Location of crossings surveyed on the Land Between the Lakes National Recreation Area during the summer of 2007. Site ID consists of the Forest abbreviation (LBL), road the crossing is on (152), and the distance (miles) from the junction road (0.2).

Site ID	# Pipes	District	Junction Road	Stream Name	Quad	6th Level Watershed
LBL134-0.6	1	LBL	152	POND CR	Fenton	051302051402
LBL134-0.7	1	LBL	152	POND CR	Fenton	051302051404
LBL134-1.8	1	LBL	152	SHANKLIN CR	Canton	051302051402
LBL144-2.8	0	LBL	453	FRANKLIN CR	Fenton	051302051403
LBL144-3	0	LBL	453	CROOKED CR	Fenton	051302051403
LBL144-3.7	1	LBL	453	CROOKED CR	Fenton	051302051403
LBL145-0.2	0	LBL	144	CROOKED CR	Fenton	051302051403
LBL145-0.4	1	LBL	144	CROOKED CR	Fenton	051302051403
LBL145-0.9	1	LBL	144	CROOKED CR	Fenton	051302051403
LBL153-0	4	LBL	145	CROOKED CR	Fenton	051302051403
LBL153-0	2	LBL	151	LONG CR	Fenton	051302051402
LBL153-1.4	2	LBL	151	LONG CR	Fenton	051302051402
LBL165-3.75	2	LBL	49	PARSONS CR	Linton	051302051401
LBL165-4.25	3	LBL	49	LICK CR	Linton	051302051401
LBL165-4.5	5	LBL	49	LICK CR	Linton	051302051401
LBL166-0.4	2	LBL	165	LICK CR	Linton	051302051401
LBL206-.5	1	LBL	230	PANTHER CR	Tharpe	060400053108
LBL230-1.1	2	LBL	49	BEAR CR	Tharpe	051302051408
LBL230-2.1	1	LBL	49	PANTHER CR	Tharpe	060400053108
LBL230-2.4	1	LBL	49	PANTHER CR	Tharpe	060400053108
LBL230-2.9	1	LBL	49	PANTHER CR	Tharpe	060400053108
LBL230-3.8	1	LBL	49	PANTHER CR	Tharpe	060400053108
LBL230-4.5	2	LBL	49	PANTHER CR	Tharpe	060400053108

Table continued on next page…

Table A3 (*continued*). Location of crossings surveyed on the Land Between the Lakes National Recreation Area during the summer of 2007. Site ID consists of the Forest abbreviation (LBL), road the crossing is on (152), and the distance (miles) from the junction road (0.2).

Site ID	# Pipes	District	Junction Road	Stream Name	Quad	6th Level Watershed
LBL230-4.7	3	LBL	49	PANTHER CR	Tharpe	060400053108
LBL230-5	2	LBL	49	PANTHER CR	Tharpe	060400053108
LBL400-0.3	1	LBL	230	PANTHER CR	Tharpe	060400053108
LBL E&B-0.2	3	LBL	453	CROOKED CR	Fenton	051302051403
LBL E&B-0.5	2	LBL	453	CROOKED CR	Fenton	051302051403
LBL E&B-1.0	3	LBL	453	CROOKED CR	Fenton	051302051403
LBL E&B-1.7	2	LBL	453	CROOKED CR	Fenton	051302051403
LBL E&B-1.9	0	LBL	453	CROOKED CR	Fenton	051302051403
LBL E&B-2.5	3	LBL	453	CROOKED CR	Fenton	060400053101
LBLWC-0.2	0	LBL	165	LICK CR	Rushing Creek	051302051401
LBLWC-0.4	0	LBL	165	LICK CR	Rushing Creek	051302051401
LBLWC-0.6	1	LBL	165	LICK CR	Rushing Creek	051302051401
LBLWC-0.8	1	LBL	165	LICK CR	Rushing Creek	051302051401
LBLWC-1	1	LBL	165	LICK CR	Rushing Creek	051302051401

Table A4. Coarse filter A, B, and C, classifications for crossings surveyed on the Land Between the Lakes National Recreation Area, summer 2007. At sites with multiple pipes, data are grouped by Site ID and given the most favorable passage rating for each filter to determine passage status.

Site ID	Filter A	Filter B	Filter C
LBL134-0.6	passable	passable	passable
LBL134-0.7	passable	impassable	impassable
LBL134-1.8	passable	passable	passable
LBL144-2.8	impassable	impassable	impassable
LBL144-3.0	passable	impassable	impassable
LBL144-3.7	passable	impassable	impassable
LBL145-0.2	impassable	impassable	impassable
LBL145-0.4	passable	passable	impassable
LBL145-0.9	indeterminate	impassable	impassable
LBL153-0	impassable	impassable	impassable
LBL153-0.0	impassable	impassable	impassable
LBL153-1.4	passable	impassable	impassable
LBL165-3.75	passable	passable	passable
LBL165-4.25	passable	passable	passable
LBL165-4.5	passable	passable	passable
LBL166-0.4	passable	impassable	impassable
LBL206-0.5	passable	indeterminate	impassable
LBL230-1.1	impassable	impassable	impassable
LBL230-2.1	impassable	impassable	impassable
LBL230-2.4	passable	impassable	impassable
LBL230-2.9	indeterminate	indeterminate	impassable
LBL230-3.8	passable	passable	passable
LBL230-4.5	passable	passable	passable
LBL230-4.7	passable	passable	passable
LBL230-5	passable	passable	passable
LBL400-0.3	indeterminate	indeterminate	indeterminate
LBLE&B-0.2	passable	passable	passable
LBLE&B-0.5	passable	indeterminate	indeterminate
LBLE&B-1.0	passable	passable	indeterminate
LBLE&B-1.7	passable	passable	passable
LBLE&B-1.9	passable	impassable	impassable
LBLE&B-2.5	passable	impassable	impassable
LBLWC-0.2	passable	impassable	impassable
LBLWC-0.4	impassable	impassable	impassable
LBLWC-0.6	passable	passable	indeterminate
LBLWC-0.8	passable	passable	passable
LBLWC-1.0	indeterminate	impassable	impassable

Table A5. Description of crossings surveyed on the Land Between the Lakes National Recreation Area, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site ID	Pipe #	Shape	Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
LBL134-0.6	1	PA	Fair	11.42	N	2.47	0.53	-10.44	-0.96	0.36	34.00	84.00
LBL134-0.7	1	PA	Good	7.08	N	0.34	0.85	19.20	-1.08	0	35.00	12.00
LBL134-1.8	1	C	Poor	6.50	N	1.87	0.62	-13.44	1.92	1.08	55.00	103.00
LBL144-2.8	0	F	Fair	27.25	N	1.70	2.86	37.08	42.72	0	13.50	23.00
LBL144-3.0	0	F	Fair	28.92	N	1.01	3.25	15.12	11.88	0	13.80	14.00
LBL144-3.7	1	C	Fair	13.00	N	0.43	0.19	10.09	6.25	0	23.00	9.90
LBL145-0.2	0	F	Fair	29.33	N	0.53	2.56	30.60	10.44	0	15.00	8.00
LBL145-0.4	1	PA	Fair	45.83	N	1.15	0.11	7.56	3.00	0	20.00	23.00
LBL145-0.9	1	B	Fair	12.32	N	4.50	0.31	6.36	17.52	0	12.00	54.00
LBL153-0	1	B	Good	24.75	N	0.20	0.40	30.60	14.28	0	30.00	6.00
LBL153-0	2	B	Good	24.75	N	0.37	0.40	29.76	NA	0	30.00	11.00
LBL153-0	3	B	Good	24.75	N	0.43	0.40	30.00	NA	0	30.00	13.00
LBL153-0	4	B	Good	24.75	N	0.10	0.40	30.72	NA	0	30.00	3.00
LBL153-0.0	1	B	Good	8.87	N	0.10	1.13	24.60	24.72	0	30.00	3.00
LBL153-0.0	2	B	Good	8.87	N	0.01	1.13	25.12	NA	0	30.00	0.30
LBL153-1.4	1	PA	Fair	9.25	N	0.71	0.65	13.20	15.48	0	45.00	32.00
LBL153-1.4	2	C	Fair	9.25	N	1.33	0.65	14.04	5.88	0	45.00	60.00
LBL165-3.75	1	B	Fair	32.83	Y	0.61	0.30	NA	0.84	0	24.50	15.00
LBL165-3.75	2	B	Fair	32.83	Y	1.10	0.30	NA	NA	0	24.50	27.00
LBL165-4.25	1	C	Fair	19.83	Y	1.06	0.20	-4.20	-2.64	0	35.00	37.00
LBL165-4.25	2	C	Fair	19.83	Y	0.49	0.20	-2.16	NA	4.2	35.00	17.00
LBL165-4.25	3	C	Fair	19.83	Y	1.46	0.20	-1.44	NA	7.56	35.00	51.00
LBL165-4.5	1	B	Fair	46.42	N	0.33	0.23	NA	-8.88	0	30.00	10.00
LBL165-4.5	2	B	Fair	46.42	N	5.33	0.23	NA	NA	0	30.00	160.00
LBL165-4.5	3	B	Fair	46.42	Y	7.93	0.23	NA	NA	0	30.00	238.00

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Table A5 (*continued*). Description of crossings surveyed on the Land Between the Lakes National Recreation Area, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site ID	Pipe #	Shape	Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
LBL165-4.5	4	B	Fair	46.42	N	0.93	0.23	NA	NA	0	30.00	28.00
LBL165-4.5	5	B	Fair	46.42	N	2.60	0.23	NA	NA	0	30.00	78.00
LBL166-0.4	1	C	Fair	12.08	N	4.54	0.21	16.56	17.28	0	24.00	109.00
LBL166-0.4	2	C	Fair	12.08	N	1.67	0.21	16.56	NA	0	24.00	40.00
LBL206-0.5	1	B	Good	14.83	N	0.73	0.81	8.40	9.72	0	39.50	29.00
LBL230-1.1	1	B	Fair	11.17	N	1.46	0.90	26.16	14.04	0	26.00	38.00
LBL230-1.1	2	B	Fair	11.17	N	1.54	0.90	26.16	NA	0	26.00	40.00
LBL230-2.1	1	C	Fair	8.50	N	0.90	0.29	29.28	26.76	0	48.00	43.00
LBL230-2.4	1	B	Fair	11.75	N	0.48	0.94	NA	5.76	0	44.00	21.00
LBL230-2.9	1	C	Fair	11.33	N	1.62	0.48	6.96	15.60	0	45.00	73.00
LBL230-3.8	1	C	Poor	12.08	N	0.27	0.50	NA	0.72	0	40.00	11.00
LBL230-4.5	1	B	Fair	23.92	N	0.44	0.42	NA	0.00	0	45.00	20.00
LBL230-4.5	2	B	Fair	23.92	Y	0.22	0.42	NA	-18.72	0	45.00	10.00
LBL230-4.7	1	B	Good	31.08	Y	1.34	0.39	-1.44	-18.24	0	36.50	49.00
LBL230-4.7	2	B	Good	31.08	Y	1.97	0.39	-1.32	NA	0	36.50	72.00
LBL230-4.7	3	B	Good	31.08	Y	0.22	0.39	20.52	NA	0	36.50	8.00
LBL230-5	1	B	Fair	12.25	N	0.71	0.82	12.84	19.20	0	38.00	27.00
LBL230-5	2	B	Fair	12.25	Y	1.05	0.82	12.84	NA	0	38.00	40.00
LBL400-0.3	1	C	Fair	4.58	N	2.46	0.41	2.16	1.80	0	26.00	64.00
LBLE&B-0.2	1	C	Fair	12.25	N	0.51	0.24	NA	NA	0	37.00	19.00
LBLE&B-0.2	2	C	Fair	12.25	N	0.38	0.33	NA	-0.72	0	37.00	14.00
LBLE&B-0.2	3	C	Fair	12.25	N	0.43	0.24	NA	NA	0	37.00	16.00
LBLE&B-0.5	1	C	Fair	19.00	N	1.57	0.21	NA	-0.12	0	46.00	72.00
LBLE&B-0.5	2	C	Fair	19.00	N	0.65	0.21	NA	-0.96	0	46.00	30.00

Table continued on next page…

Table A5 (*continued*). Description of crossings surveyed on the Land Between the Lakes National Recreation Area, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site ID	Pipe #	Shape	Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
LBLE&B-1.0	1	C	Poor	14.67	N	0.38	0.27	NA	-0.12	0	45.00	17.00
LBLE&B-1.0	2	C	Poor	14.67	N	0.11	0.27	NA	5.04	0	45.00	5.00
LBLE&B-1.0	3	C	Poor	14.67	N	0.91	0.27	NA	-0.12	0	45.00	41.00
LBLE&B-1.7	1	C	Fair	11.92	Y	0.83	0.32	NA	-0.24	0	37.50	31.00
LBLE&B-1.7	2	C	Fair	11.92	Y	0.88	0.32	NA	-5.04	0	37.50	33.00
LBLE&B-1.9	0	F	Good	23.00	N	0.44	2.59	NA	10.08	0	16.00	7.00
LBLE&B-2.5	1	C	Good	18.58	N	0.55	0.22	18.60	13.32	0	38.00	21.00
LBLE&B-2.5	2	C	Good	18.58	N	0.97	0.22	18.96	NA	0	38.00	37.00
LBLE&B-2.5	3	C	Good	18.58	N	0.95	0.22	25.80	NA	0	38.00	36.00
LBLWC-0.2	0	F	Good	11.50	N	1.35	3.78	NA	6.84	0	20.00	27.00
LBLWC-0.4	0	F	Good	17.42	N	3.33	4.79	NA	14.40	0	9.00	30.00
LBLWC-0.6	1	C	Fair	9.00	N	1.28	0.22	2.76	5.28	0	18.00	23.00
LBLWC-0.8	1	C	Fair	14.08	Y	1.00	0.36	NA	0.60	0	25.00	25.00
LBLWC-1.0	1	C	Fair	10.75	N	5.82	0.28	1.44	8.88	0	28.00	163.00

Appendix B: Results for the Daniel Boone National Forest

We completed surveys at 59 (30%) of 196 documented crossings on the London and Redbird Ranger Districts in 2007 (Figure B1, Tables B1 and B2). Filter A (strong swimmers and leapers) classified 10% (n=6) of crossings as impassable, 46% (n=27) as passable, and 44% (n=26) as indeterminate (Figure B2, Table B2). Filter B (moderate swimmers and leapers) classified 53% (n=31) of crossings as impassable, 15% (n=9) as passable, and 32% (n=19) as indeterminate (Figure B2, Table B2). Filter C (weak swimmers and leapers) classified 78% (n=46) of crossings as impassable, 7% (n=4) as passable, and 15% (n=9) as indeterminate (Figure B2, Table B2). Characteristics and filter classifications for each crossing are presented in Tables B3-B5.

The majority of the crossings surveyed were circular culverts (47%, n=28), vented fords (5%, n=3), fords (41%, n=24) and pipe arches (7%, n=4). Open bottom arches and box culverts, were not encountered during surveys conducted in 2007. Filter A classified 7% of circular culverts, 25% of pipe arches, and 13% of fords as impassable (Figure B2). Filter B classified 50% of circular culverts, 75% of pipe arches, 54% of fords, and 33% of vented fords as impassable (Figure B2). Filter C classified 68% of circular culverts, 75% of pipe arches, 92% of fords, and 67% of vented fords as impassable (Figure B2). The mean crossings width to channel width ratio (excluding fords, vented fords and multiple structure crossings) was 0.32 ± 0.18 (mean ± SD) (n=19) (Figure B3). The sample size was insufficient to calculate mean crossing width to channel width ratio for surveyed crossings classified impassable by Filter A. The mean ratio for crossings classified impassable by Filter B was 0.32 ± 0.18 (n=11), and was 0.33 ± 0.18 (n=15) for Filter C (Figure B4). The mean crossing width to channel width ratio for crossings classified passable by Filter A was 0.27 ± 0.17 (n=6). The mean ratio for crossings classified passable by Filter B was 0.31 ± 0.13 (n=4). The sample size was insufficient to calculate mean crossing width to channel width ratio for surveyed crossings classified as passable by Filter C (Figure B4).

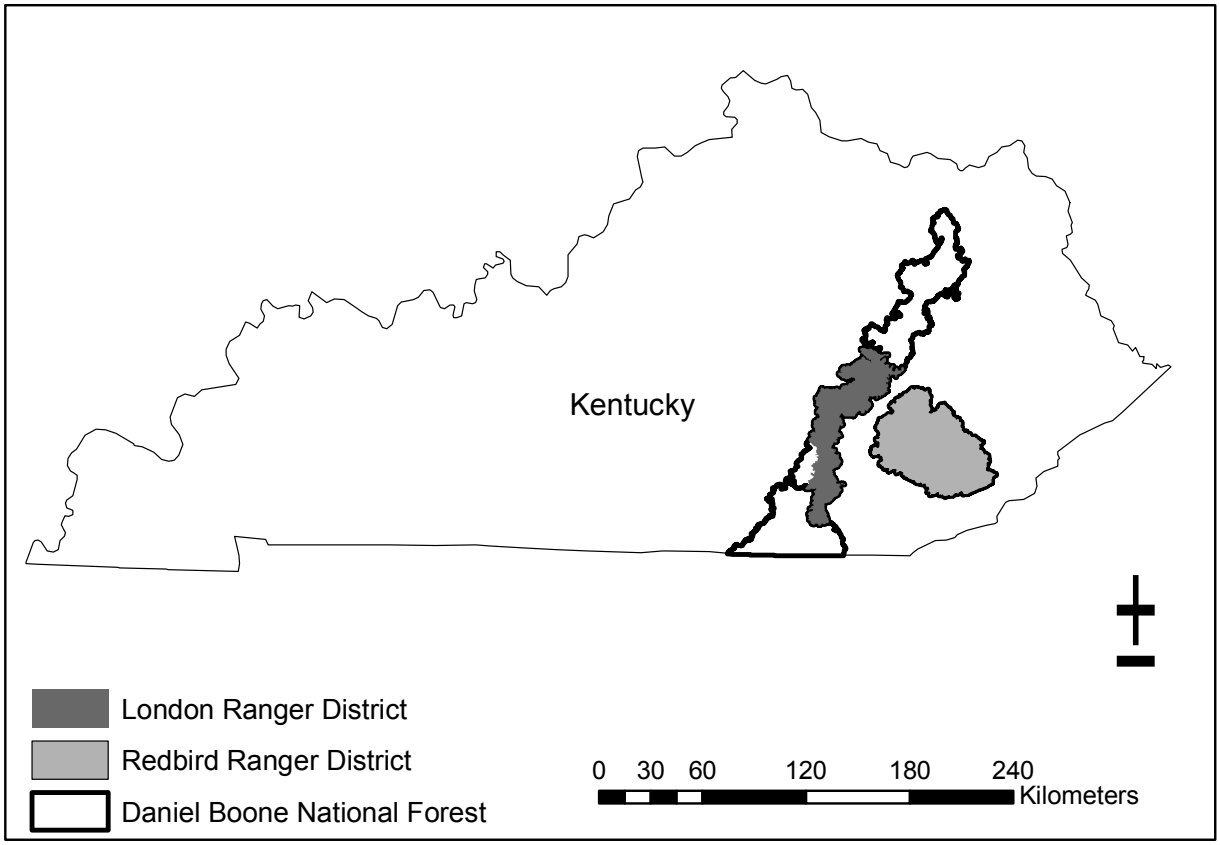

Figure B1. Ranger Districts on the Daniel Boone National Forest where road-stream crossing surveys were conducted, summer 2007.

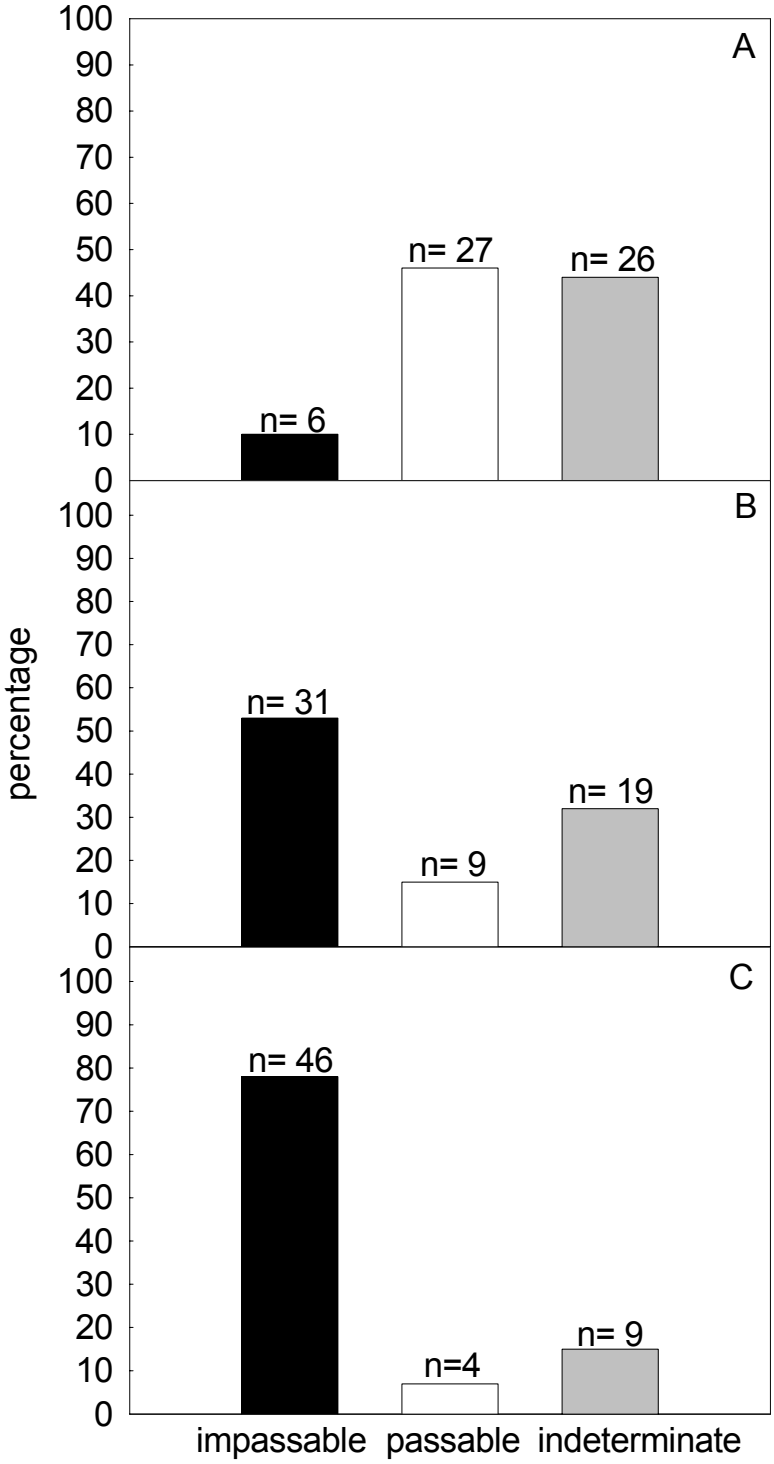

Figure B2. Percentage of crossings classified as impassable, passable, or indeterminate for Filters A, B, and C; Daniel Boone National Forest, Kentucky, summer 2007 (N=59).

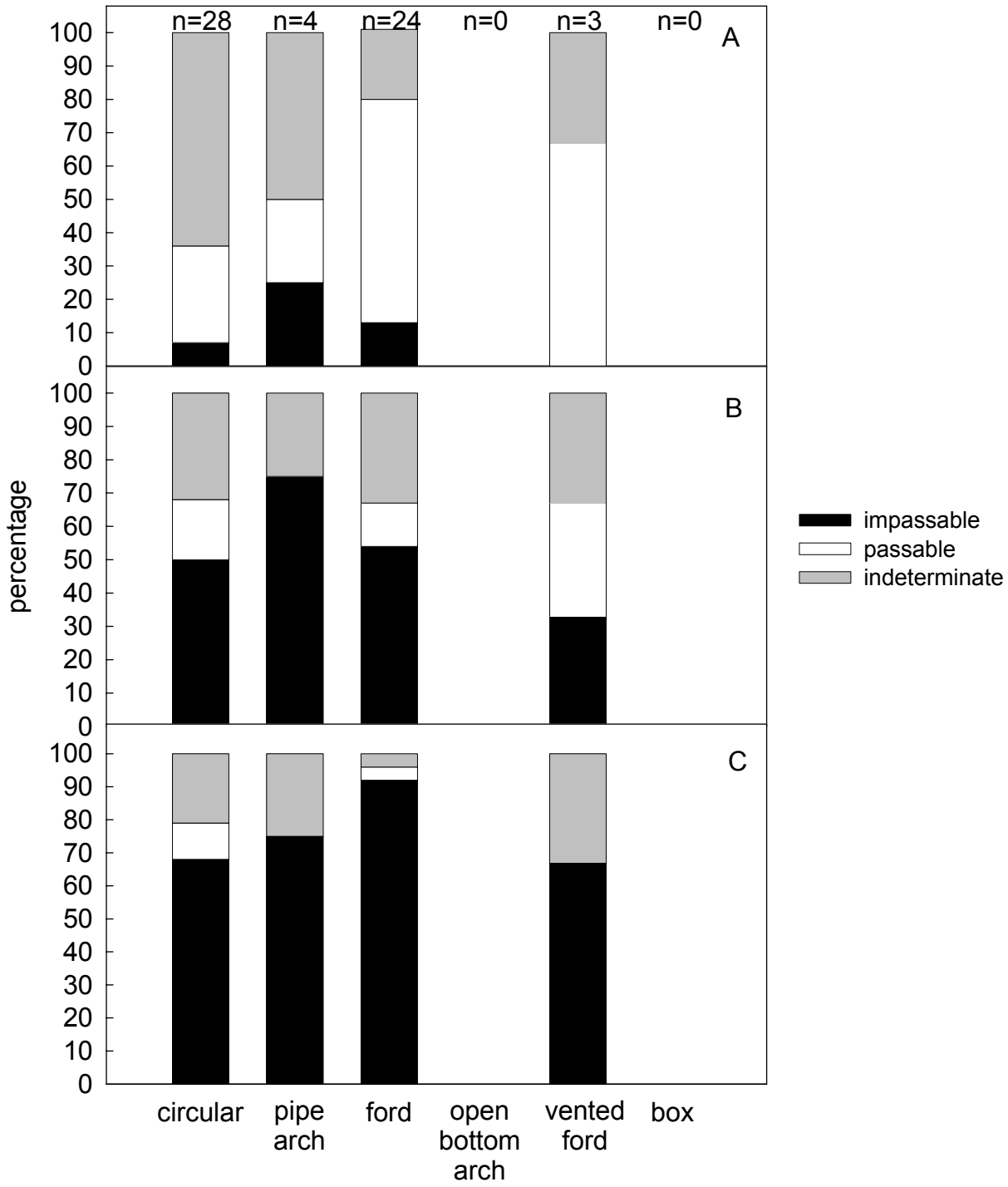

Figure B3. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter A, B, and C; Daniel Boone National Forest, summer 2007 (N=59).

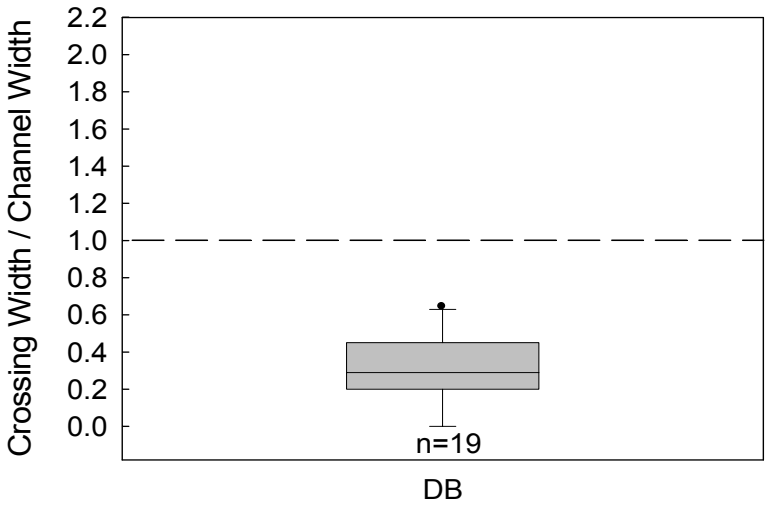

Figure B4. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2007 on the Daniel Boone National Forest (excluding fords, vented fords and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

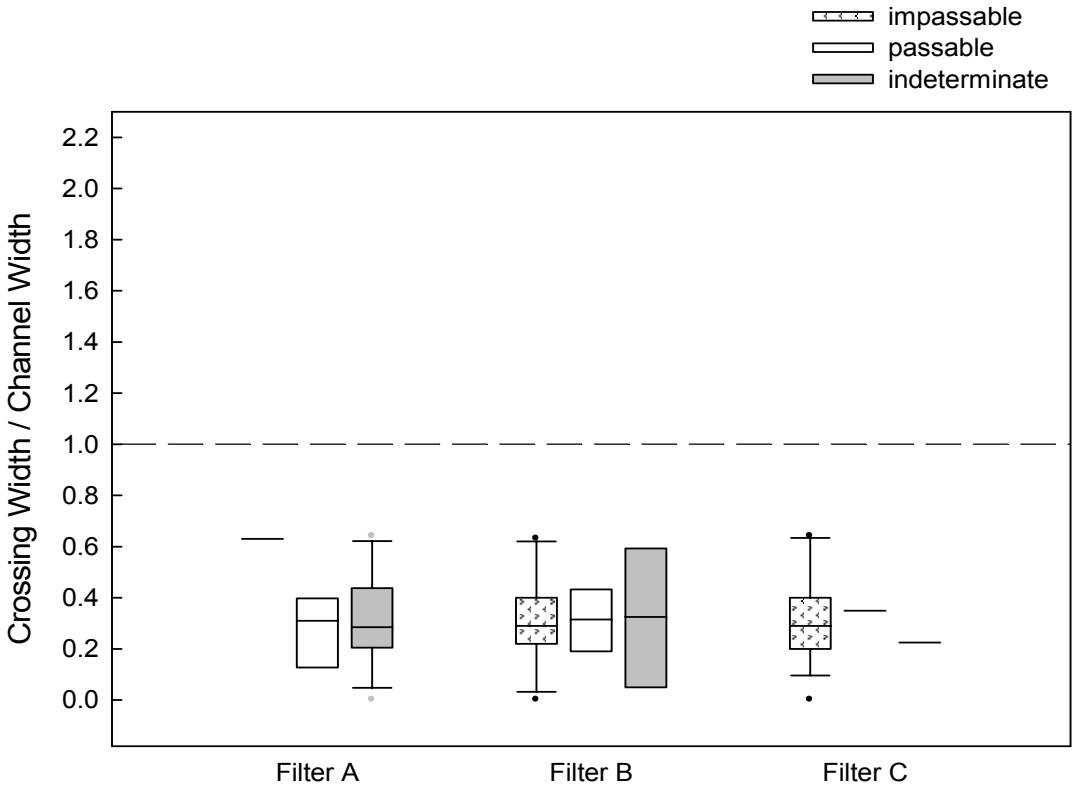

Figure B5. Crossing width to bankfull channel width ratio for crossings classified as impassable, passable, or indeterminate in summer 2007 on the Daniel Boone National Forest (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The symbol inside each set of whiskers represents the median, and the top and bottom of the whiskers represent the maximum and minimum values.

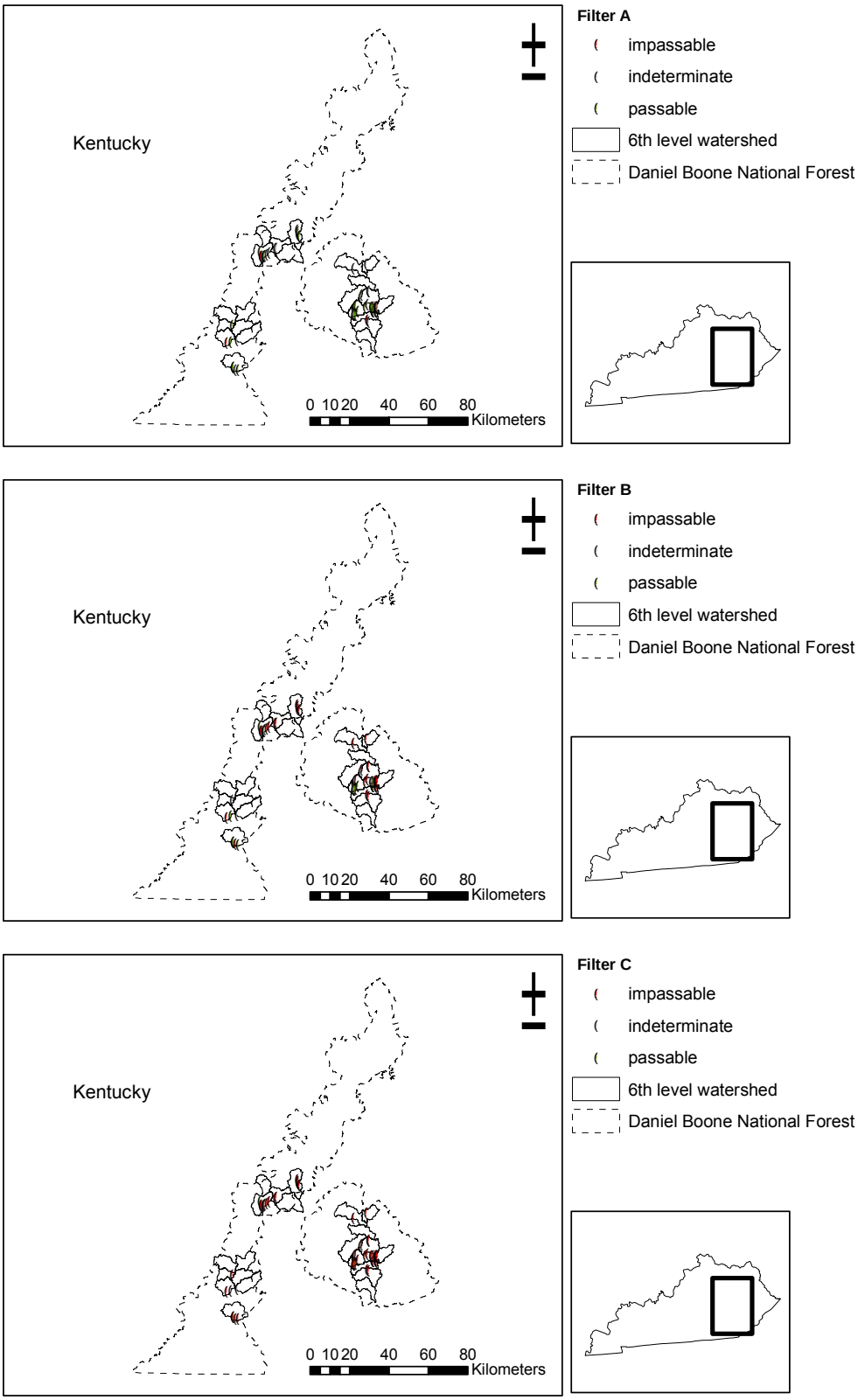

Figure B6. Location of crossings classified for fish passage by coarse filters A, B and C within 6th level watersheds on the Daniel Boone National Forest, summer 2007.

Table B1. Number of crossings documented (Total crossings documented) and not surveyed (Crossings not surveyed) on the Daniel Boone National Forest in summer 2007. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossings documented	Crossings not surveyed (n,[%])				
		NH	NA	NF	BR	Total not surveyed
DBNF	196	15 (8)	104 (53)	13 (7)	5 (3)	137 (70)

Table B2. Number of crossings surveyed (Total surveyed) with coarse filter results for the Daniel Boone National Forest in summer 2007. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse Filter Results								
		Impassable (n,[%])			Passable (n,[%])			Indeterminate (n,[%])		
		A	B	C	A	B	C	A	B	C
DB	59	6 (10)	31 (53)	46 (78)	27 (46)	9 (15)	4 (7)	26 (44)	19 (32)	9 (15)

Table B3. Location of crossings surveyed on the Daniel Boone National Forest during the summer of 2007. Site ID consists of the Forest abbreviation (DB), road the crossing is on (1600) and the distance (miles) from the junction road (0.6).

Site ID	# of Pipes	District	Junction Road	Stream Name	Quad	6th Level Watershed
DB1600-0.6	2	Redbird	1533	Sugar Creek	Hyden West	51002020302
DB1600-0.7	1	Redbird	1533	Sugar Creek	Hyden West	51002020302
DB1600-0.8	2	Redbird	1533	Sugar Creek	Hyden West	51002020302
DB1600-0.9	0	Redbird	1533	Sugar Creek	Hyden West	51002020302
DB1600-1.5	1	Redbird	1533	Sugar Creek	Hyden West	51002020302
DB195-1.1	1	London	1956	Hogbed Branch	Bernstadt	51002020503
DB4094-1.44	3	London	1956	Hawk Creek	Bernstadt	51002020503
DB4094-1.5	1	London	1956	Hawk Creek	Bernstadt	51002020503
DB1530-0.6	1	Redbird	66	Bowen Creek	Creekville	51002030203
DB1530-2.4	1	Redbird	66	Bowen Creek	Creekville	51002030203
DB1500-0.3	2	Redbird	66	Little Double Creek	Creekville	51002030205
DB1500-0.6	0	Redbird	66	Little Double Creek	Creekville	51002030205
DB1500-0.9	0	Redbird	66	Little Double Creek	Creekville	51002030205
DB1500-1.1	0	Redbird	66	Little Double Creek	Creekville	51002030205
DB1500-1.3	0	Redbird	66	Little Double Creek	Creekville	51002030205
DB1500-1.4	0	Redbird	66	Little Double Creek	Creekville	51002030205
DB1500-1.7	0	Redbird	66	Little Double Creek	Creekville	51002030205
DB1501-2.5	4	Redbird	66	Big Double Creek	Creekville	51002030205
DB1501-3.8	0	Redbird	66	Big Double Creek	Creekville	51002030205
DB1501-4.1	0	Redbird	66	Big Double Creek	Creekville	51002030205
DB1501-4.3	0	Redbird	66	L. Fork Big Double Creek	Creekville	51002030205
DB1533-4.6	0	Redbird	66	Gilberts Big Creek	Hoskinston	51002030205
DB1533-4.7	0	Redbird	66	Gilberts Big Creek	Creekville	51002030205
DB1583-3.3	2	Redbird	421	Ulysses Creek	Creekville	51002030205
DB1600-1.8	0	Redbird	1533	Sugar Creek	Hoskinston	51002030205
DB1600-2.3	2	Redbird	1533	Sugar Creek	Creekville	51002030205
DB1600-2.6	1	Redbird	1533	Sugar Creek	Creekville	51002030205
DB1600-5	0	Redbird	66	Gilberts Big Creek	Creekville	51002030205
DB1600-5.6	1	Redbird	1533	Sugar Creek	Big Creek	51002030205
DB1703-0.1	0	Redbird	1501	R. Fork Big Double Creek	Creekville	51002030205
DB1703-0.2	0	Redbird	1501	R. Fork Big Double Creek	Creekville	51002030205

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Table B3 (*continued*). Location of crossings surveyed on the Daniel Boone National Forest during the summer of 2007. Site ID consists of the Forest abbreviation (DB), road the crossing is on (1533) and the distance (miles) from the junction road (0.6).

Site ID	# of Pipes	District	Junction Road	Stream Name	Quad	6th Level Watershed
DB1711-0.1	1	Redbird	1533	Gilberts Big Creek	Hoskinston	51002030205
DB1711-0.5	1	Redbird	1533	Gilberts Big Creek	Hoskinston	51002030205
DB1583-3.4	2	Redbird	421	Ulysses Creek	Big Creek	51002030206
DB1600-0.05	2	Redbird	1533	Sugar Creek	Hoskinston	51002030206
DB1604-1.4	1	Redbird	421	Grannys Branch	Big Creek	51002030207
DB1604-2.3	2	Redbird	421	Grannys Branch	Big Creek	51002030207
DB1651-0.3	1	Redbird	1656	Rockhouse Branch	Mistletoe	51002030404
DB195-3.2	1	London	88	S.F. Dog Slaughter Creek	Cumberland Falls	51002040207
DB2022-6.5	2	Redbird	484	Enoch Fork	Mistletoe	51002040207
DB448-0.1	1	London	290	War Fork	McKee	51002040207
DB482-0.01	7	London	345	Elsam Fork	McKee	51002040207
DB487-1.9	0	London	1955	Dry Fork	Johnetta	51002040207
DB131-0.3	1	London	1193	N. F. Dog Slaughter Creek	Sawyer	51301011309
DB132-0.8	1	London	1193	N. F. Dog Slaughter Creek	Sawyer	51301011404
DB3109-.8	4	London	4	Hughes Fork	McKee	51301011404
DB4-0.6	1	London	345	Hughes Fork	McKee	51301011404
DB43-0.3	2	London	89	Whetstone Branch	Sandgap	51301020204
DB43-0.6	2	London	89	Whetstone Branch	Sandgap	51301020204
DB437-0.6	1	London	20	Raccoon Creek	Sandgap	51301020207
DB437-2.5	0	London	20	Raccoon Creek	Sandgap	51301020207
DB437-2.9	0	London	437	Horse Lick Creek	Parrot	51301020207
DB437-2.91	0	London	437	Horse Lick Creek	Parrot	51301020207
DB455-0.1	0	London	437	Dry Fork	Livingston	51301020207
DB487-0.2	0	London	437	Dry Fork	Livingston	51301020207
DB487-1.8	0	London	455	Dry Fork	Johnetta	51301020207
DB487-3.3	1	London	455	Raccoon Creek	Livingston	51301020207
DB119b-0.8	3	London	119	Lick Branch	Ano	51301020507
DB615-0.8	1	London	131	Unnamed Tributary of Ned Branch	Sawyer	51301020509

Table B4. Coarse filter A, B, and C, classifications for crossings surveyed on the Daniel Boone National Forest, summer 2007. At sites with multiple pipes, data are grouped by Site ID and given the most favorable passage rating for each filter to determine passage status.

Site ID	Filter A	Filter B	Filter C
DB119b-0.8	passable	indeterminate	indeterminate
DB131-0.3	indeterminate	impassable	impassable
DB132-0.8	indeterminate	impassable	impassable
DB1500-0.3	passable	indeterminate	indeterminate
DB1500-0.6	passable	indeterminate	impassable
DB1500-0.9	passable	impassable	impassable
DB1500-1.1	passable	indeterminate	indeterminate
DB1500-1.3	passable	impassable	impassable
DB1500-1.4	indeterminate	impassable	impassable
DB1500-1.7	passable	indeterminate	impassable
DB1501-2.5	indeterminate	indeterminate	impassable
DB1501-3.8	passable	impassable	impassable
DB1501-4.1	passable	passable	impassable
DB1501-4.3	passable	impassable	impassable
DB1530-0.6	passable	indeterminate	indeterminate
DB1530-2.4	passable	impassable	impassable
DB1533-4.6	indeterminate	impassable	impassable
DB1533-4.7	passable	indeterminate	impassable
DB1583-3.3	indeterminate	indeterminate	indeterminate
DB1583-3.4	indeterminate	impassable	impassable
DB1600-0.05	indeterminate	impassable	impassable
DB1600-0.6	indeterminate	indeterminate	indeterminate
DB1600-0.7	indeterminate	impassable	impassable
DB1600-0.8	indeterminate	indeterminate	indeterminate
DB1600-0.9	passable	indeterminate	impassable
DB1600-1.5	indeterminate	impassable	impassable
DB1600-1.8	passable	passable	impassable
DB1600-2.3	impassable	impassable	impassable
DB1600-2.6	impassable	impassable	impassable
DB1600-5	passable	impassable	impassable
DB1600-5.6	indeterminate	impassable	impassable
DB1604-1.4	passable	passable	impassable
DB1604-2.3	indeterminate	indeterminate	impassable
DB1651-0.3	indeterminate	impassable	impassable
DB1703-0.1	indeterminate	indeterminate	impassable
DB1703-0.2	passable	indeterminate	impassable
DB1711-0.1	passable	passable	passable
DB1711-0.5	passable	passable	impassable
DB195-1.1	indeterminate	impassable	impassable
DB195-3.2	indeterminate	indeterminate	indeterminate
DB2022-6.5	indeterminate	impassable	impassable
DB3109-.8	passable	passable	indeterminate
DB4-0.6	indeterminate	indeterminate	impassable
DB4094-1.44	passable	passable	passable
DB4094-1.5	indeterminate	impassable	impassable
DB43-0.3	impassable	impassable	impassable

Table continued on next page…

Table B4 (*continued*). Coarse filter A, B, and C, classifications for crossings surveyed on the Daniel Boone National Forest, summer 2007. At sites with multiple pipes, data are grouped by Site ID and given the most favorable passage rating for each filter to determine passage status.

Site ID	Filter A	Filter B	Filter C
DB43-0.6	indeterminate	impassable	impassable
DB437-0.6	indeterminate	impassable	impassable
DB437-2.5	passable	passable	passable
DB437-2.9	indeterminate	impassable	impassable
DB437-2.91	passable	passable	passable
DB448-0.1	indeterminate	impassable	impassable
DB455-0.1	passable	indeterminate	impassable
DB482-0.01	passable	impassable	impassable
DB487-0.2	impassable	impassable	impassable
DB487-1.8	impassable	impassable	impassable
DB487-1.9	passable	impassable	impassable
DB487-3.3	impassable	impassable	impassable
DB615-0.8	indeterminate	indeterminate	impassable

Table B5. Description of crossings surveyed on Daniel Boone National Forest, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site Id	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
DB119b-0.8	1	C	fair	23.40	N	1.98	0.19	1.32	-3.84	0	36.30	72.00
DB119b-0.8	2	C	fair	23.40	N	0.88	0.19	2.22	-2.58	0	35.10	31.00
DB119b-0.8	3	C	fair	23.40	N	0.99	0.19	1.68	-3.30	0	33.90	33.50
DB131-0.3	1	C	good	12.60	N	3.66	0.28	11.28	15.84	0	77.10	282.00
DB132-0.8	1	C	fair	16.60	N	2.12	0.29	12.96	12.36	0	60.00	127.00
DB1500-0.3	1	C	good	19.30	N	1.43	0.21	3.30	1.38	0	21.00	30.00
DB1500-0.3	2	C	good	19.30	N	2.43	0.21	2.40	1.14	0	21.00	51.00
DB1500-0.6	0	F	good	15.50	N	2.12	0.26	8.16	15.12	0	20.00	42.50
DB1500-0.9	0	F	good	11.50	N	3.92	0.00	NA	10.80	0	12.00	47.00
DB1500-1.1	0	F	good	16.00	N	2.19	0.00	3.18	1.98	0	13.00	28.50
DB1500-1.3	0	F	good	13.60	N	2.93	0.00	23.76	6.36	0	14.00	41.00
DB1500-1.4	0	F	good	14.80	N	6.12	0.00	NA	8.34	0	13.00	79.50
DB1500-1.7	0	F	good	11.60	N	2.42	0.00	NA	4.68	0	12.40	30.00
DB1501-2.5	1	VF	good	25.30	N	2.96	0.14	5.76	4.68	0	34.50	102.00
DB1501-2.5	2	VF	good	25.30	N	2.87	0.14	5.76	4.68	0	34.50	99.00
DB1501-2.5	3	VF	good	25.30	N	3.07	0.14	5.40	4.32	0	34.50	106.00
DB1501-2.5	4	VF	good	25.30	N	2.96	0.14	5.40	4.32	0	34.50	102.00
DB1501-3.8	0	F	good	20.70	N	0.04	0.00	11.46	20.10	0	12.00	0.50
DB1501-4.1	0	F	good	17.60	N	0.14	0.00	NA	2.46	0	20.00	16.00
DB1501-4.3	0	F	good	16.70	N	1.48	0.00	22.44	13.80	0	33.00	49.00
DB1530-0.6	1	C	poor	22.00	N	2.71	0.00	NA	1.68	0	14.00	38.00

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Table B5 (*continued*). Description of crossings surveyed on Daniel Boone National Forest, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site Id	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
DB1530-2.4	1	PA	poor	13.00	N	2.04	0.37	4.50	8.10	0	20.30	41.50
DB1533-4.6	0	F	good	13.50	N	2.22	0.44	NA	1.92	0	34.40	76.50
DB1533-4.7	0	F	good	25.70	N	0.86	0.00	15.96	12.66	0	21.50	18.50
DB1583-3.3	1	C	good	13.50	N	2.22	0.44	NA	1.92	0	34.40	76.50
DB1583-3.3	2	C	good	13.50	N	3.20	0.44	-1.44	-2.52	0	34.40	110.00
DB1583-3.4	1	C	good	14.30	N	3.51	0.28	5.10	3.72	0	45.00	158.00
DB1583-3.4	2	C	good	14.30	N	2.78	0.25	10.14	8.04	0	45.00	125.00
DB1600-0.05	1	C	good	13.40	N	3.92	0.45	NA	4.86	0	43.90	172.00
DB1600-0.05	2	C	good	13.40	N	4.55	0.45	NA	3.60	0	44.30	201.50
DB1600-0.6	1	C	good	7.20	N	2.55	0.55	3.60	1.56	0	30.20	77.00
DB1600-0.6	2	C	good	6.70	N	2.61	0.60	3.24	2.88	0	30.90	80.50
DB1600-0.7	1	C	good	5.20	N	4.72	0.00	9.60	8.82	0	31.80	150.00
DB1600-0.8	1	C	good	13.40	N	1.23	0.37	NA	-3.60	0	44.80	55.00
DB1600-0.8	2	C	good	13.40	N	1.34	0.37	-3.54	-3.12	0	44.30	59.50
DB1600-0.9	0	F	fair	10.30	N	2.17	0.00	5.28	5.76	0	14.30	31.00
DB1600-1.5	1	C	good	12.30	N	4.64	0.16	4.62	10.98	0	19.50	90.50
DB1600-1.8	0	F	fair	10.40	N	0.87	2.16	4.92	7.32	0	14.40	12.50
DB1600-2.3	1	C	fair	17.30	N	7.66	0.29	8.94	8.28	0	46.50	356.00
DB1600-2.3	2	C	fair	17.30	N	7.52	0.29	14.52	6.72	0	47.80	359.50
DB1600-2.6	1	PA	good	19.20	N	1.70	0.63	24.72	20.58	0	67.70	115.00
DB1600-5	0	F	fair	10.80	N	1.22	0.00	12.96	12.96	0	18.00	22.00

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Table B5 (*continued*). Description of crossings surveyed on Daniel Boone National Forest, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site Id	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
DB1600-5.6	1	C	good	6.60	N	5.75	0.38	11.10	10.62	0	58.80	338.00
DB1604-1.4	1	C	good	18.60	N	1.06	0.38	9.24	6.60	0	21.70	23.00
DB1604-2.3	1	C	good	14.30	N	2.38	0.18	5.28	4.56	0	42.00	100.00
DB1604-2.3	2	C	good	14.30	N	4.24	0.18	-0.72	-1.80	0	42.00	178.00
DB1651-0.3	1	C	good	9.70	N	4.53	0.40	5.34	0.30	0	20.00	90.50
DB1703-0.1	0	F	good	17.40	N	5.53	0.00	14.82	14.46	0	16.00	88.50
DB1703-0.2	0	F	good	10.00	N	2.50	0.00	8.64	10.98	0	15.00	37.50
DB1711-0.1	1	C	good	12.20	Y	4.04	0.25	NA	-10.32	0	23.00	93.00
DB1711-0.5	1	C	good	14.50	N	0.16	0.17	9.96	21.12	0	24.80	4.00
DB195-1.1	1	PA	good	23.10	N	0.99	0.58	19.44	13.80	0	77.00	76.00
DB195-3.2	1	PA	good	24.30	N	1.17	0.45	3.36	2.40	0	68.50	80.00
DB2022-6.5	1	C	fair	23.30	N	3.03	0.26	11.88	10.08	0	33.00	100.00
DB2022-6.5	2	C	fair	23.30	N	4.13	0.25	5.82	4.98	0	32.70	135.00
DB3109-.8	1	VF	fair	39.20	N	0.96	0.05	2.64	1.32	0	24.00	23.00
DB3109-.8	2	VF	fair	39.20	N	1.21	0.05	1.92	0.60	0	24.00	29.00
DB3109-.8	3	VF	fair	39.20	N	1.08	0.05	2.28	0.96	0	24.00	26.00
DB3109-.8	4	VF	fair	39.20	N	1.04	0.05	2.40	1.08	0	24.00	25.00
DB4-0.6	1	PA	poor	21.80	N	1.05	0.64	4.80	2.28	0	56.00	59.00
DB4094-1.44	1	C	good	19.30	N	4.75	0.08	1.92	0.96	4.92	12.00	57.00
DB4094-1.44	2	C	good	19.30	N	0.59	0.08	NA	NA	0	69.00	41.00
DB4094-1.44	3	C	good	19.30	N	0.28	0.08	NA	NA	0	69.00	19.00

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Table B5 (*continued*). Description of crossings surveyed on Daniel Boone National Forest, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site Id	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
DB4094-1.5	1	C	good	17.80	N	2.57	0.22	10.32	8.76	0	30.00	77.00
DB43-0.3	1	C	fair	11.50	N	9.79	0.22	NA	15.90	0	43.10	422.00
DB43-0.3	2	C	fair	11.50	N	8.10	0.22	NA	8.40	0	41.00	332.00
DB43-0.6	1	C	good	7.40	N	4.49	0.27	18.90	14.52	0	44.40	199.50
DB43-0.6	2	C	good	7.40	N	3.85	0.27	22.74	18.60	0	44.40	171.00
DB437-0.6	1	C	fair	11.20	N	5.62	0.45	6.48	5.46	0	28.90	162.50
DB437-2.5	0	F	good	26.70	N	0.93	0.00	-2.52	-2.82	4.08	14.00	13.00
DB437-2.9	0	F	good	12.30	N	6.10	0.00	9.18	8.22	0	15.90	97.00
DB437-2.91	0	F	good	46.30	N	0.59	0.00	2.40	-2.28	0	16.90	10.00
DB448-0.1	1	C	fair	18.00	N	4.12	0.22	17.10	24.66	0	36.80	151.50
DB455-0.1	0	F	good	25.00	N	2.69	0.00	9.18	9.60	0	15.03	40.50
DB482-0.01	1	VF	good	54.40	N	2.40	0.05	13.32	10.92	0	30.80	74.00
DB482-0.01	2	VF	good	54.40	N	2.00	0.05	12.90	10.50	0	30.80	61.50
DB482-0.01	3	VF	good	54.40	N	1.80	0.05	12.96	10.56	0	30.80	55.50
DB482-0.01	4	VF	good	54.40	N	1.62	0.05	13.08	10.68	0	30.80	50.00
DB482-0.01	5	VF	good	54.40	N	1.85	0.05	12.72	10.32	0	30.80	57.00
DB482-0.01	6	VF	good	54.40	N	1.87	0.05	12.48	10.08	0	30.80	57.50
DB482-0.01	7	VF	good	54.40	N	1.66	0.05	13.20	10.80	0	30.80	51.00
DB487-0.2	0	F	good	6.70	N	0.63	0.00	NA	16.26	0	16.60	10.50
DB487-1.8	0	F	good	30.80	N	0.58	0.00	NA	NA	0	13.90	8.00
DB487-1.9	0	F	good	15.90	N	0.61	0.00	10.80	12.06	0	17.10	10.50

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Table B5 (*continued*). Description of crossings surveyed on Daniel Boone National Forest, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site Id	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
DB487-3.3	0	F	poor	6.10	N	7.75	0.65	3.42	2.64	0	20.20	156.50
DB615-0.8	1	C	good	12.30	N	2.62	0.20	7.68	7.02	0	26.00	68.00

Appendix C: Results for the Ozark-St. Francis National Forest

We completed surveys at 84 (9%) of 903 documented crossings on the Magazine and Sylamore Ranger Districts in 2007 (Figure C1, Tables C1 and C2). Filter A (strong swimmers and leapers) classified 13% (n=11) of crossings as impassable, 45% (n=38) as passable, and 42% (n=35) as indeterminate (Figure C2, Table C2). Filter B (moderate swimmers and leapers) classified 48% (n=41) of crossings as impassable, 22% (n=19) as passable, and 29% (n=24) as indeterminate (Figure C3, Table C2). Filter C (weak swimmers and leapers) classified 62% (n=53) of crossing as impassable, 17% (n=14) as passable, and 21% (n=17) as indeterminate (Figure C4, Table C2). Characteristics and filter classifications for each crossing are presented in Tables C3-C5.

The majority of the crossings surveyed were circular culverts (34%, n=29), and fords (29%, n=25), while box culverts (12%, n=10), vented fords (9%, n=7), pipe arches (14%, n=12), and open bottom arches (1%, n=1) were less frequently encountered. Filter A classified 14% of circular culverts, 8% of pipe arches, 16% of fords, 0% of vented fords and 20% of box culverts as impassable (Figure C3). Filter B classified 52% of circular culverts, 58% of pipe arches, 52% of fords, 50% of vented fords and 20% of box culverts as impassable (Figure C3). Filter C classified 62% of circular culverts, 58% of pipe arches, 76% of fords, 75% of vented fords and 30% of box culverts as impassable (Figure C3). The mean crossing width to channel width ratio (excluding fords, vented fords, and multiple structure crossings) was 0.50 ± 0.23 (mean ± SD) (n=32), and 1 crossing was greater than or equal to the bankfull channel width (Figure C4). The mean crossing width to channel width ratio for surveyed crossings classified impassable by Filter A was 0.40 ± 0.24 (n=5). The mean ratio for crossings classified impassable by Filter B was 0.47 ± 0.20 (n=16), and was 0.45 ± 0.20 (n=18) for Filter C (Figure C5). The mean crossing width to channel width ratio for surveyed crossings classified passable by Filter A was 0.55 ± 0.32 (n=10). The mean ratio for crossings classified passable by Filter B and Filter C was 0.51 ± 0.30 (n=4) (Figure C5).

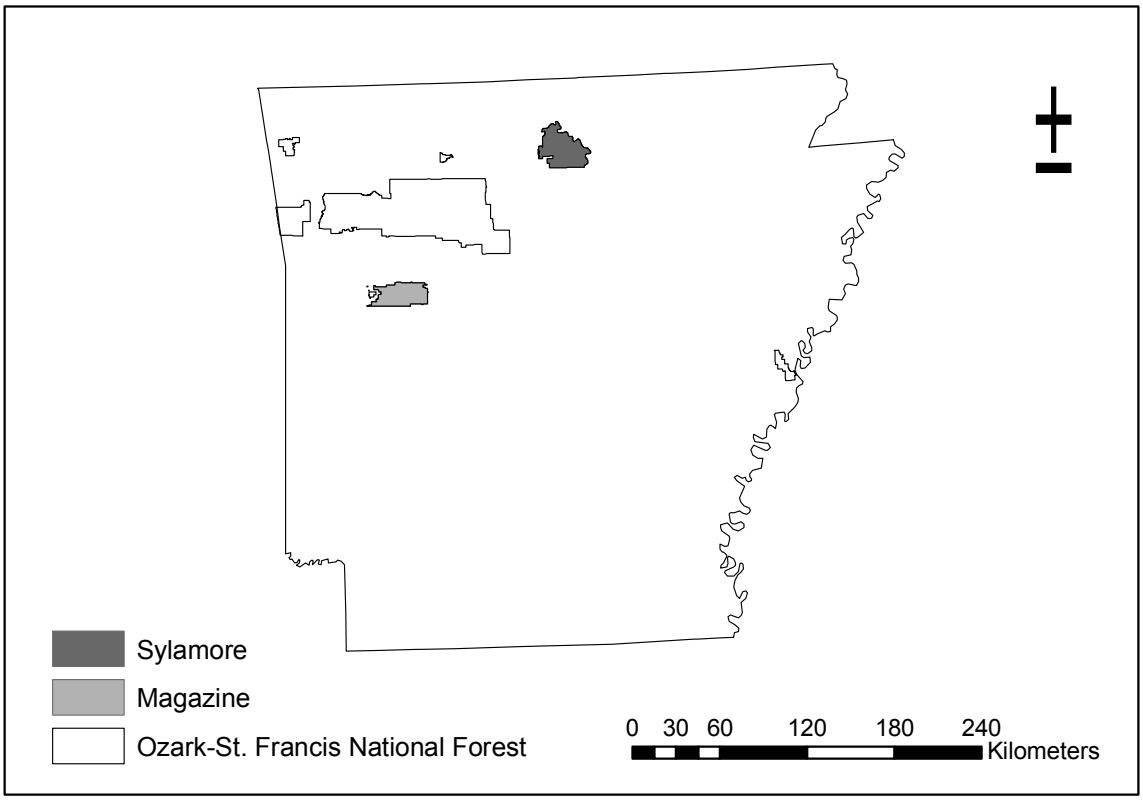

Figure C1. Ranger Districts on the Ozark-St. Francis National Forest where road-stream crossing surveys were conducted in 2007.

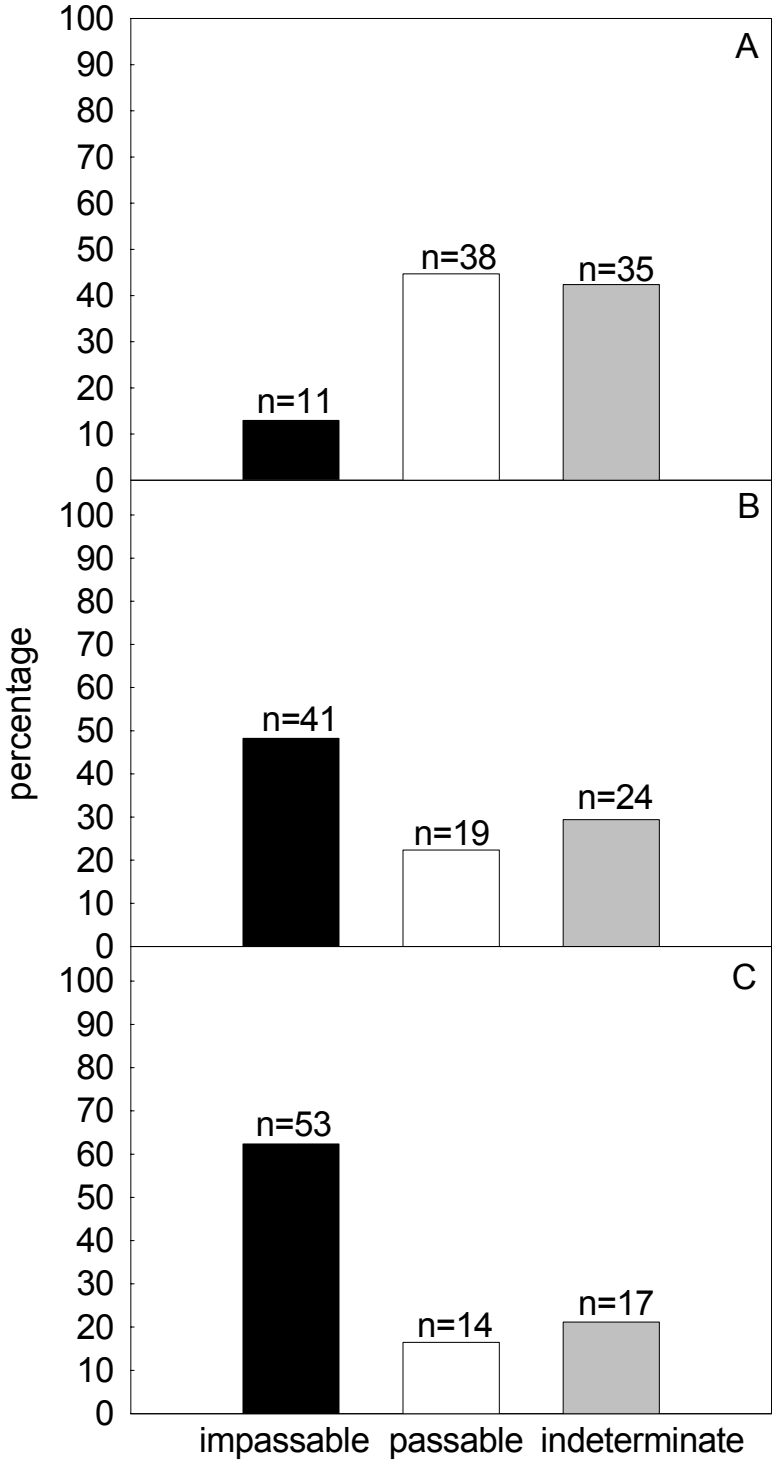

Figure C2. Percentage of crossings classified as impassable, passable, or indeterminate for Filters A, B, and C; Ozark-St. Francis National Forest, Arkansas, summer 2007 (N=84).

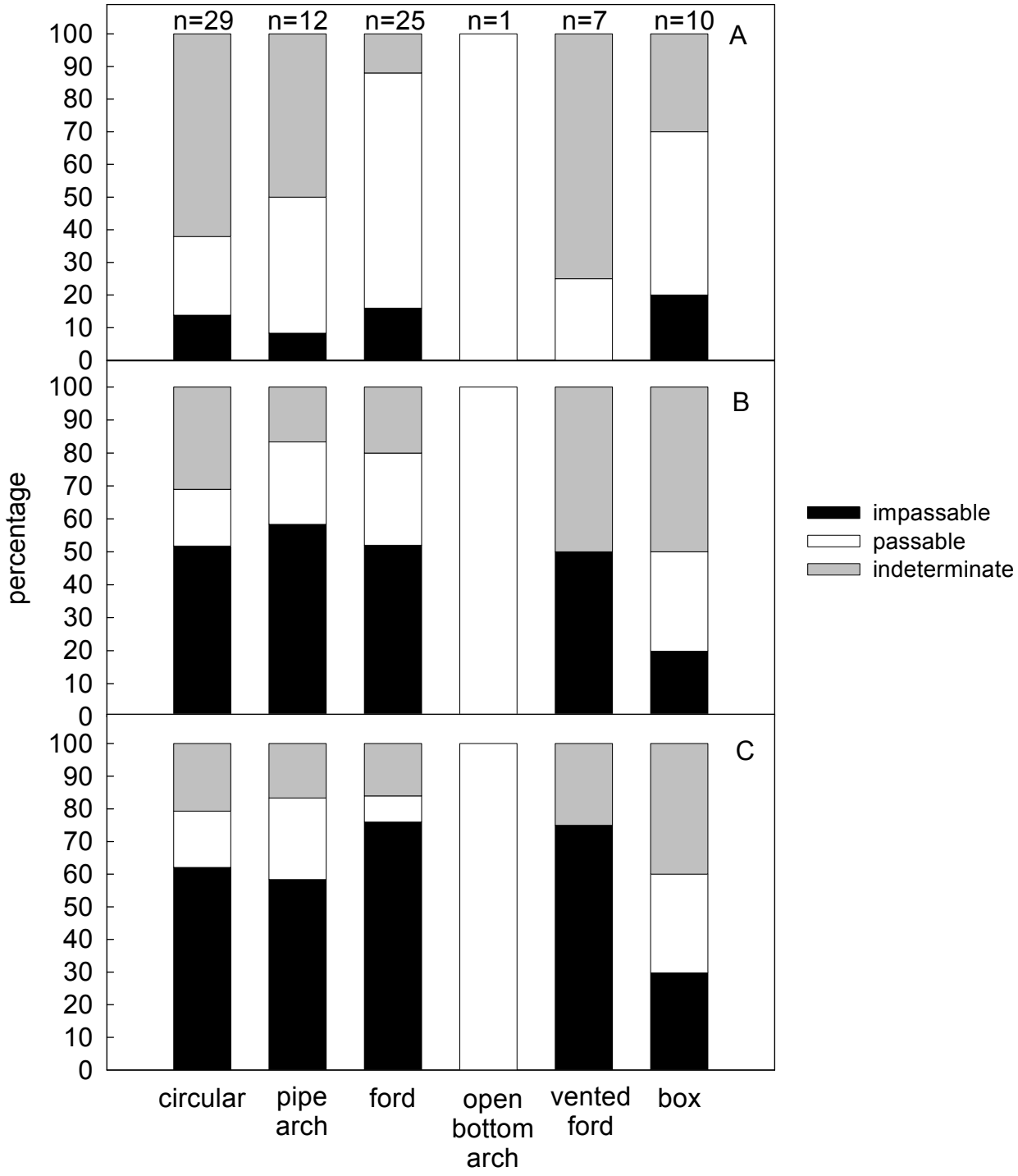

Figure C3. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter A, B, and C; Ozark-St. Francis National Forest, Arkansas, summer 2007 (N=84).

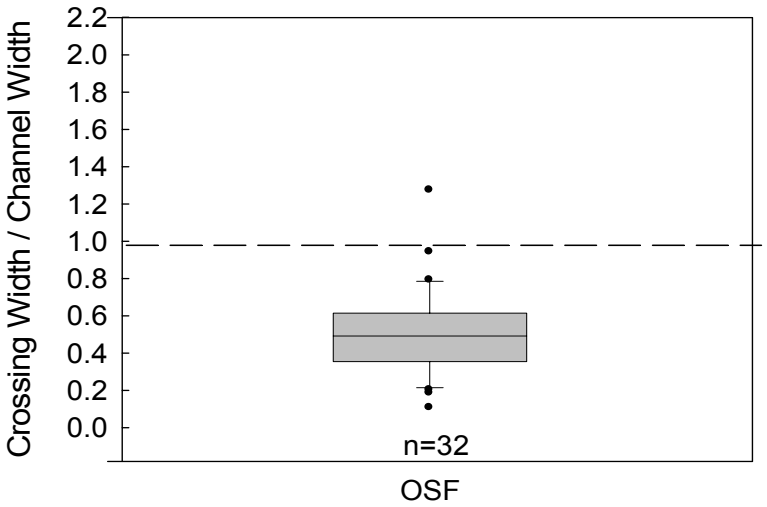

Figure C4. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2007 on the Ozark-St. Francis National Forest (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

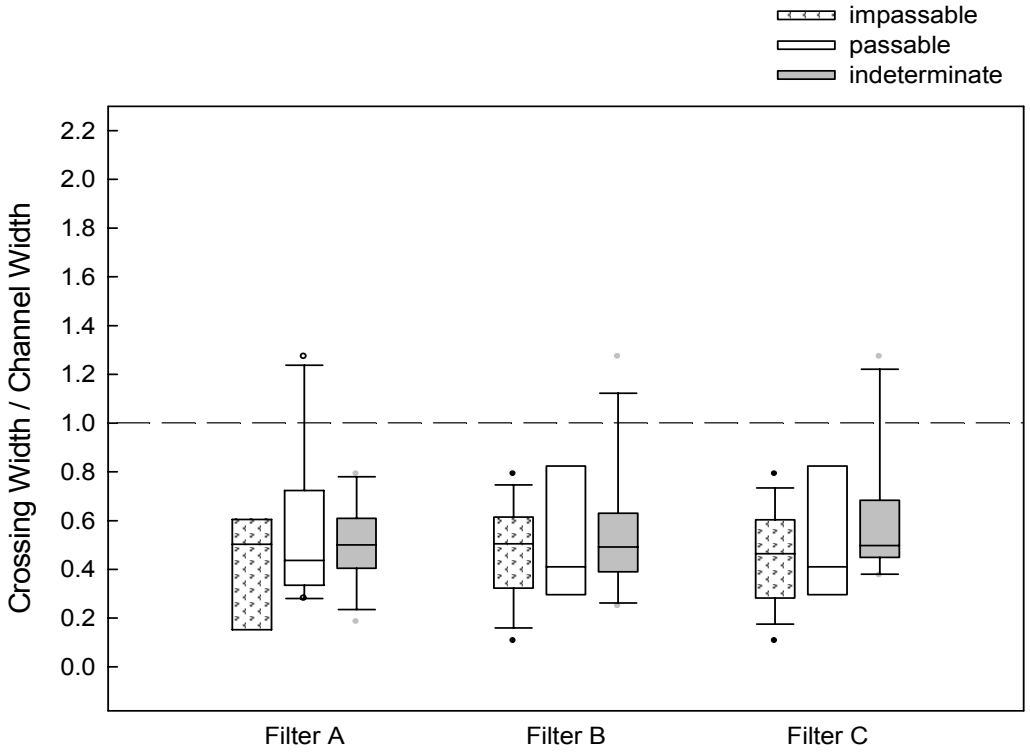

Figure C5. Crossing width to bankfull channel width ratio for crossings classified as impassable, passable, or indeterminate in summer 2007 on the Ozark-St. Francis National Forest (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The symbol inside each set of whiskers represents the median, and the top and bottom of the whiskers represent the maximum and minimum values.

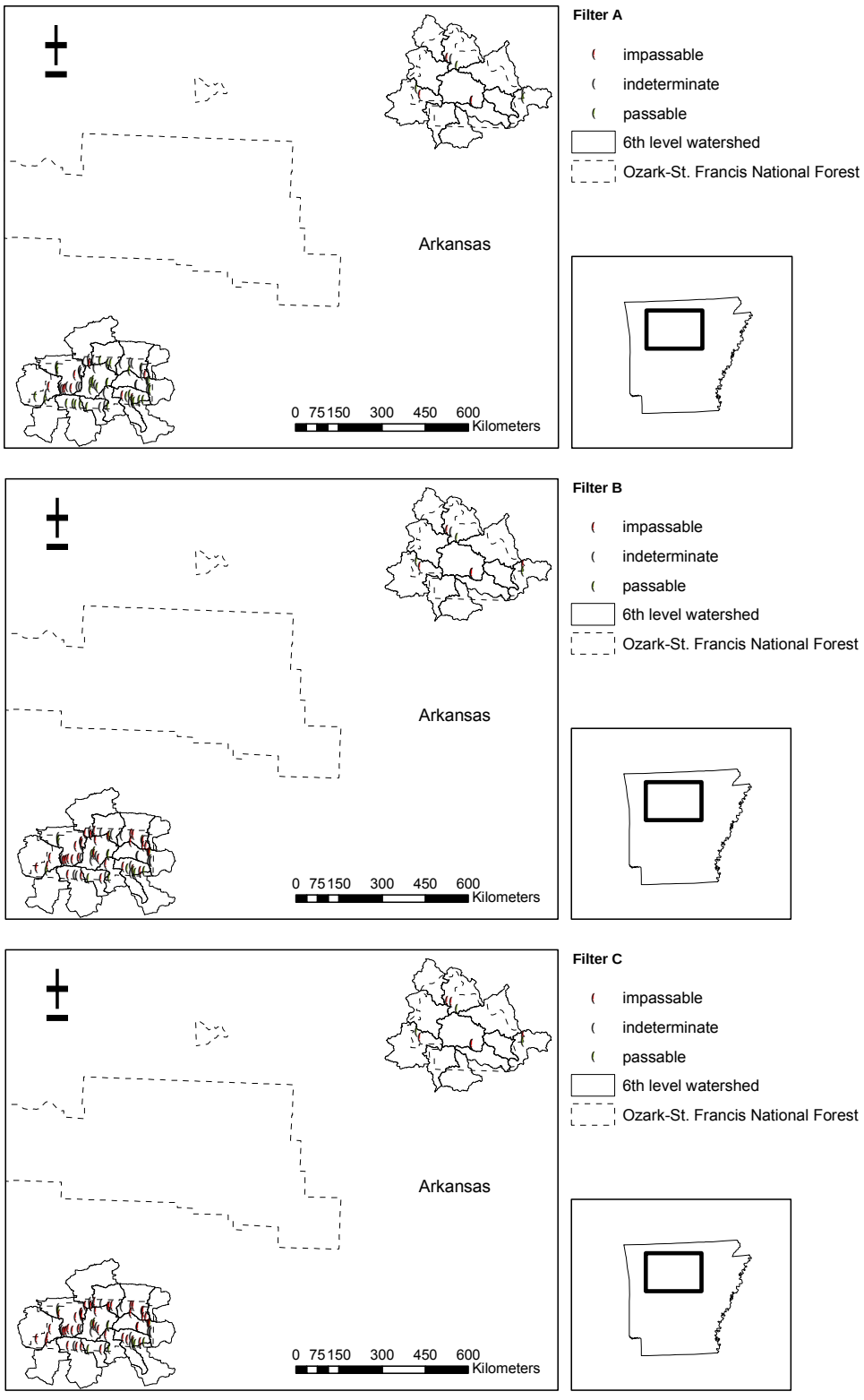

Figure C6. Location of crossings classified for fish passage by coarse filters A, B, and C within 6th level watersheds, on the Ozark-St. Francis National Forest, summer 2007.

Table C1. Number of crossings documented (Total crossing documented) and not surveyed (Crossings not surveyed) on the Ozark-St. Francis National Forest in summer 2007. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossings documented	Crossings not surveyed (n,[%])				
		NH	NA	NF	BR	Total not surveyed
OSF	903	106 (12)	357 (40)	322 (36)	34 (4)	819 (91)

Table C2. Number of crossings surveyed (Total surveyed) with coarse filter results for the Ozark-St. Francis National Forest in summer 2007. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse Filter Results								
		Impassable (n,[%])			Passable (n,[%])			Indeterminate (n,[%])		
		A	B	C	A	B	C	A	B	C
OSF	84	11 (13)	41 (48)	53 (62)	38 (45)	19 (22)	14 (16)	35 (42)	24 (29)	17 (21)

Table C3. Location of crossings surveyed on the Ozark-St. Francis National Forest during the summer of 2007. Unique site ID as assigned by the forest.

Site ID	# Pipes	District	Junction Road	Stream Name	Quad	6th level watershed
172	2	Sylamore	14	Twin Creek	Norfork	110100040103
183	3	Sylamore	14	Farris Creek	Norfork	110100040103
227	3	Sylamore	14	Sneeds Creek	Norfork	110100040103
346	2	Sylamore	72	Unnamed	Boswell	110100040301
394	1	Sylamore	72	Unnamed	Boswell	110100040301
410	2	Sylamore	14	Unnamed	Calico Rock	110100040402
411	1	Sylamore	14	North Sylamore Creek	Fiftysix	110100040402
325	1	Sylamore	14	Unnamed	Big Flat	110100050503
358	1	Sylamore	14	Unnamed	Big Flat	110100050503
1676.1	0	Magazine	309	Unnamed	Blue Mountain	111102020401
4146	2	Magazine	309	Unnamed	Blue Mountain	111102020401
4160	4	Magazine	309	Unnamed	Blue Mountain	111102020401
4172	2	Magazine	Rich Mtn Rd	Unnamed	Magazine Mountain NE	111102020401
4175	2	Magazine	Rich Mtn Rd	Unnamed	Magazine Mountain NE	111102020401
4184	0	Magazine	1676	Unnamed	Blue Mountain	111102020401
4187	2	Magazine	Rich Mtn Rd	Short Mountain Creek	Magazine Mountain NE	111102020401
4203	2	Magazine	Rich Mtn Rd	Short Mountain Creek	Magazine Mountain NE	111102020401
4218	1	Magazine	309	Unnamed	Blue Mountain	111102020401
4338	1	Magazine	1665	Unnamed	Magazine Mountain NE	111102020401
4344	2	Magazine	1665	Unnamed	Magazine Mountain NE	111102020401
4347	1	Magazine	309	Unnamed	Blue Mountain	111102020401
4353	1	Magazine	309	Gutter Rock Creek	Blue Mountain	111102020401
4358	0	Magazine	309	Unnamed	Blue Mountain	111102020401
4364	2	Magazine	309	Lick Creek	Blue Mountain	111102020401
4366	0	Magazine	309	Unnamed	Blue Mountain	111102020401
4367	1	Magazine	309	Short Mountain Creek	Blue Mountain	111102020401
4084	1	Magazine	55	Unnamed	Scranton	111102020701
4110	1	Magazine	1687	Unnamed	Scranton	111102020701
4158	2	Magazine	1615	Unnamed	Magazine Mountain NE	111102021001
4260	2	Magazine	1617	Unnamed	Magazine Mountain NE	111102021001
4292	4	Magazine	1601	Unnamed	Magazine Mountain NE	111102021001

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Table C3 (*continued*). Location of crossings surveyed on the Ozark-St. Francis National Forest during the summer of 2007. Unique site ID as assigned by the forest.

Site ID	# Pipes	District	Junction Road	Stream Name	Quad	6th level watershed
4299	0	Magazine	1601	Unnamed	Magazine Mountain NE	111102021001
4300	0	Magazine	1627	Lee Creek	Magazine Mountain NE	111102021001
4308	2	Magazine	1601	Unnamed	Magazine Mountain NE	111102021001
4327	2	Magazine	1627	Unnamed	Magazine Mountain NE	111102021001
4350	1	Magazine	309	Unnamed	Magazine Mountain NE	111102021001
4088	2	Magazine	55	Unnamed	Scranton	111102021002
4092	1	Magazine	1687	Unnamed	Scranton	111102021002
4094	0	Magazine	1687	Unnamed	Scranton	111102021002
4115	1	Magazine	54	Unnamed	Magazine Mountain NE	111102021002
4130	0	Magazine	54	Unnamed	Scranton	111102021002
4135	0	Magazine	54	Unnamed	Magazine Mountain NE	111102021002
4218.1	1	Magazine	1687	Unnamed	Scranton	111102021002
4218.2	1	Magazine	1687	Unnamed	Scranton	111102021002
4109	1	Magazine	56	Unnamed	Magazine Mountain NE	111102021003
4120	1	Magazine	56	Unnamed	New Blaine	111102021003
4127	3	Magazine	123	Little Bigger Creek	New Blaine	111102021003
4156	0	Magazine	58	Unnamed	Chickalah Mountain West	111102021003
4161	0	Magazine	58	Little Shoal Creek	Chickalah Mountain West	111102021003
4170	0	Magazine	58	Unnamed	Chickalah Mountain West	111102021003
4211	1	Magazine	58	Little Shoal Creek	Chickalah Mountain West	111102021003
4214	1	Magazine	58	Unnamed	Chickalah Mountain West	111102021003
4341	2	Magazine	720	North Wicked Creek	Blue Mountain	111102040207
4403	1	Magazine	720	Unnamed	Blue Mountain	111102040207
4433	0	Magazine	109	Briar Creek	Magazine	111102040207
4455	0	Magazine	724	Briar Creek	Blue Mountain	111102040207
4482	0	Magazine	503	West Bass Creek	Blue Mountain	111102040302
4484	0	Magazine	503	Unnamed	Blue Mountain	111102040302
4488	0	Magazine	530	Unnamed	Blue Mountain	111102040302
4492	0	Magazine	503	Big Piney Creek	Magazine Mountain NE	111102040302
4495	0	Magazine	503	Clear Creek	Magazine Mountain NE	111102040302
4494	1	Magazine	532	Unnamed	Magazine Mountain NE	111102040303

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Table C3 (*continued*). . Location of crossings surveyed on the Ozark-St. Francis National Forest during the summer of 2007. Unique site ID as assigned by the forest.

Site ID	# Pipes	District	Junction Road	Stream Name	Quad	6th level watershed
4505.1	2	Magazine	22	Truett Creek	Magazine Mountain NE	111102040303
4507	1	Magazine	309	Little Piney Creek	Magazine Mountain NE	111102040303
4510	2	Magazine	309	Unnamed	Magazine Mountain NE	111102040303
9001	1	Magazine	309	Unnamed	Magazine Mountain NE	111102040303
4397	2	Magazine	1607	Unnamed	Magazine Mountain NE	111102040304
4407	1	Magazine	36	Spring Creek	Chickalah Mountain West	111102040401
4426	0	Magazine	35	Unnamed	Chickalah Mountain West	111102040401
4438	0	Magazine	25	Unnamed	Chickalah Mountain West	111102040401
4447	1	Magazine	438	Spring Creek	Chickalah Mountain West	111102040401
4457	0	Magazine	CR-36	Spring Creek	Chickalah Mountain West	111102040401
4458	2	Magazine	307	Spring Creek	Chickalah Mountain West	111102040401
4460	0	Magazine	1639	Spring Creek	Chickalah Mountain West	111102040401
4467	1	Magazine	307	Spring Creek	Chickalah Mountain West	111102040401
4471	2	Magazine	36	Spring Creek	Chickalah Mountain West	111102040401
4272	1	Magazine	1623	Long Branch	Chickalah Mountain East	111102040403
4274	0	Magazine	1611	Long Branch	Chickalah Mountain East	111102040403
4276	1	Magazine	1623	Long Branch	Chickalah Mountain East	111102040403
4324	1	Magazine	39	Unnamed	Chickalah Mountain West	111102040403
4325	3	Magazine	123	Long Branch	Chickalah Mountain West	111102040403
4356	1	Magazine	1641	Unnamed	Chickalah Mountain East	111102040403
4380	1	Magazine	Slo Fork	Jordan Branch	Chickalah Mountain East	111102040403
4382	1	Magazine	1641	Unnamed	Chickalah Mountain East	111102040403

Table C4. Coarse filters A, B, and C, classifications for surveyed crossings on the Ozark-St. Francis National Forest, summer 2007. At sites with multiple pipes, data are grouped by site ID and given the most favorable passage rating for each filter to determine passage status.

Site ID	Filter A	Filter B	Filter C
172	impassable	impassable	impassable
183	indeterminate	indeterminate	impassable
227	passable	passable	passable
325	passable	passable	passable
346	indeterminate	impassable	impassable
358	impassable	impassable	impassable
394	passable	passable	passable
410	indeterminate	impassable	impassable
411	impassable	impassable	impassable
4084	indeterminate	indeterminate	indeterminate
4088	indeterminate	impassable	impassable
4092	indeterminate	indeterminate	indeterminate
4094	passable	indeterminate	indeterminate
4109	indeterminate	impassable	impassable
4110	indeterminate	impassable	impassable
4115	passable	indeterminate	impassable
4120	indeterminate	impassable	impassable
4127	indeterminate	indeterminate	indeterminate
4130	passable	passable	impassable
4135	indeterminate	impassable	impassable
4146	indeterminate	indeterminate	indeterminate
4156	passable	passable	impassable
4158	indeterminate	impassable	impassable
4160	passable	indeterminate	indeterminate
4161	indeterminate	impassable	impassable
4170	passable	impassable	impassable
4172	indeterminate	impassable	impassable
4175	indeterminate	impassable	impassable
4184	passable	indeterminate	impassable
4187	indeterminate	impassable	impassable
4203	indeterminate	indeterminate	impassable
4211	impassable	impassable	impassable
4214	indeterminate	impassable	impassable
4218	impassable	impassable	impassable
4218.1	indeterminate	impassable	impassable
4218.2	impassable	impassable	impassable
4260	passable	passable	passable
4272	passable	passable	passable
4274	passable	impassable	impassable
4276	indeterminate	impassable	impassable
4292	passable	passable	passable
4299	passable	passable	indeterminate
4300	passable	impassable	impassable
4308	passable	passable	passable
4324	indeterminate	indeterminate	impassable
4325	indeterminate	indeterminate	impassable

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Table C4 (*continued*). Coarse filters A, B, and C, classifications for surveyed crossings on the Ozark-St. Francis National Forest, summer 2007. At sites with multiple pipes, data are grouped by site ID and given the most favorable passage rating for each filter to determine passage status.

Site ID	Filter A	Filter B	Filter C
4327	indeterminate	indeterminate	indeterminate
4338	indeterminate	indeterminate	indeterminate
4341	indeterminate	impassable	impassable
4344	indeterminate	impassable	impassable
4347	indeterminate	impassable	impassable
4350	passable	impassable	impassable
4353	indeterminate	indeterminate	indeterminate
4356	passable	indeterminate	indeterminate
4358	impassable	impassable	impassable
4364	impassable	impassable	impassable
4366	impassable	impassable	impassable
4367	indeterminate	impassable	impassable
4380	indeterminate	indeterminate	indeterminate
4382	passable	indeterminate	indeterminate
4397	indeterminate	impassable	impassable
4403	indeterminate	impassable	impassable
4407	passable	indeterminate	indeterminate
4426	impassable	impassable	impassable
4433	passable	impassable	impassable
4438	passable	passable	impassable
4447	impassable	impassable	impassable
4455	passable	passable	impassable
4457	passable	passable	passable
4458	passable	passable	passable
4460	passable	impassable	impassable
4467	passable	passable	passable
4471	passable	passable	passable
4483	passable	indeterminate	impassable
4484	passable	indeterminate	indeterminate
4488	passable	impassable	impassable
4492	passable	indeterminate	impassable
4494	indeterminate	indeterminate	indeterminate
4495	passable	impassable	impassable
4505.1	passable	passable	passable
4507	indeterminate	impassable	impassable
4510	passable	passable	passable
9001	passable	indeterminate	indeterminate
1676-1.1	passable	passable	passable

Table C5. Description of crossings surveyed on the Ozark-St. Francis National Forest, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, V= vented ford, B= box, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, 0= discontinuous substrate, 1= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
172	1	B	good	9.63	N	1.13	0.62	74.88	70.92	0	60.20	68.00
172	2	B	good	9.63	N	1.12	0.62	74.52	70.56	0	60.30	67.50
183	1	B	good	17.12	N	1.66	0.38	9.42	19.14	0	44.40	73.50
183	2	B	good	17.12	N	1.66	0.38	9.42	19.14	0	44.40	73.50
183	3	B	good	17.12	N	1.66	0.38	9.42	19.14	0	44.40	73.50
227	1	B	good	16.45	Y	1.06	0.52	NA	-7.44	0	52.00	55.00
227	2	B	good	16.45	Y	1.06	0.52	NA	-10.92	0	52.00	55.00
227	3	B	good	16.45	Y	1.02	0.52	NA	-5.52	0	52.00	53.00
325	1	PA	fair	9.57	Y	10.51	0.94	-3.30	-3.54	0	22.50	236.50
346	1	PA	fair	13.75	N	5.06	0.45	NA	5.04	0	54.10	274.00
346	2	PA	fair	13.75	N	4.16	0.45	NA	11.04	0	54.10	225.00
358	1	C	good	28.60	N	6.02	0.10	NA	105.36	0	37.70	227.00
394	1	PA	good	10.37	N	0.68	0.47	NA	-0.96	0	19.80	13.50
410	1	C	fair	11.57	N	6.67	0.26	6.24	14.70	0	18.00	120.00
410	2	C	fair	11.57	N	4.06	0.26	6.24	15.42	0	18.00	73.00
411	0	F	fair	11.57	N	0.18	0.26	27.54	8.58	0	25.50	4.50
1676.1	0	F	good	25.82	N	2.18	0.00	5.46	5.22	0.96	24.50	53.50
4084	1	C	good	8.08	N	2.61	0.49	-3.72	2.76	0	39.50	103.00
4088	1	PA	fair	9.95	N	9.19	0.44	22.80	14.64	0	103.60	952.00
4088	2	PA	fair	9.95	N	2.22	0.44	22.08	19.86	0	28.80	64.00
4092	1	C	good	9.20	N	1.70	0.49	NA	1.38	0	40.30	68.50
4094	0	F	good	9.62	N	1.77	0.00	-1.26	-1.80	0	18.10	32.00
4109	1	C	good	15.88	N	4.11	0.53	17.64	17.64	0	42.10	173.00
4110	1	PA	good	6.73	N	5.71	0.73	7.98	7.14	0	35.40	202.00
4115	1	C	good	9.88	N	1.40	0.29	7.62	6.12	0	32.40	45.50

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Table C5 (*continued*). Description of crossings surveyed on the Ozark-St. Francis National Forest, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, V= vented ford, B= box, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, 0= discontinuous substrate, 1= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
4120	1	C	good	8.87	N	4.45	0.62	12.72	17.28	0	40.90	182.00
4127	1	VF	good	23.42	N	2.01	0.13	8.10	8.16	0	37.80	76.00
4127	2	VF	good	23.42	N	3.09	0.13	3.96	4.02	0	38.30	118.50
4127	3	VF	good	23.42	N	2.76	0.13	4.32	4.38	0	42.70	118.00
4130	0	F	good	20.28	N	0.30	0.59	6.30	5.04	0	13.20	4.00
4135	0	F	good	8.15	N	4.44	0.37	9.24	7.74	0	30.50	135.50
4146	1	C	fair	10.28	N	2.91	0.29	0.18	-1.92	0	30.20	88.00
4146	2	C	fair	10.28	N	5.54	0.29	-1.68	-2.76	0	30.40	168.50
4156	0	F	good	10.02	N	1.38	8.09	7.26	6.12	0	14.50	20.00
4158	1	C	good	9.02	N	1.27	0.51	11.88	9.12	0	57.70	73.00
4158	2	C	good	9.02	N	3.66	0.49	11.64	5.40	0	57.70	211.00
4160	1	VF	poor	32.48	N	1.62	0.05	0.18	-8.58	0	31.40	51.00
4160	2	VF	poor	32.48	N	1.15	0.05	0.12	-8.64	0	30.80	35.50
4160	3	VF	poor	32.48	N	1.15	0.05	0.12	-8.64	0	30.80	35.50
4160	4	VF	poor	32.48	N	1.33	0.05	0.18	-8.58	0	30.80	41.00
4161	0	F	fair	20.92	N	4.03	1.59	14.70	10.50	0	123.60	498.50
4170	0	F	good	11.28	N	0.95	1.21	14.94	13.68	0	18.50	17.50
4172	1	VF	good	7.78	N	2.36	0.26	11.58	10.50	0	27.70	65.50
4172	2	VF	good	7.78	N	2.27	0.26	11.16	10.08	0	27.70	63.00
4175	1	F	good	9.98	N	6.10	0.20	14.70	13.86	0	27.80	169.50
4175	2	VF	good	9.98	N	6.17	0.20	17.34	16.50	0	27.70	171.00
4184	0	VF	good	25.92	N	1.88	0.00	8.28	4.32	0	14.60	27.50
4187	1	VF	good	7.27	N	20.66	0.28	14.10	13.20	0	46.10	952.50
4187	2	VF	good	7.27	N	4.40	0.28	13.14	12.24	0	29.90	131.50
4203	1	VF	good	6.10	N	23.04	0.33	9.84	9.54	0	38.20	880.00

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Table C5 (*continued*). Description of crossings surveyed on the Ozark-St. Francis National Forest, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, V= vented ford, B= box, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, 0= discontinuous substrate, 1= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
4203	2	VF	good	6.10	N	3.29	0.33	8.76	8.46	0	27.70	91.00
4211	1	C	poor	6.87	N	9.90	2.02	-0.78	1.20	0	14.80	146.50
4214	1	C	good	9.70	N	3.87	0.60	8.22	7.08	0	36.40	141.00
4218	1	C	fair	9.95	N	4.57	0.50	25.92	34.32	0	49.10	224.50
4218.1	1	C	fair	8.87	N	2.23	0.51	NA	8.52	0	50.80	113.50
4218.2	1	C	fair	7.75	N	7.16	0.55	NA	8.58	0	38.60	276.50
4260	1	PA	good	15.87	N	0.55	0.52	-3.96	1.20	5.64	25.50	14.00
4260	2	PA	good	15.87	N	1.27	0.47	-6.42	-2.28	10.32	25.50	32.50
4272	1	C	good	6.45	N	1.59	0.28	-2.46	-4.02	6.3	20.10	32.00
4274	0	F	good	8.68	N	1.38	1.64	13.20	12.24	0	13.80	19.00
4276	1	C	fair	10.90	N	3.80	0.18	1.98	-10.68	0	21.20	80.50
4292	1	C	good	11.97	N	1.80	0.33	-7.20	-6.90	0.06	33.10	59.50
4292	2	C	good	11.97	N	1.83	0.33	-6.36	-6.54	0	33.10	60.50
4292	3	C	good	11.97	N	1.75	0.33	-6.36	-6.48	0	33.10	58.00
4292	4	C	good	11.97	N	0.63	0.33	-0.84	-0.06	0	33.10	21.00
4299	0	F	good	18.15	N	1.90	0.00	3.12	2.52	0	10.50	20.00
4300	0	F	good	16.47	N	0.04	0.00	10.56	11.10	0	13.30	0.50
4308	1	C	fair	18.53	N	0.54	0.17	-8.16	-23.16	1.62	100.59	54.50
4308	2	C	fair	18.53	N	1.75	0.16	-6.24	-20.82	0	32.60	57.00
4324	1	C	good	9.68	N	2.01	0.25	4.26	3.48	0	30.30	61.00
4325	1	C	fair	15.68	N	1.84	0.19	4.86	-1.98	0	32.10	59.00
4325	2	C	fair	15.68	N	1.67	0.19	6.72	0.48	0	32.10	53.50
4325	3	C	fair	15.68	N	1.88	0.19	6.30	0.18	0	32.10	60.50
4327	1	PA	good	13.57	N	1.54	0.35	NA	-0.60	0	74.80	115.00
4327	2	PA	good	13.57	N	1.32	0.35	NA	-1.02	0	73.30	97.00

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Table C5 (*continued*). Description of crossings surveyed on the Ozark-St. Francis National Forest, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, V= vented ford, B= box, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, 0= discontinuous substrate, 1= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
4338	1	B	good	14.15	N	2.10	0.57	3.54	-1.38	0	48.40	101.50
4341	1	VF	fair	11.87	N	2.52	0.25	17.94	20.76	0	29.60	74.50
4341	2	VF	fair	11.87	N	2.11	0.25	26.70	25.92	0	29.60	62.50
4344	1	C	good	8.88	N	3.08	0.34	17.10	19.08	0	48.60	149.50
4344	2	C	good	8.88	N	2.87	3.71	16.44	12.48	0	48.60	139.50
4347	1	PA	good	12.20	N	2.99	0.43	11.16	9.96	0	37.10	111.10
4350	1	PA	other	10.93	N	0.98	0.42	15.72	28.68	0	40.19	39.50
4353	1	C	good	6.38	N	3.22	0.44	-2.22	1.20	0	28.60	92.00
4356	1	C	good	8.28	N	0.80	0.65	0.18	-0.96	0	34.50	27.50
4358	0	F	good	25.08	N	1.41	0.00	24.84	28.80	0	16.30	23.00
4364	1	PA	poor	16.58	N	35.36	0.54	10.68	-0.36	0	39.90	1411.00
4364	2	PA	poor	16.58	N	33.13	0.54	1.98	0.12	0	40.90	1355.00
4366	0	F	poor	17.18	N	1.21	0.00	89.10	5.04	0	12.00	14.50
4367	1	C	good	10.45	N	7.00	0.38	15.60	11.88	0	48.30	338.00
4380	1	B	good	15.43	N	2.12	0.78	1.02	-1.20	0	44.00	93.50
4382	1	B	good	19.88	N	1.04	0.45	0.36	-2.40	0	48.30	50.00
4397	1	C	good	16.07	N	5.48	0.25	4.98	4.98	0	48.70	267.00
4397	2	C	good	16.07	N	5.77	0.25	22.56	11.94	0	47.50	274.00
4403	1	PA	good	13.18	N	3.74	0.30	15.36	13.32	0	32.10	120.00
4407	1	B	good	9.60	N	1.37	1.27	1.62	1.86	0	30.40	41.50
4426	0	F	good	16.05	N	1.65	5.92	28.20	42.48	0	12.40	20.50
4433	0	F	good	19.70	N	2.13	2.94	16.56	15.96	0	22.80	48.50
4438	0	F	good	16.15	N	1.62	5.14	8.46	11.94	0	14.80	24.00
4447	1	B	good	9.62	N	8.09	0.66	0.30	1.74	0	27.00	218.50
4455	0	F	good	22.28	N	0.77	0.00	5.34	10.92	0	13.00	10.00

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Table C5 (*continued*). Description of crossings surveyed on the Ozark-St. Francis National Forest, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, V= vented ford, B= box, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, 0= discontinuous substrate, 1= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
4457	0	F	other	8.12	N	1.03	0.00	NA	-0.54	0	14.60	15.00
4458	1	B	good	18.47	N	2.24	0.32	-7.02	-7.98	0.48	24.30	54.50
4458	2	B	good	18.47	N	0.84	0.32	-0.54	-2.10	0	24.30	20.50
4460	0	F	good	14.25	N	1.73	0.00	12.72	9.84	0	14.20	24.50
4467	1	B	good	18.08	N	1.92	0.35	-1.74	-1.68	8.58	29.70	57.00
4471	1	OBA	good	12.00	N	6.90	0.83	2.40	-1.32	0	21.80	150.50
4471	2	OBA	good	12.00	N	3.12	0.82	0.48	-0.36	0	21.80	68.00
4483	0	F	good	16.98	N	1.61	0.00	4.50	2.64	0	17.10	27.50
4484	0	F	good	64.20	N	2.06	0.00	NA	1.86	0	20.40	42.00
4488	0	F	good	16.05	N	1.30	0.00	19.98	0.12	0	14.60	19.00
4492	0	F	good	15.82	N	2.64	0.00	8.22	6.72	0	14.20	37.50
4494	1	C	good	9.98	N	3.01	0.50	-3.96	0.00	0	21.10	63.50
4495	0	F	good	17.80	N	2.14	0.00	22.08	29.28	0	16.10	34.50
4505.1	1	C	good	9.62	N	0.54	0.18	NA	-1.98	0	26.70	14.50
4505.1	2	C	good	9.62	N	0.70	0.18	NA	-3.00	0	26.60	18.50
4507	1	C	good	10.13	N	4.35	0.79	8.52	9.42	0	64.90	282.00
4510	1	C	good	14.47	N	0.35	0.11	0.12	-3.00	0	34.70	12.00
4510	2	C	good	14.47	N	0.78	0.11	-2.40	-5.34	0	36.10	28.00
9001	1	PA	good	12.32	N	0.98	0.37	-0.24	-0.66	0	38.90	38.00

Appendix D: Results for the Uwharrie National Forest

We completed surveys at 21 (57%) of 37 documented crossings on the Uwharrie National Forest in 2007 (Figure D1, Tables D1 and D2). Filter A (strong swimmers and leapers) classified 24% (n=5) of crossings as impassable, 38% (n=8) as passable, and 38% (n=8) as indeterminate (Figure D2, Table D2). Filter B (moderate swimmers and leapers) classified 52% (n=11) of crossings as impassable, 19% (n=4) as passable, and 29% (n=6) as indeterminate (Figure D2, Table D2). Filter C (weak swimmers and leapers) classified 67% (n=14) of crossings as impassable, 10% (n=2) as passable, and 24% (n=5) as indeterminate (Figure D2, Table D2). Characteristics and filter classifications for each crossing are presented in Tables D3-D5.

The majority of the crossings surveyed were circular culverts (90%, n=19), while fords (10%, n=2) were encountered less frequently. No open bottom arches, pipe arches, box culverts, or vented fords were surveyed. Filter A classified 26% of circular culverts and 0% of fords as impassable (Figure D3). Filter B classified 47% of circular culverts and 100% of fords as impassable (Figure D3). Filter C classified 63% of circular culverts and 100% of fords as impassable (Figure D3). The mean crossing width to channel width ratio (excluding fords, vented fords, and multiple structure crossings) was 0.45 ± 0.27 (mean ± SD) (n=14) (Figure D4). The sample size was insufficient to calculate mean crossing width to channel width ratio for surveyed crossings classified impassable by Filter A. The mean ratio for crossings classified impassable by Filter B was 0.39 ± 0.41 (n=5), and was 0.42 ± 0.34 (n=8) for Filter C (Figure D5). The mean crossing width to channel width ratio for surveyed crossings classified passable by Filter A was 0.50 ± 0.17 (n=6). The sample size was insufficient to calculate mean ratio for crossings classified passable by Filter B and Filter C (Figure D5).

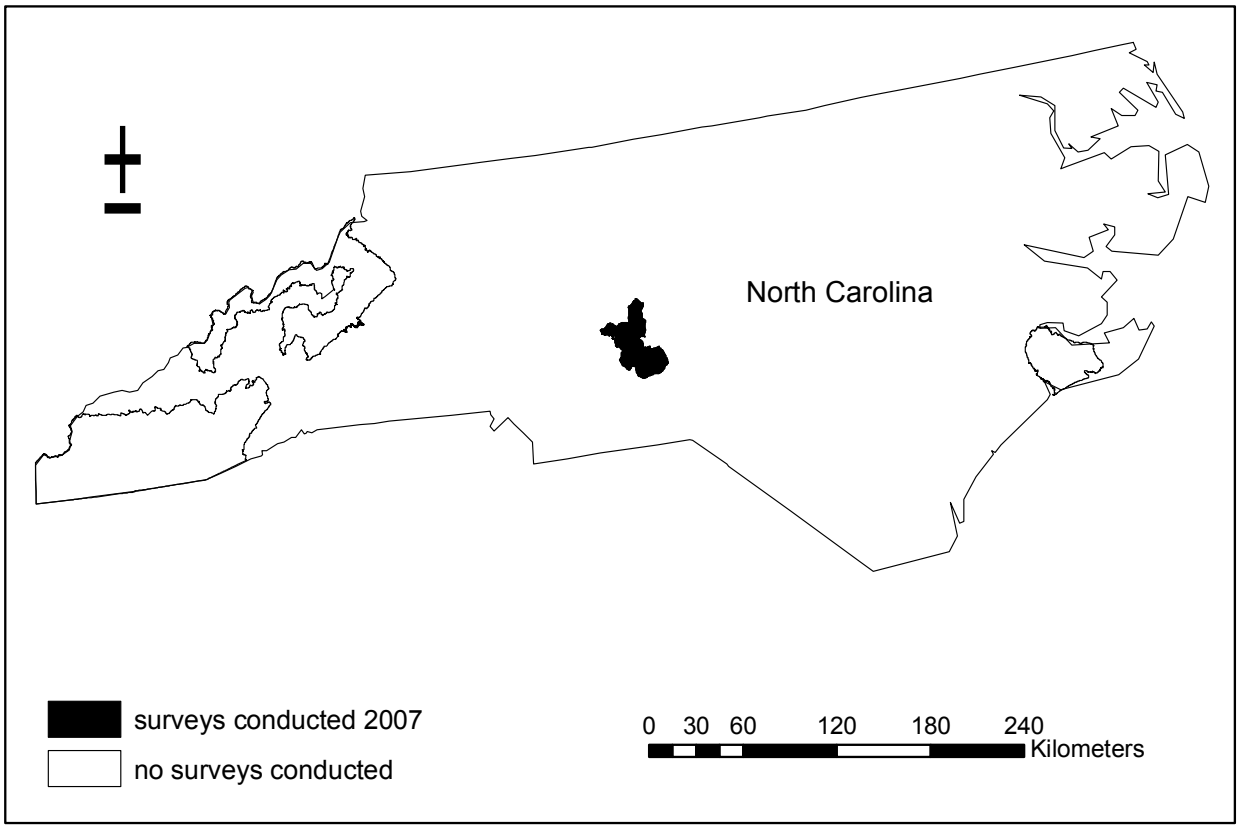

Figure D1. National Forests surveyed in North Carolina, summer 2007.

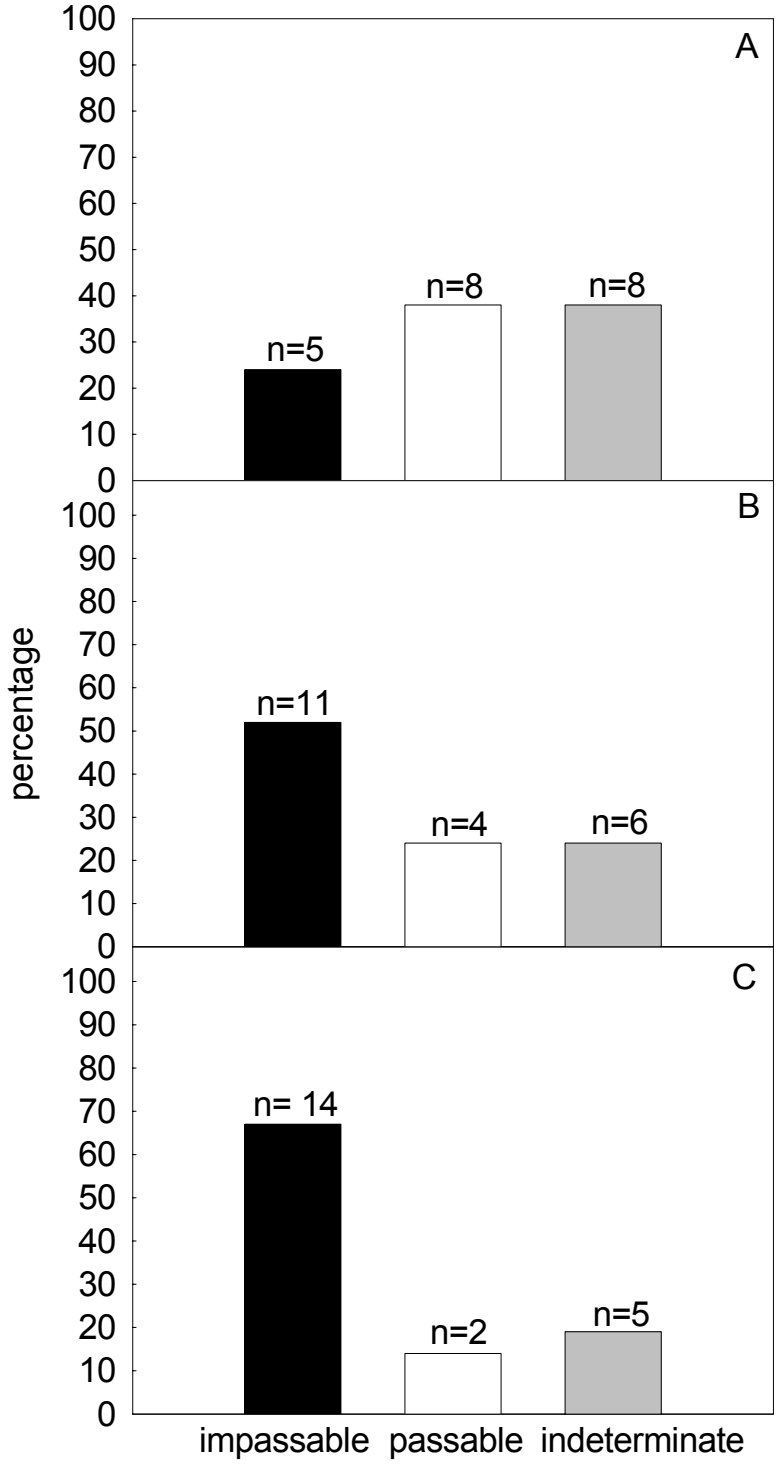

Figure D2. Percentage of crossings classified as impassable, passable, or indeterminate for Filters A, B, and C; Uwharrie National Forest, North Carolina, summer 2007 (N=21).

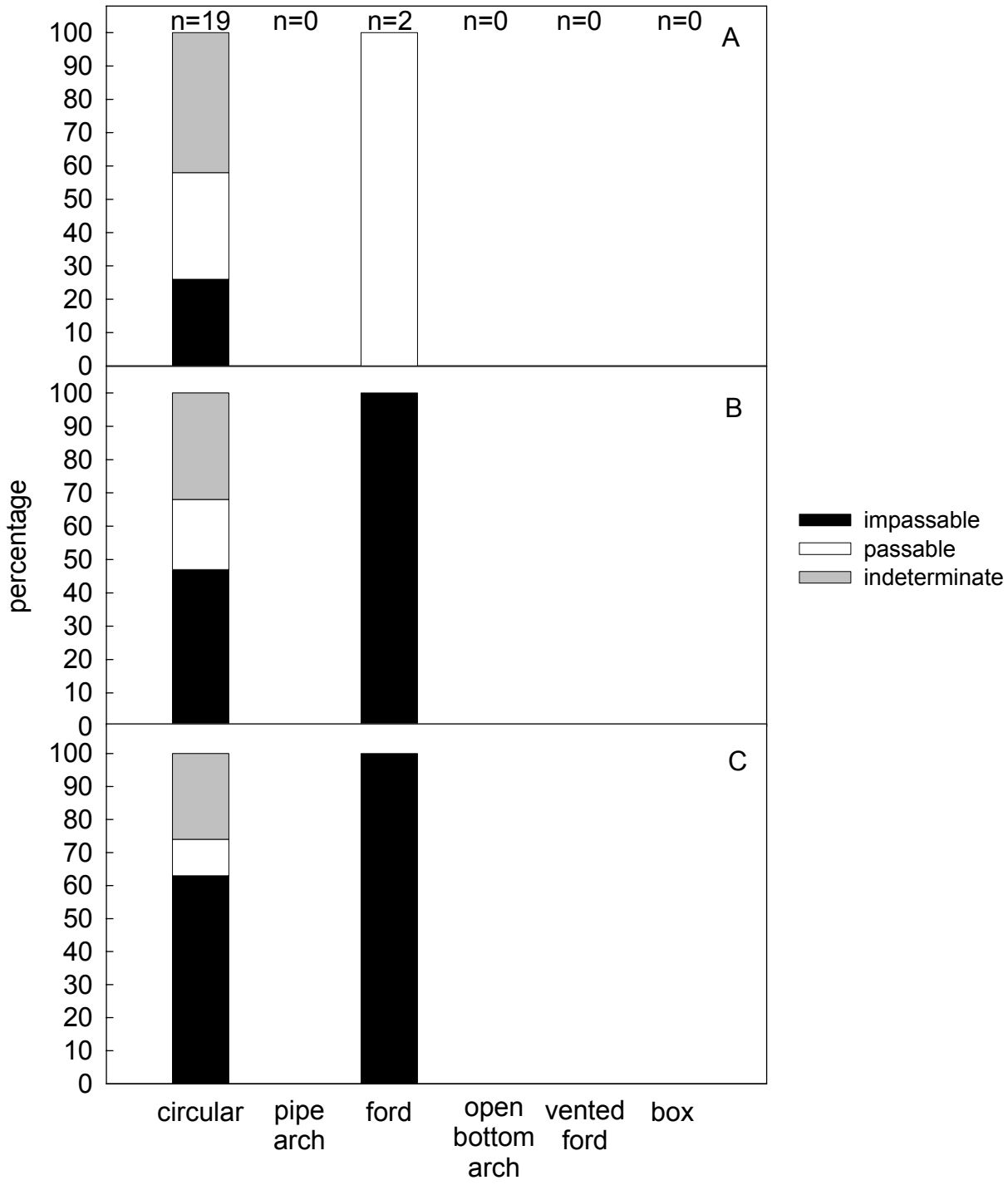

Figure D3. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter A, B, and C; Uwharrie National Forest, North Carolina, summer 2007 (N= 21).

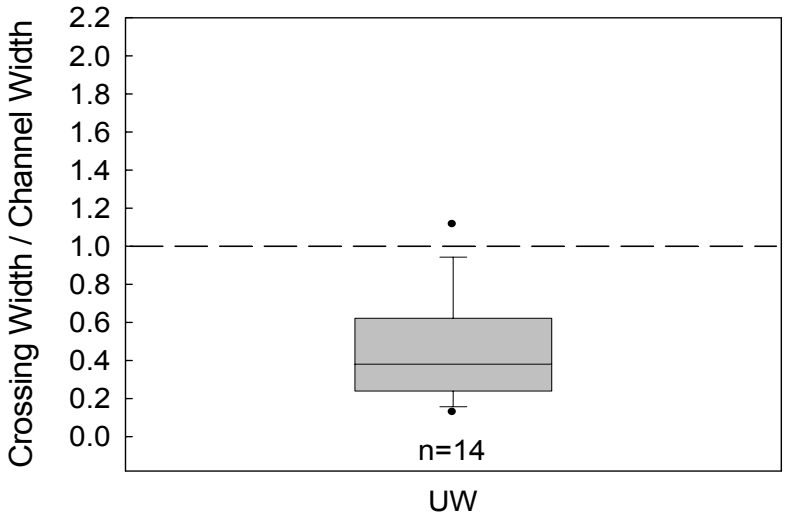

Figure D4. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2007 on the Uwharrie National Forest (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

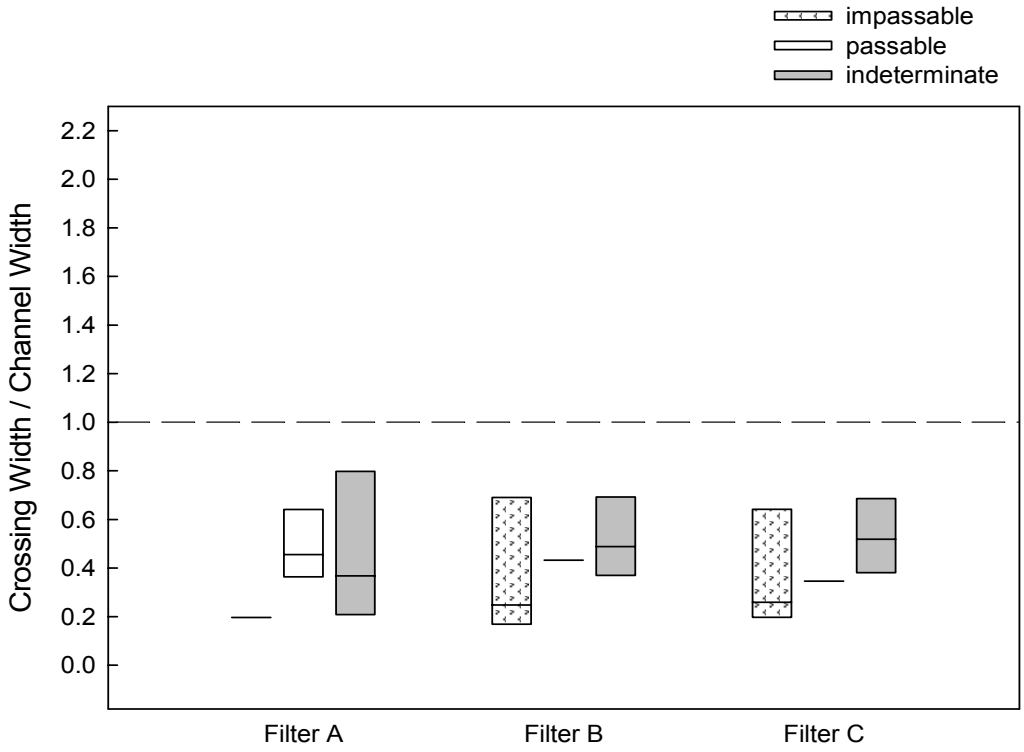

Figure D5. Crossing width to bankfull channel width ratio for crossings classified as impassable, passable, or indeterminate in summer, 2007 on the Uwharrie National Forest (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The symbol inside each set of whiskers represents the median, and the top and bottom of the whiskers represent the maximum and minimum values.

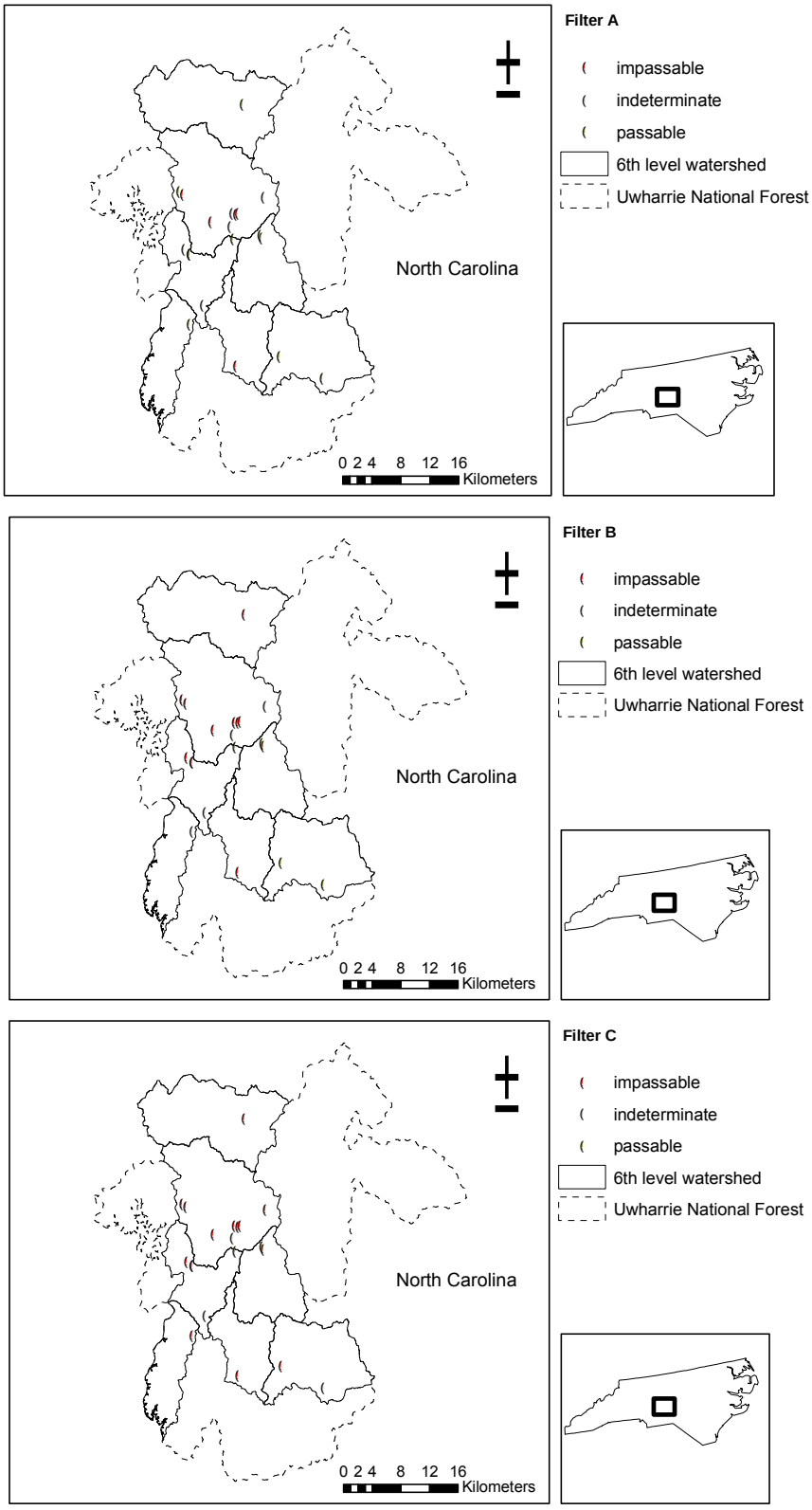

Figure D6. Location of crossings classified for fish passage by coarse filters A, B, and C within 6th level watersheds on the Uwharrie National Forest, summer 2007.

Table D1. Number of crossings documented (Total crossings documented) and not surveyed (Crossings not surveyed) on the Uwharrie National Forest, summer 2007. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossings documented	Crossings not surveyed (n,[%])				
		NH	NA	NF	BR	Total not surveyed
UW	37	4 (25)	2 (13)	1 (6)	9 (56)	16 (43)

Table D2. Number of crossings surveyed (Total surveyed) with coarse filter results for the Uwharrie National Forest, summer 2007. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse Filter Results								
		Impassable (n,[%])			Passable (n,[%])			Indeterminate (n,[%])		
		A	B	C	A	B	C	A	B	C
UW	21	5 (24)	11 (52)	14 (67)	8 (38)	4 (19)	2 (10)	8 (38)	6 (29)	5 (24)

Table D3. Location of crossings surveyed in Uwharrie National Forest, summer 2007. Site ID consists of the Forest abbreviation (UWH), road the crossing is on (553), and the distance (miles) from the junction road (0.1).

Site ID	# Pipes	District	Junction Road	Stream Name	Quad	6th level watershed
UWH1134-4.3	1	Uwharrie	109	Spencer	Lovejoy	30401030500
UWH1134-5.4	1	Uwharrie	109	Unnamed	Lovejoy	30401030500
UWH553-0.1	1	Uwharrie	576	Tributary of Moccasin Creek	Badin	30401030500
UWH553-0.2	1	Uwharrie	576	Tributary of Moccasin Creek	Badin	30401030500
UWH555-0.2	2	Uwharrie	576	Tributary of Moccasin Creek	Badin	30401030500
UWH555-1.2	1	Uwharrie	576	Goldmine Branch	Badin	30401030500
UWH576-3.0	1	Uwharrie	1153	Unnamed	Badin	30401030500
UWH576-6.69	1	Uwharrie	1153	Tributary of Yadkin River	Badin	30401030500
UWH576-6.7	1	Uwharrie	1153	Tributary of Yadkin River	Badin	30401030500
UWH597-1.7	1	Uwharrie	576	Tributary of Moccasin Creek	Badin	30401030500
UWH6560-0.1	1	Uwharrie	576	Tributary of Yadkin River	Badin	30401030500
UWH6678-.3	1	Uwharrie	1146	Unnamed	Morrow Mountain	30401030500
UWH6750-0.2	0	Uwharrie	1184	Unnamed	Handy	30401030500
UWH6750-0.6	0	Uwharrie	1184	Unnamed	Handy	30401030500
UWH6752-0.4	0	Uwharrie	1303	Duncombe	Lovejoy	30401030500
UWH517-3.6	1	Uwharrie	42/47	Unnamed	Morrow Mountain	30401040200
UWH576-1.1	2	Uwharrie	555	Tributary of Moccasin Creek	Badin	30401040300
UWH576-2.3	1	Uwharrie	1153	Tributary of Moccasin Creek	Badin	30401040300
UWH1516-4.5	1	Uwharrie	220A	Unnamed	Biscoe	30401040400
UWH1578-0.3	1	Uwharrie	1005	Unnamed	Troy	30401040400
UWHFOR-0.4	1	Uwharrie	1547	Unnamed	Troy	30401040400

Table D4. Coarse filters A, B, and C, classifications for surveyed crossings in Uwharrie National Forest, summer 2007. At sites with multiple pipes, data are grouped by site ID and given the most favorable passage rating for each filter to determine passage status.

Site ID	Filter A	Filter B	Filter C
UWH1134-4.3	passable	passable	passable
UWH1134-5.4	indeterminate	indeterminate	indeterminate
UWH1516-4.5	passable	passable	indeterminate
UWH1578-0.3	passable	passable	impassable
UWH517-3.6	passable	indeterminate	impassable
UWH553-0.1	indeterminate	indeterminate	impassable
UWH553-0.2	passable	impassable	impassable
UWH555-0.01	indeterminate	indeterminate	indeterminate
UWH555-1.2	indeterminate	impassable	impassable
UWH576-1.1	indeterminate	impassable	impassable
UWH576-2.3	indeterminate	impassable	impassable
UWH576-3.0	passable	passable	passable
UWH576-6.69	impassable	impassable	impassable
UWH576-6.7	impassable	impassable	impassable
UWH597-1.7	impassable	impassable	impassable
UWH6560-0.1	indeterminate	impassable	impassable
UWH6678-.3	indeterminate	indeterminate	indeterminate
UWH6750-0.2	impassable	impassable	impassable
UWH6750-0.6	passable	impassable	impassable
UWH6752-0.4	impassable	impassable	impassable
UWHFOR-0.4	passable	passable	passable

Table D5. Description of crossings surveyed in Uwharrie National Forest, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width Ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%)* Length (ft)
UWH1134-4.3	1	C	fair	7.80	N	0.73	0.77	-5.40	-5.88	8.64	36.80	27.00
UWH1134-5.4	1	C	fair	5.40	N	2.24	1.11	1.80	0.60	0	31.00	69.50
UWH1516-4.5	1	C	fair	13.50	N	0.46	0.37	2.94	4.20	0	37.80	17.50
UWH1578-0.3	1	C	fair	10.10	N	0.00	0.60	7.92	7.08	0	45.00	0.00
UWH517-3.6	1	C	fair	13.00	N	1.02	0.39	4.98	3.90	0	33.00	33.50
UWH553-0.1	0	F	fair	8.10	N	1.86	0.25	9.12	13.92	0	32.00	59.50
UWH553-0.2	1	C	fair	13.80	N	1.67	0.00	NA	12.30	0	12.00	20.00
UWH555-0.01	1	C	fair	9.00	N	2.80	0.36	2.04	7.44	0	30.00	84.00
UWH555-0.01	2	C	fair	9.00	N	2.18	0.36	0.48	6.30	0	30.00	65.50
UWH555-1.2	1	C	poor	14.00	N	5.80	0.21	-0.36	1.44	0	30.70	178.00
UWH576-1.1	1	C	poor	13.50	N	3.94	0.22	12.24	5.94	0	25.00	98.50
UWH576-1.1	2	C	poor	13.50	N	5.22	0.33	NA	2.76	0	23.00	120.00
UWH576-2.3	1	C	good	5.10	N	4.40	0.49	6.54	3.42	0	34.00	149.50
UWH576-3.0	1	C	fair	6.80	Y	0.47	0.52	NA	-1.92	0	31.60	15.00
UWH576-6.69	1	C	good	33.10	N	4.34	0.12	33.84	20.04	0	39.40	171.00
UWH576-6.7	1	C	good	14.80	N	3.40	0.27	31.26	29.28	0	39.80	135.50
UWH597-1.7	1	C	good	11.60	N	3.01	0.35	3.72	4.08	0	16.30	49.00
UWH6560-0.1	1	C	poor	7.80	N	5.54	0.19	6.36	10.44	0	24.00	133.00
UWH6678-0.3	1	C	fair	7.20	N	2.39	0.69	2.52	-8.88	0	51.30	122.50
UWH6750-0.2	1	C	good	5.40	N	1.09	0.00	29.40	24.30	0	8.70	9.50
UWH6750-0.6	0	F	good	15.00	N	0.54	0.00	17.82	14.34	0	10.20	5.50
UWH6752-0.4	1	C	fair	17.40	N	0.57	0.00	25.56	25.14	0	12.20	7.00
UWHFOR-0.4	1	C	fair	11.60	N	0.73	0.26	3.78	3.60	0	36.80	27.00

Appendix E: Results for the Sam Houston National Forest

We completed surveys at 21 (84%) of 25 documented crossings on the Sam Houston National Forest in 2007 (Figure E1, Tables E1 and E2). Filter A (strong swimmers and leapers) classified 10% (n=2) of crossings as impassable, 52% (n=11) as passable, and 38% (n=8) as indeterminate (Figure E2, Table E2). Filter B (moderate swimmers and leapers) classified 29% (n=6) of crossings as impassable, 43% (n=9) as passable, and 29% (n=6) as indeterminate (Figure E2, Table E2). Filter C (weak swimmers and leapers) classified 52% (n=11) of crossing as impassable, 33% (n=7) as passable, and 14% (n=3) as indeterminate (Figure E2, Table E2). Characteristics and filter classifications for each crossing are presented in Tables E3-E5.

The majority of the crossings surveyed were circular culverts (95%, n=20) and pipe arches (5%, n=1). Box culverts, fords, vented fords, and open bottom arches were not encountered during surveys conducted in 2007. Filter A classified 10% of circular culverts and 0% of pipe arches as impassable (Figure E3). Filter B classified 29% of circular culverts and 0% of pipe arches as impassable (Figure E3). Filter C classified 52% of circular culverts and 0% of pipe arches as impassable (Figure E3). The mean crossing width to channel width ratio (excluding fords, vented fords, and multiple structure crossings) was 0.74 ± 0.39 (mean ± SD) (n=16), and 5 crossings were greater than or equal to the bankfull channel width (Figure E4). The mean crossing width to channel width ratio for surveyed crossings classified impassable by Filter A was 0.72 ± 0.40 (n=2). The mean ratio for crossings classified impassable by Filter B was 0.77 ±0.42 (n=6), and was 0.70 ± 0.39 (n=10) for Filter C (Figure E5). The mean crossing width to channel width ratio for surveyed crossings classified passable by Filter A was 0.81 ± 0.44 (n=7). The mean ratio for crossings classified passable by Filter B was 0.82 ± 0.42 (n=8), and was 0.87 ± 0.57 (n=3) for Filter C (Figure E5).

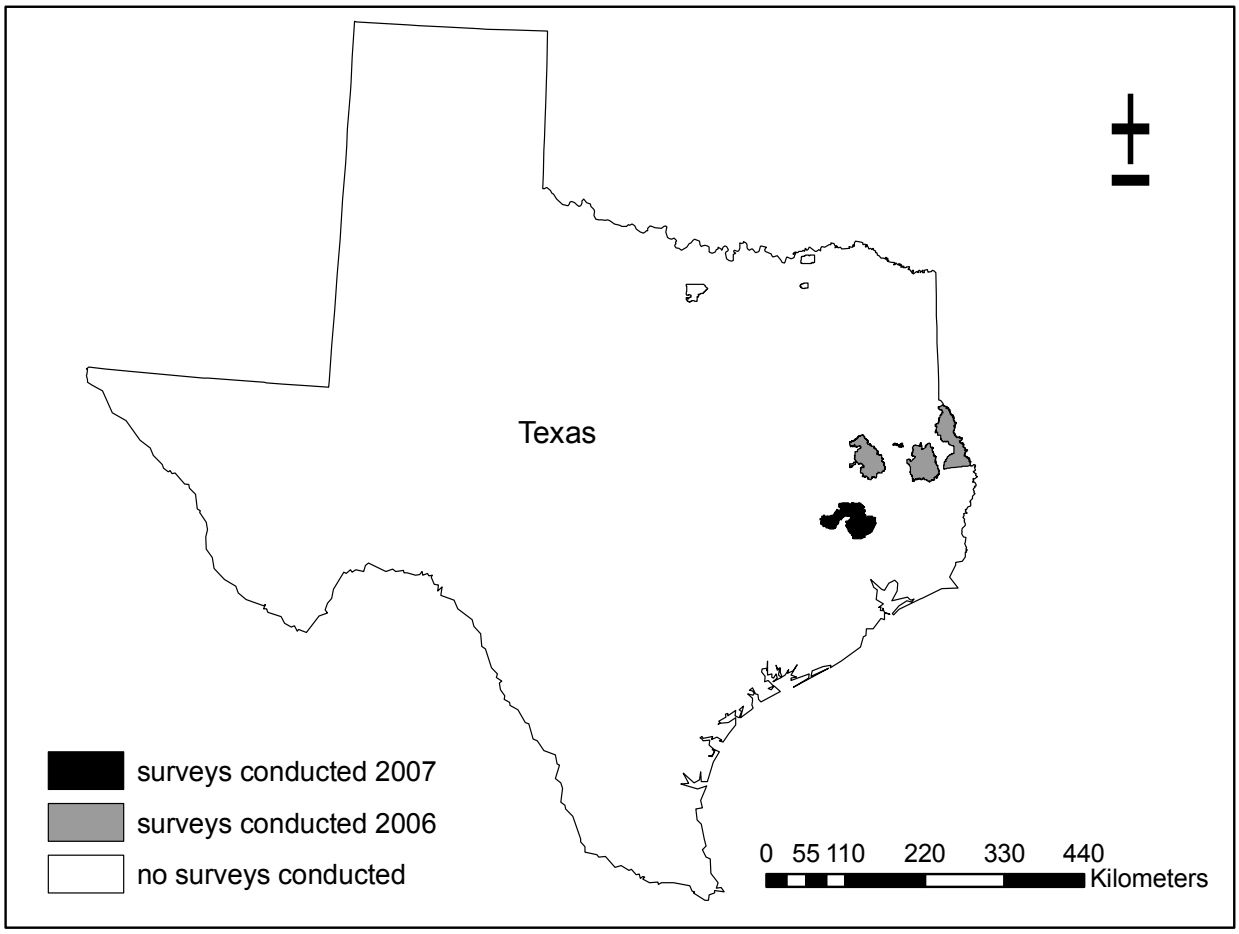

Figure E1. National Forests surveyed in Texas, summer 2006 and summer 2007. (Crossings surveyed in 2006 can be found in Coffman et al. 2006)

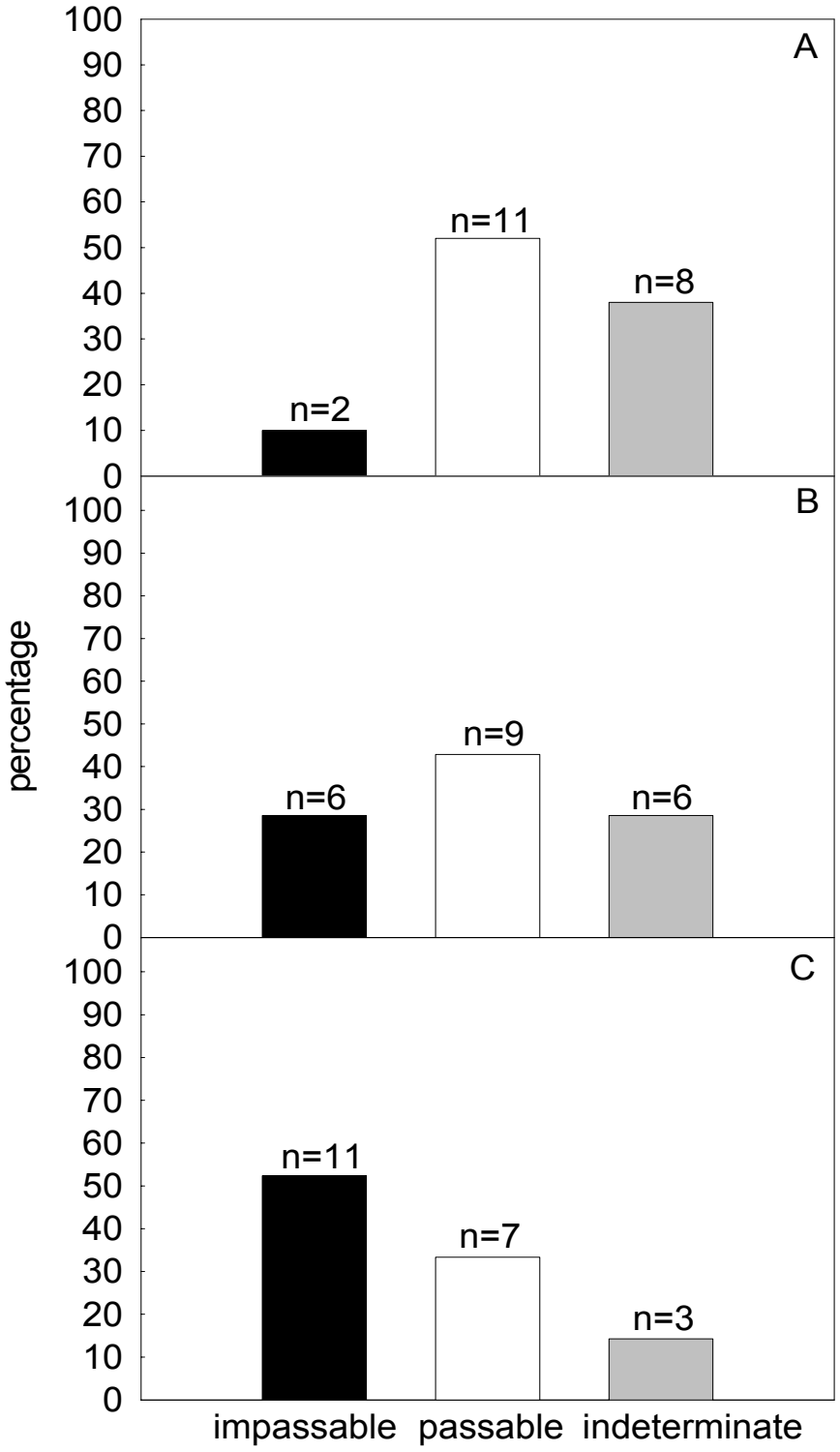

Figure E2. Percentage of crossings classified as impassable, passable, or indeterminate for Filter A, B, and C; Sam Houston National Forest, Texas, summer 2007 (N= 21).

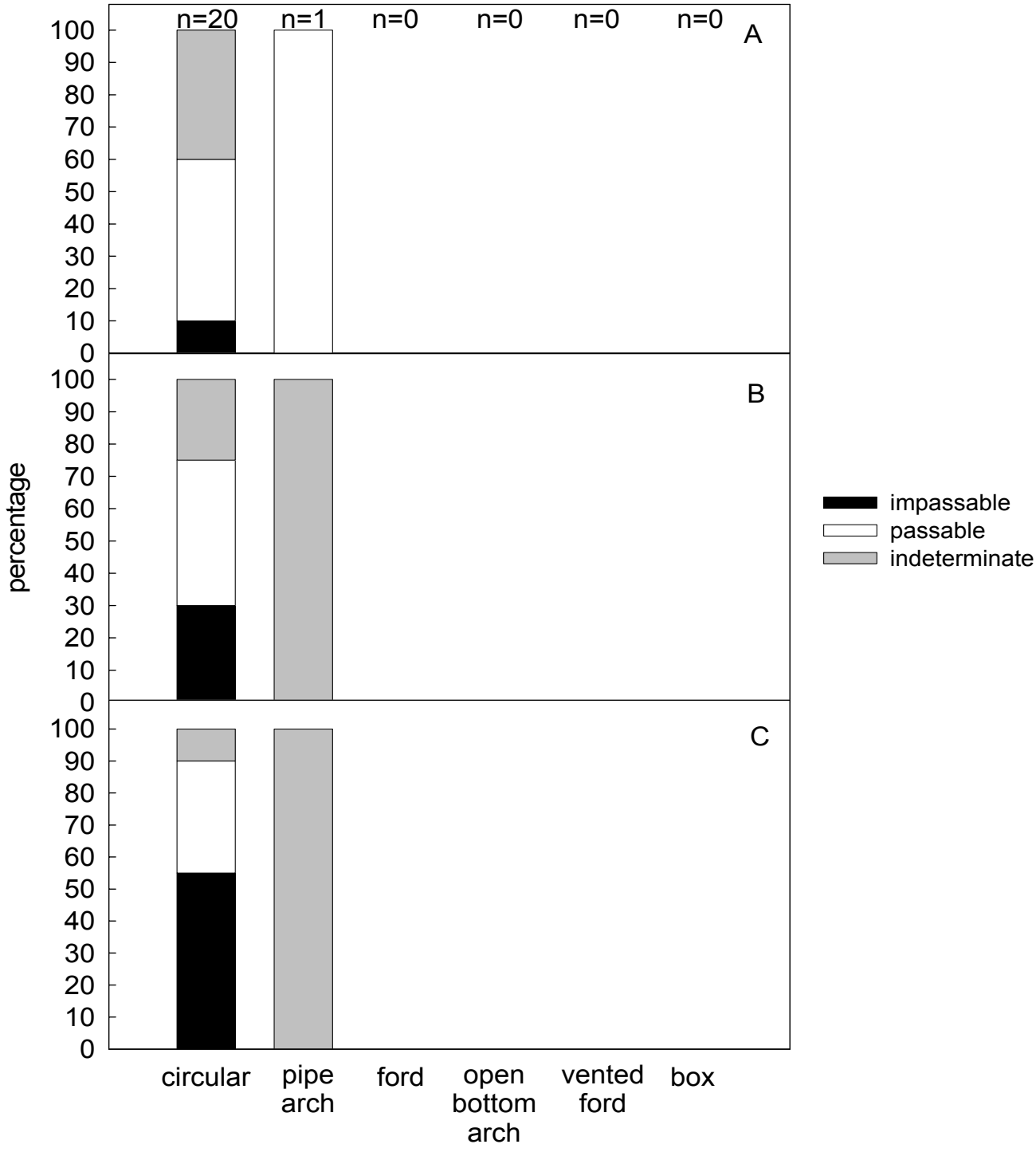

Figure E3. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter A, B, and C; Sam Houston National Forest, Texas, summer 2007 (N= 21).

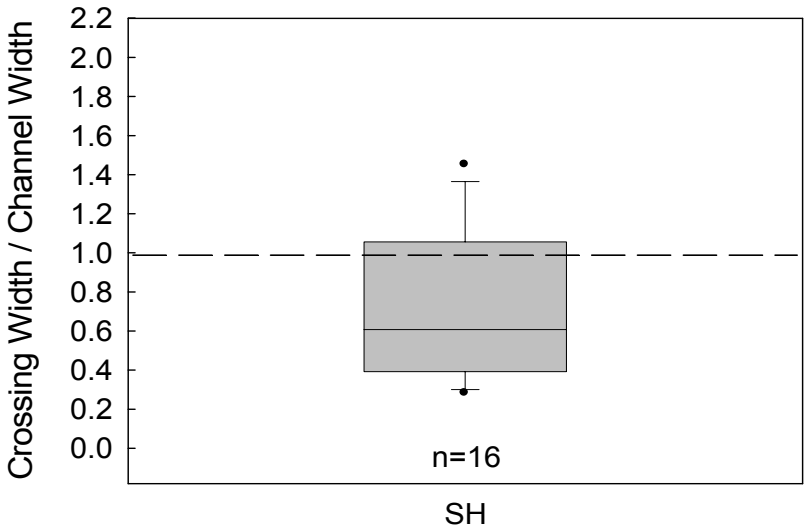

Figure E4. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2007 on the Sam Houston National Forest, Texas (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

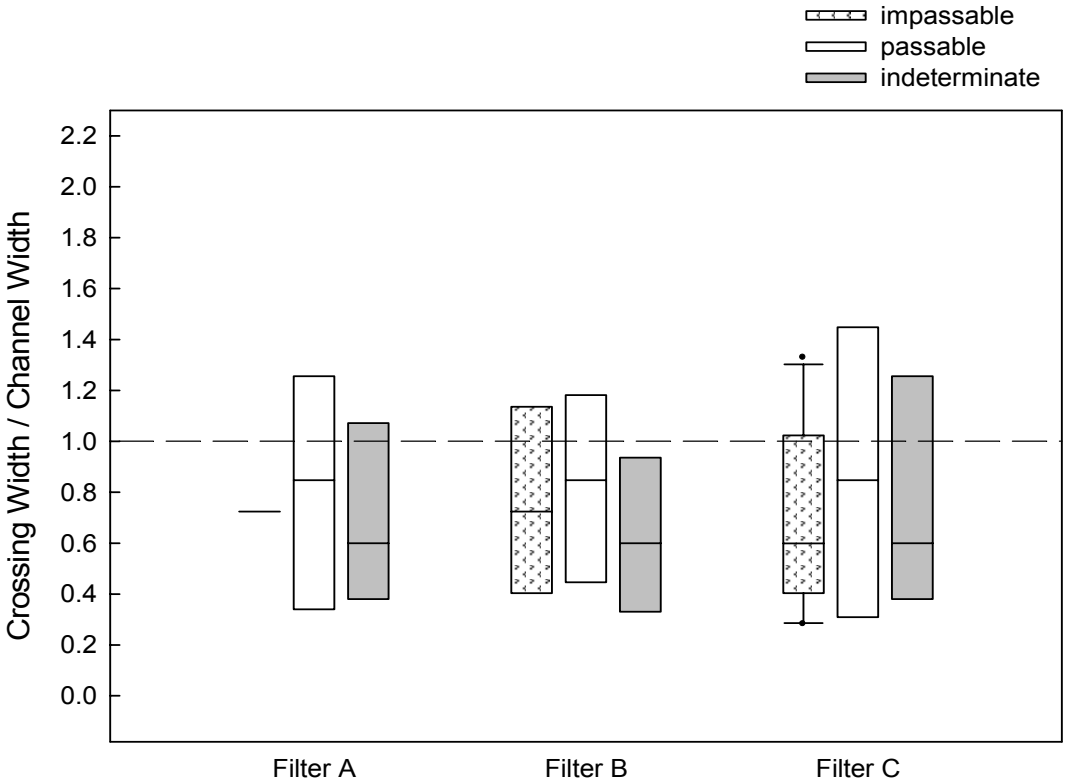

Figure E5. Crossing width to bankfull channel width ratio for crossings classified impassable, passable, or indeterminate in summer 2006 on the Sam Houston National Forest, Texas (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The symbol inside each set of whiskers represents the median, and the top and bottom of the whiskers represent the maximum and minimum values.

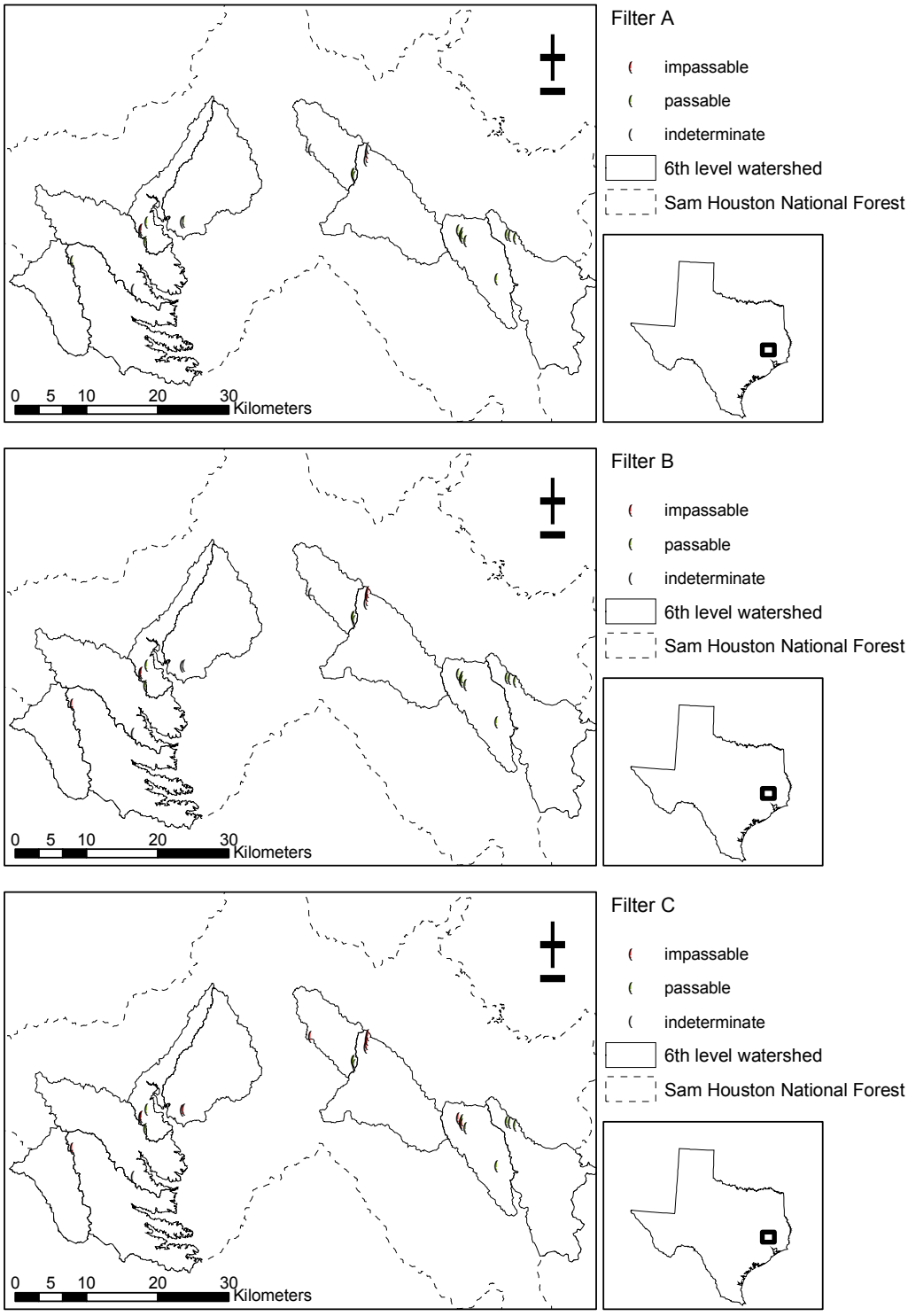

Figure E6. Location of crossings classified for fish passage by coarse filters A, B, and C within 6th level watersheds on the Sam Houston National Forest, summer 2007.

Table E1. Number of crossings documented (Total crossings documented) and not surveyed (Crossings not surveyed) on the Sam Houston National Forest, Texas, summer 2007. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossings documented	Crossings not surveyed (n,[%])				
		NH	NA	NF	BR	Total not surveyed
SH	25	3 (12)	1 (4)	0 (0)	0 (0)	4 (16)

Table E2. Number of crossings surveyed (Total surveyed) with coarse filter results for the Sam Houston National Forest, Texas, summer 2007. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse Filter Results								
		Impassable (n,[%])			Passable (n,[%])			Indeterminate (n,[%])		
		A	B	C	A	B	C	A	B	C
SH	21	2 (10)	6 (29)	11 (52)	11 (52)	9 (42)	7 (33)	8 (38)	6 (29)	3 (15)

Table E3. Location of crossings surveyed on the Sam Houston National Forest, Texas, summer of 2007. Site ID consists of the Forest abbreviation (SH), road the crossing is on (233), and the distance (miles) from the junction road (0.8).

Site ID	# Pipes	District	Junction Road	Stream Name	Quad	6th Level Watershed
SH233-0.8	1	SamHouston	233C	Smith Branch	Moore Grove	120401010105
SH256-0.9	1	SamHouston	945	Smith Branch	Cold Spring	120401010105
SH223-1.6	1	SamHouston	213	Unnamed	Phelps	120401010106
SH224-0.6	1	SamHouston	2002	Unnamed	Montgomery	120401010106
SH233-0.7	2	SamHouston	233C	Unnamed	Moore Grove	120401010106
SH221-1.6	1	SamHouston	217	Unnamed	Camilla	120401010107
SH221-1.9	2	Sam Housto	221	Unnamed	Camilla	120401010107
SH221-1.0	1	SamHouston	217	Tributary of Little Lake Creek	Camilla	120401010109
SH204-0.3	1	SamHouston	1375	Tributary of Boswell Creek	San Jacinto	120401030202
SH207-1.8	1	SamHouston	202	Pea Creek	Maynard	120401030202
SH207-2.2	1	SamHouston	202	Pea Creek	Maynard	120401030202
SH207A-2.8	1	SamHouston	207	Pea Creek	Phelps	120401030202
SH211A-0.6	1	SamHouston	211	Unnamed	Richards	120401030203
SH215-0.3	1	SamHouston	208	Hopkins Branch	San Jacinto	120401030203
SH215-0.5	1	SamHouston	208	Hopkins Branch	San Jacinto	120401030203
SH215-1.2	1	SamHouston	208	Hopkins Branch	San Jacinto	120401030203
SH256A-0.2	1	SamHouston	256	Tributary of the E. Fork San Jacinto River	Cold Spring	120401030207
SH256A-0.4	1	SamHouston	256	Tributary of the E. Fork San Jacinto River	Cold Spring	120401030207
SH256A-0.6	2	SamHouston	256	Tributary of the E. Fork San Jacinto River	Cold Spring	120401030207
SH256A-1.3	1	SamHouston	256	Tributary of the E. Fork San Jacinto River	Cold Spring	120401030207
SH261-0.3	2	SamHouston	262	Tarkington Bayou	Bear Creek	120401030301

Table E4. Coarse filters A, B, and C, classifications for surveyed crossings on the Sam Houston National Forest, Texas, summer 2007. At sites with multiple pipes, data are grouped by site ID and given the most favorable passage rating for each filter to determine passage status.

Site ID	Filter A	Filter B	Filter C
SH204-0.3	indeterminate	indeterminate	impassable
SH207-1.8	indeterminate	indeterminate	indeterminate
SH207-2.2	passable	passable	passable
SH207A-2.8	passable	passable	passable
SH211A-0.06	impassable	impassable	impassable
SH215-0.3	indeterminate	indeterminate	impassable
SH215-0.5	indeterminate	impassable	impassable
SH215-1.2	indeterminate	impassable	impassable
SH221-1.0	passable	impassable	impassable
SH221-1.6	indeterminate	indeterminate	indeterminate
SH221-1.9	passable	passable	passable
SH223-1.6	indeterminate	impassable	impassable
SH224-0.6	impassable	impassable	impassable
SH233-0.7	passable	passable	passable
SH233-0.8	passable	indeterminate	indeterminate
SH256-0.9	indeterminate	indeterminate	impassable
SH256A-0.2	passable	passable	impassable
SH256A-0.4	passable	passable	passable
SH256A-0.6	passable	passable	passable
SH256A-1.3	passable	passable	impassable
SH261-0.3	passable	passable	passable

Table E5. Description of crossings surveyed on the Sam Houston National Forest, Texas, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, 0= discontinuous substrate, 1= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
SH204-0.3	1	C	fair	4.28	N	2.03	0.28	6.00	13.80	0	62.00	126.00
SH207-1.8	1	C	fair	5.83	N	2.63	0.60	-7.92	-3.48	0	35.00	92.00
SH207-2.2	1	C	fair	7.08	Y	2.35	0.85	-1.44	0.60	12.72	40.00	94.00
SH207A-2.8	1	C	poor	8.08	Y	2.86	0.31	NA	0.00	0	45.50	130.00
SH211A-0.6	1	C	good	6.25	N	0.56	1.01	35.52	42.24	0	48.00	27.00
SH215-0.3	1	C	fair	7.82	N	0.97	0.64	8.52	11.88	0	58.00	56.00
SH215-0.5	1	C	good	3.92	N	3.31	1.33	15.60	13.80	0	66.50	220.00
SH215-1.2	1	C	fair	4.67	N	5.27	1.07	17.88	12.36	0	66.00	348.00
SH221-1.0	1	C	fair	8.83	N	1.13	0.34	14.40	18.96	0	38.00	43.00
SH221-1.6	1	C	fair	8.42	N	2.08	0.38	2.16	14.88	0	25.00	52.00
SH221-1.9	1	C	fair	14.58	N	2.00	0.22	-6.24	-3.84	11.04	20.00	40.00
SH221-1.9	2	C	fair	14.58	Y	2.20	0.22	-13.92	0.48	8.64	20.00	44.00
SH223-1.6	1	C	good	9.42	N	3.81	0.42	6.12	3.84	0	36.00	137.00
SH224-0.6	1	C	good	10.25	N	14.92	0.44	100.08	104.40	0	46.19	689.00
SH233-0.7	1	C	fair	13.17	N	0.41	0.48	1.92	-2.40	0.24	43.50	18.00
SH233-0.7	2	C	fair	13.17	N	0.73	0.48	-1.32	-3.24	4.92	41.10	30.00
SH233-0.8	1	PA	poor	7.17	N	0.52	1.26	NA	-0.60	0	50.00	26.00
SH256-0.9	1	C	good	6.50	N	2.11	0.62	7.08	6.24	0	37.00	78.00
SH256A-0.2	1	C	fair	8.75	N	0.10	0.91	9.12	6.12	0	50.00	5.00
SH256A-0.4	1	C	fair	4.83	Y	0.26	1.45	NA	-3.48	0	50.00	13.00
SH256A-0.6	1	C	good	8.17	N	2.05	0.73	NA	NA	0	29.70	61.00

Table continued on next page…

Table E5 (*continued*). Description of crossings surveyed on the Sam Houston National Forest, Texas, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, 0= discontinuous substrate, 1= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
SH256A-0.6	2	C	good	8.17	N	0.06	0.73	NA	0.00	0	77.50	5.00
SH256A-1.3	1	C	poor	8.58	N	0.17	0.58	8.52	6.12	0	36.00	6.00
SH261-0.3	1	C	poor	9.17	N	35.00	0.55	-7.68	-7.56	0	30.00	1050.00
SH261-0.3	2	C	poor	9.17	N	8.83	0.55	-8.28	-8.88	40.08	30.00	265.00

Appendix F: Results for the Kisatchie National Forest

We completed surveys at 39 (22%) of 181 documented crossings on the Kisatchie National Forest in 2007 (Figure F1, Tables F1 and F2). Filter A (strong swimmers and leapers) classified 8% (n=3) of crossings as impassable, 64% (n=25) as passable, and 28% (n=11) as indeterminate (Figure F2, Table F2). Filter B (moderate swimmers and leapers) classified 23% (n=9) of crossings as impassable, 49% (n=19) as passable, and 28% (n=11) as indeterminate (Figure F2, Table F2). Filter C (weak swimmers and leapers) classified 46% (n=18) of crossing as impassable, 38% (n=15) as passable, and 15% (n=6) as indeterminate (Figure F2, Table F2). Characteristics and filter classifications for each crossing are presented in Tables F3-F5.

The majority of the crossings surveyed were circular culverts (74%, n=29), while box culverts (8%, n=3), pipe arches (18%, n=7), were less frequently encountered. Vented fords, fords, and open bottom arches were not encountered during surveys conducted in 2007. Filter A classified 3% of circular culverts, 67% of box culverts, and 0% of pipe arches as impassable (Figure F3). Filter B classified 21% of circular culverts, 67% of box culverts, and 14% of pipe arches as impassable (Figure F3). Filter C classified 41% of circular culverts, 67% of box culverts, and 57% of pipe arches as impassable (Figure F3). The mean crossing width to channel width ratio (excluding fords, vented fords, and multiple structure crossings) was 0.69 ± 0.22 (mean ± SD) (n=22) (Figure F4). The sample size was insufficient to calculate mean crossing width to channel width ratio for surveyed crossings classified impassable by Filter A. The mean ratio for crossings classified impassable by Filter B was 0.75 ± 0.18 (n=7), and was 0.73 ± 0.17 (n=12) for Filter C (Figure F5). The mean crossing width to channel width ratio for surveyed crossings classified passable by Filter A was 0.67 ± 0.25 (n=13). The mean ratio for crossings classified passable by Filter B was 0.70 ± 0.28 (n=8), and was 0.69 ± 0.32 (n=6) for Filter C (Figure F5).

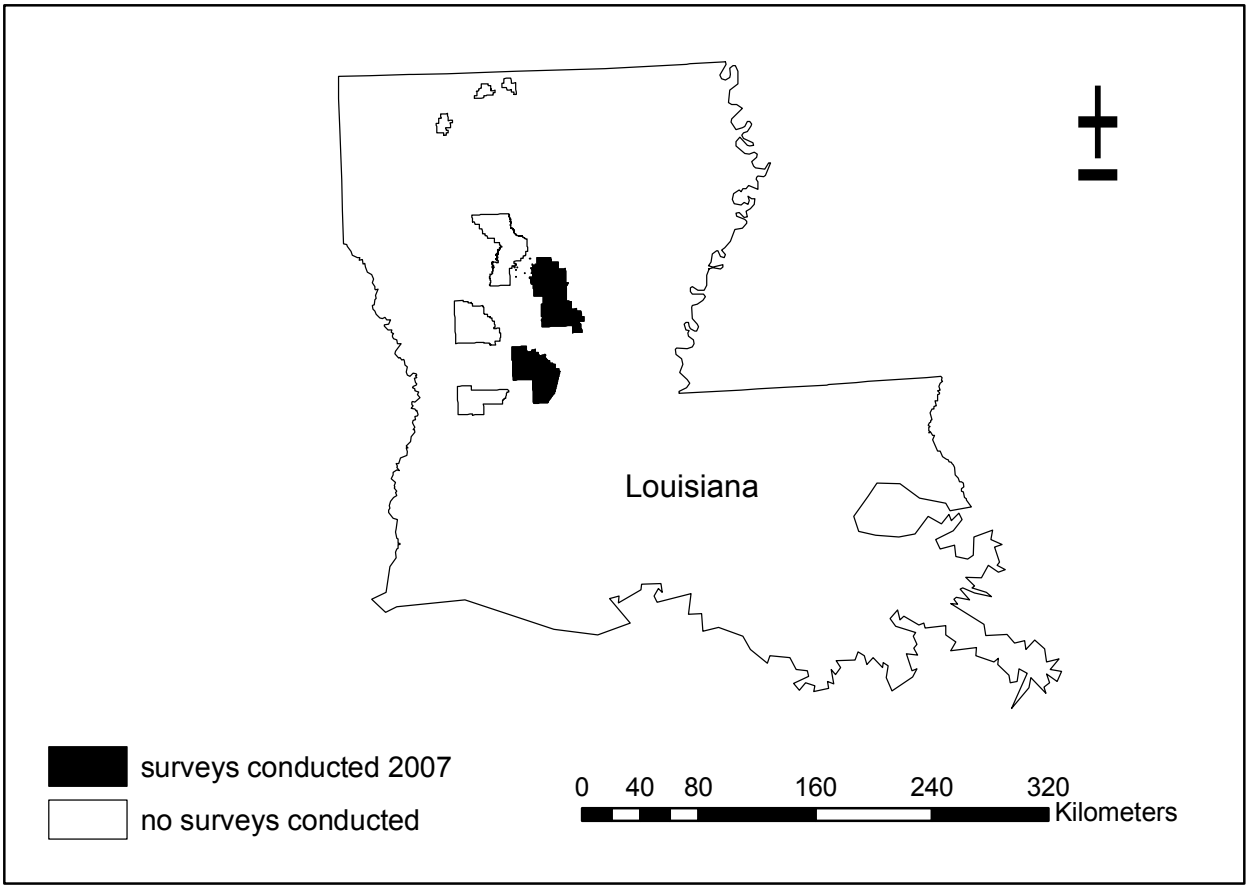

Figure F1. Ranger Districts on the Kisatchie National Forest, Louisiana where road-stream crossing surveys were conducted, summer 2007.

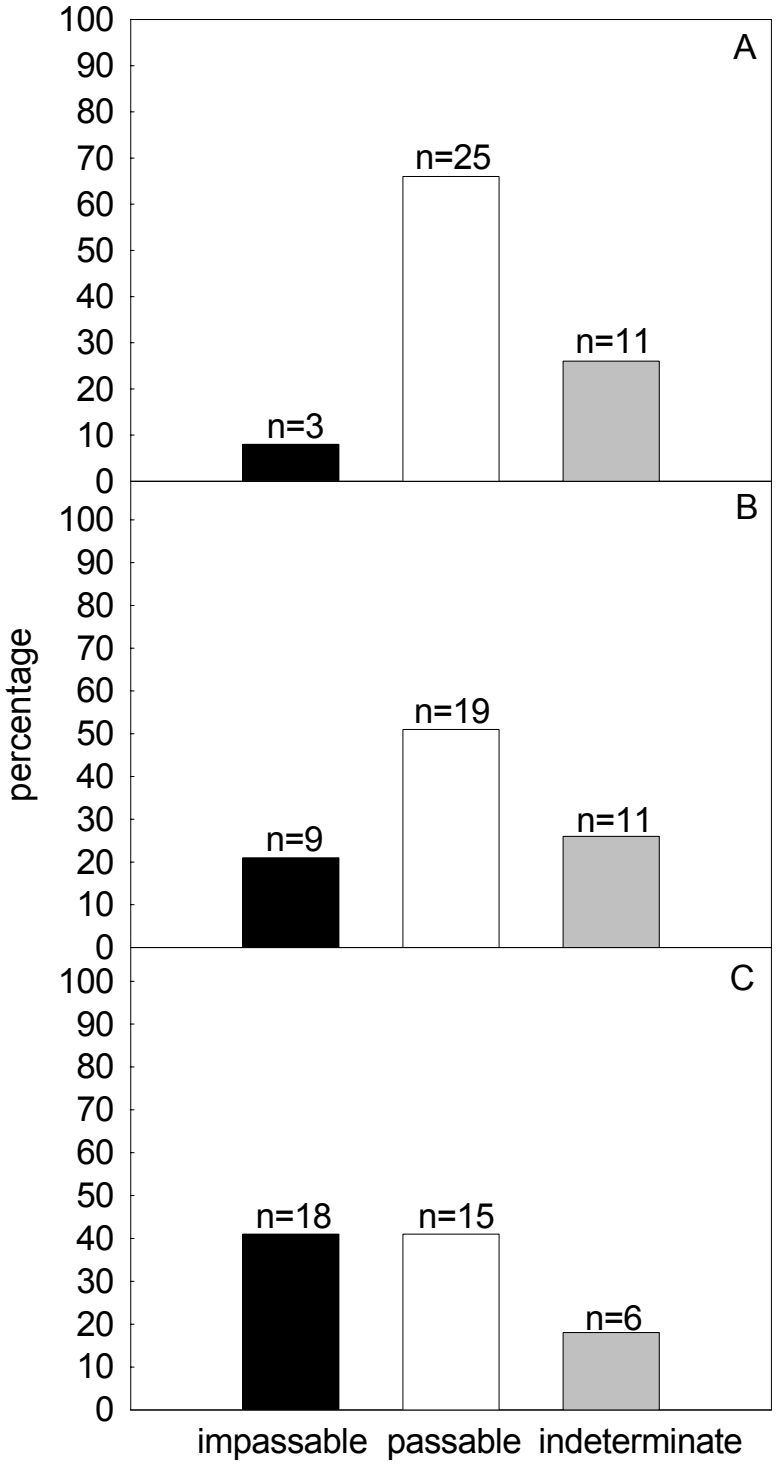

Figure F2. Percentage of crossings classified as impassable, passable, or indeterminate for Filter A, B, and C; Kisatchie National Forest, Louisiana, summer 2007 (N=39).

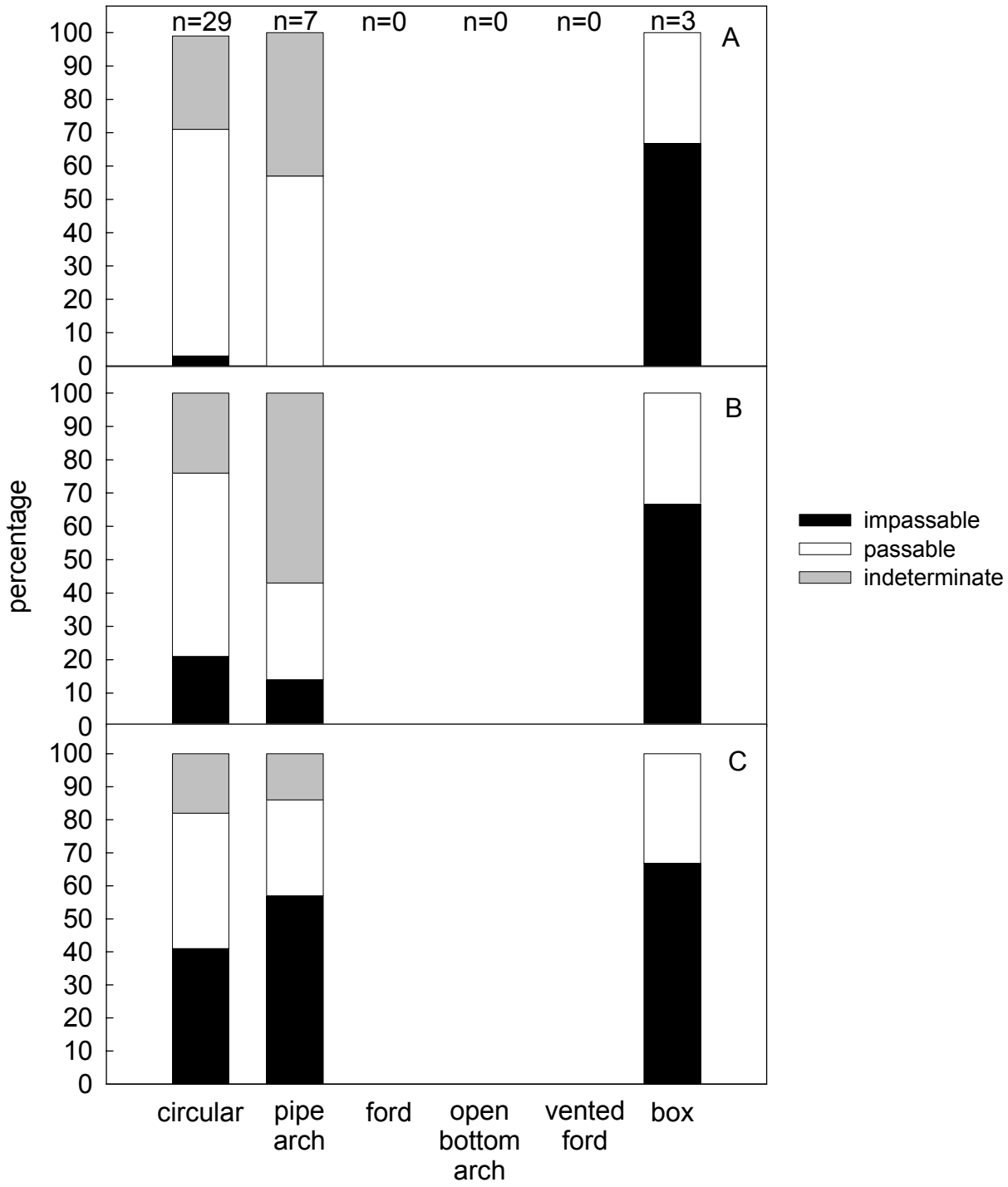

Figure F3. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter A, B, and C; Kisatchie National Forest, Louisiana, summer 2007 (N=39).

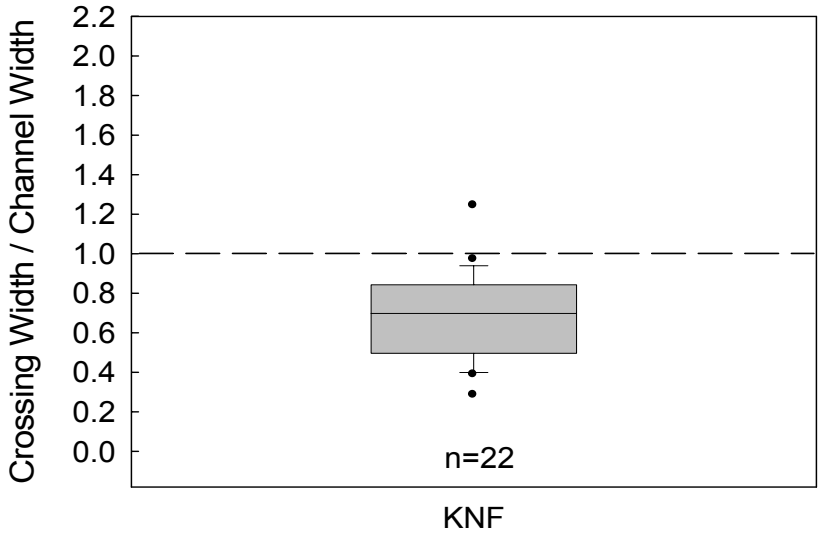

Figure F4. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2007 on the Kisatchie National Forest in Louisiana (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

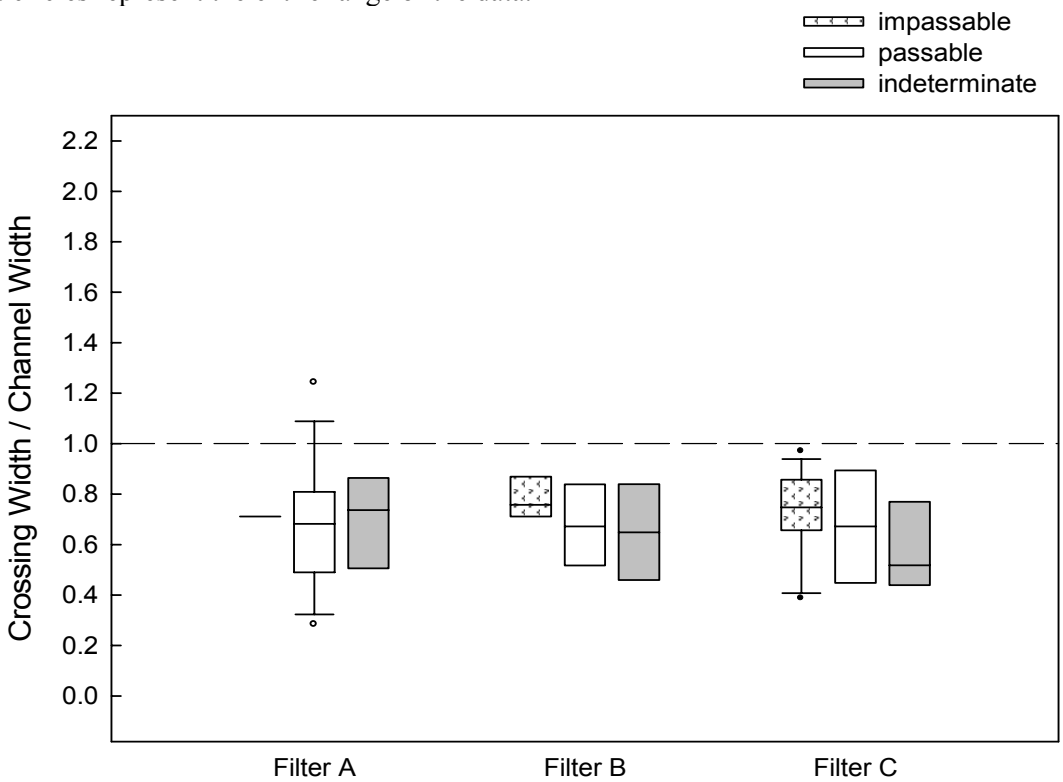

Figure F5. Crossing width to bankfull channel width ratio for crossings classified impassable, passable, or indeterminate in summer 2007 on the Kisatchie National Forest in Louisiana (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The symbol inside each set of whiskers represents the median, and the top and bottom of the whiskers represent the maximum and minimum values.

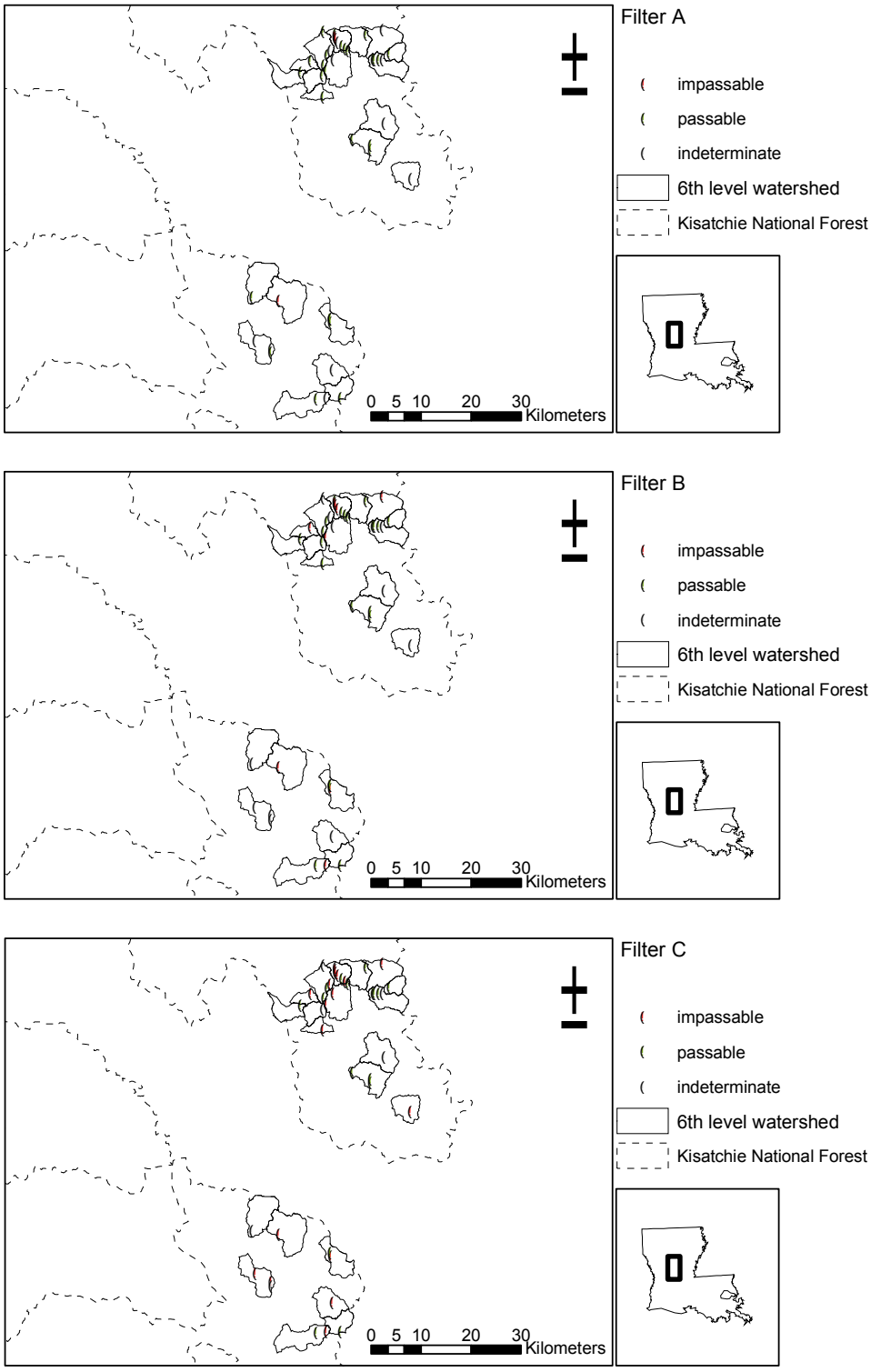

Figure F6. Location of crossings classified for fish passage by coarse filters A, B, and C within 6th level watersheds on the Kisatchie National Forest, summer 2007.

Table F1. Number of crossings documented (Total crossings documented) and not surveyed (Crossings not surveyed) on the Kisatchie National Forest in Louisiana, summer 2007. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossings documented	Crossings not surveyed (n,[%])				
		NH	NA	NF	BR	Total not surveyed
KNF	181	75 (41)	65 (36)	2 (1)	0 (0)	142 (78)

Table F2. Number of crossings surveyed (Total surveyed) with coarse filter results for the Kisatchie National Forest in Louisiana, summer 2007. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse Filter Results								
		Impassable (n,[%])			Passable (n,[%])			Indeterminate (n,[%])		
		A	B	C	A	B	C	A	B	C
KNF	39	3 (8)	9 (23)	18 (46)	25 (64)	19 (49)	15 (38)	11 (28)	11 (28)	6 (15)

Table F3. Location of crossings surveyed on the Kisatchie National Forest in Louisiana, summer of 2007. Site ID consists of the Forest abbreviation (KNF), road the crossing is on (E046O), and the distance (miles) from the junction road (0.2).

Site ID	# Pipes	District	Junction Road	Stream Name	Quad	6th level watershed
KNFE046O-0.2	1	Calcasieu	267	Upper branch of Mill Creek	Forest Hill	080403040106
KNFJ09-0.2	2	Calcasieu	283	Unnamed	Elmer	080403040107
KNF188-0.2	2	Catahoula	155	Tributary of Camp Pond Creek	Williana	080403040108
KNF188-0.8	1	Catahoula	hwy 156	Bear Creek	Williana	080403040108
KNF202-0.1	2	Calcasieu	hwy 112	Harper Branch	Forest Hill	080403040108
KNF212-2.3	1	Calcasieu	287	Unnamed	Woodworth West	080403040108
KNF212-2.8	2	Calcasieu	287	Unnamed	Woodworth West	080403040108
KNF247-2.4	2	Calcasieu	208	Unnamed	Woodworth West	080403040108
KNFE040B-0.4	2	Calcasieu	283	Unnamed	Elmer	080403040109
KNF212-2.9	2	Calcasieu	287	Unnamed	Woodworth West	080403040201
KNF556-0.3	1	Catahoula	hwy 167	Unnamed	Williana	080403040201
KNFC057S-0.2	1	Catahoula	109	Unnamed	Pollock	080403040201
KNFC071A-0.5	1	Catahoula	hwy 113	Dyson Creek	Dry Prong	080403040203
KNFC083X-0.1	1	Catahoula	hwy 124	Unnamed	Ball	080403040203
KNFE018A-0.4	1	Calcasieu	279	Lathe Branch	Gardner	080403040203
KNFE038C-0.2	2	Calcasieu	1199	Unnamed	Elmer	080403040203
KNF167-0.7	2	Catahoula	128	Unnamed	Mudville	080403040208
KNF167-1.4	1	Catahoula	hwy 524	Unnamed	Mudville	080403040213
KNF167-0.5	2	Catahoula	128	Unnamed	Mudville	080403040218
KNF133-1.5	1	Catahoula	167	Glady Hollow	Dry Prong	080801020201
KNF145-0.4	2	Catahoula	556	Unnamed	Williana	080801020202
KNF145-1.4	1	Catahoula	hwy 472	Upper Tributary. of Caney Branch	Williana	080801020302
KNF145-1.5	2	Catahoula	556	Upper Tributary of Indian Creek	Williana	080801020302
KNF154-0.7	1	Catahoula	hwy 167	Unnamed	Williana	080801020302
KNF154-1.8	1	Catahoula	hwy 167	Unnamed	Williana	080801020307
KNF145-1.0	3	Catahoula	556	Unnamed	Williana	080801020308
KNF120A-0.5	1	Catahoula	hwy 120	Unnamed	Williana	080801020501
KNF130-1.3	2	Catahoula	hwy 524	Upper Tributary of Cypress Creek	Mudville	080801020501
KNF145-0.4	2	Catahoula	hwy 472	Lower Fork of Log Bayou	Williana	080801020501
KNF145-0.7	2	Catahoula	556	Tributary of Indian Creek	Williana	080801020504
KNF145-0.9	1	Catahoula	hwy 472	Unnamed	Williana	080801020504
KNF178-0.9	1	Catahoula	163	Unnamed	Mudville	111402070410

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Table F3 (*continued*). Location of crossings surveyed on the Kisatchie National Forest in Louisiana, summer of 2007. Site ID consists of the Forest abbreviation (KNF), road the crossing is on (E046O), and the distance (miles) from the junction road (0.2).

Site ID	# Pipes	District	Junction Road	Stream Name	Quad	6th level watershed
KNF257-0.6	2	Calcasieu	121	Patterson Branch	Gardner	111402070410
KNF269-1.3	1	Calcasieu	267	Unnamed	Forest Hill	111402070410
KNFC008G-0.1	1	Catahoula	102	Tributary of Indian Creek	Mudville	111402070410
KNFC026C-0.1	1	Catahoula	C026E	Unnamed	Williana	111402070413
KNFC024A-0.7	1	Catahoula	167	Unnamed	Williana	111402070414
KNFC026A-0.1	1	Catahoula	hwy 167	Unnamed	Williana	111402070415
KNF167-1.8	1	Catahoula	hwy 524	Unnamed	Mudville	111402070417

Table F4. Coarse filters A, B, and C, classifications for surveyed crossings on the Kisatchie National Forest, summer 2007. At sites with multiple pipes, data are grouped by site ID and given the most favorable passage rating for each filter to determine passage status.

Site ID	Filter A	Filter B	Filter C
KNF120A-0.5	indeterminate	indeterminate	impassable
KNF130-1.3	passable	indeterminate	indeterminate
KNF133-1.5	passable	indeterminate	indeterminate
KNF145-0.4	impassable	impassable	impassable
KNF145-0.7	indeterminate	indeterminate	impassable
KNF145-0.9	passable	passable	passable
KNF145-1.0	indeterminate	impassable	impassable
KNF145-1.2	passable	passable	passable
KNF145-1.4	passable	impassable	impassable
KNF145-1.5	passable	passable	passable
KNF154-0.7	passable	passable	passable
KNF154-1.8	indeterminate	indeterminate	impassable
KNF167-0.5	indeterminate	indeterminate	impassable
KNF167-0.7	indeterminate	indeterminate	indeterminate
KNF167-1.4	passable	passable	passable
KNF167-1.8	passable	passable	impassable
KNF178-0.9	passable	indeterminate	indeterminate
KNF188-0.2	passable	passable	impassable
KNF188-0.8	impassable	impassable	impassable
KNF202-0.1	impassable	impassable	impassable
KNF212-2.3	indeterminate	impassable	impassable
KNF212-2.8	passable	passable	passable
KNF212-2.9	passable	passable	passable
KNF247-2.4	passable	passable	impassable
KNF257-0.6	passable	passable	passable
KNF269-1.3	indeterminate	indeterminate	impassable
KNF556-0.3	indeterminate	indeterminate	impassable
KNFC008G-0.1	passable	passable	passable
KNFC024A-0.7	passable	passable	passable
KNFC026A-0.1	passable	passable	indeterminate
KNFC026C-0.1	passable	impassable	impassable
KNFC057S-0.2	passable	impassable	impassable
KNFC071A-0.5	passable	passable	passable
KNFC083X-0.1	passable	passable	passable
KNFE018A-0.4	indeterminate	indeterminate	indeterminate
KNFE038C-0.2	passable	passable	passable
KNFE040B-0.4	passable	passable	passable
KNFE046O-0.2	indeterminate	impassable	impassable
KNFJ09-0.2	passable	passable	passable

Table F5. Description of crossings surveyed on the Kisatchie National Forest in Louisiana, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, F= ford, and O= Other. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site Id	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
KNF120A-.5	1	PA	poor	13.07	N	3.28	0.46	6.60	2.64	0	40.00	131.00
KNF130-1.3	1	C	fair	8.67	N	1.10	0.52	NA	-0.60	0	60.00	66.00
KNF130-1.3	2	C	fair	8.67	N	0.75	0.52	NA	-3.00	0	60.00	45.00
KNF133-1.5	1	PA	good	6.43	N	0.71	0.84	2.28	-5.04	0	45.00	32.00
KNF145-0.4	1	B	good	9.48	N	0.09	0.63	33.36	39.60	0	32.00	3.00
KNF145-0.4	2	B	fair	9.48	N	0.22	0.63	33.12	35.16	0	32.00	7.00
KNF145-0.4	1	PA	fair	6.58	N	2.52	0.55	-0.48	-1.56	0	87.00	219.00
KNF145-0.4	2	PA	fair	6.58	N	0.75	0.55	5.64	2.76	0	87.00	65.00
KNF145-0.7	1	C	fair	6.27	N	0.47	0.48	-0.24	2.28	2.28	36.00	17.00
KNF145-0.7	2	C	good	6.27	N	0.61	0.48	-6.36	-1.20	9	36.00	22.00
KNF145-0.9	1	C	good	7.02	N	1.72	0.97	12.84	5.16	0	72.00	124.00
KNF145-1.0	1	B	good	8.50	Y	0.57	0.59	-2.76	-2.16	4.80	30.00	17.00
KNF145-1.0	2	B	good	8.50	Y	0.07	0.59	-5.52	-4.08	5.28	30.00	2.00
KNF145-1.0	3	B	fair	8.50	Y	0.77	0.59	-2.04	-4.68	0	30.00	23.00
KNF145-1.4	1	PA	fair	7.92	N	0.15	0.76	13.32	8.64	0	75.00	11.00
KNF145-1.5	1	C	fair	6.63	N	1.61	0.45	-3.84	0.24	10.80	36.00	58.00
KNF145-1.5	2	C	fair	6.63	N	0.44	0.45	-5.64	-2.04	7.56	36.00	16.00
KNF154-0.7	1	C	fair	10.42	N	0.74	0.66	-9.00	-0.60	3.24	65.00	48.00
KNF154-1.8	1	C	good	6.93	N	3.42	0.85	-4.08	-6.36	0	45.00	154.00
KNF167-0.5	1	C	fair	5.30	N	2.07	0.38	9.60	4.20	0	42.00	87.00

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Table F5 (*continued*). Description of crossings surveyed on the Kisatchie National Forest in Louisiana, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, F= ford, and O= Other. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site Id	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
KNF167-0.5	2	C	fair	5.30	N	1.26	0.38	6.36	0.00	0	42.00	53.00
KNF167-0.7	1	C	good	7.83	N	1.39	0.64	NA	0.36	0	51.00	71.00
KNF167-0.7	2	C	good	7.83	N	1.61	0.64	NA	-0.12	0	51.00	82.00
KNF167-1.4	1	C	good	11.12	Y	1.91	1.24	-5.76	-8.88	0	44.00	84.00
KNF167-1.8	1	C	good	7.57	N	0.24	0.86	NA	2.16	0	51.00	12.00
KNF178-0.9	1	C	good	8.38	N	0.60	0.48	-1.80	3.12	0	57.00	34.00
KNF188-0.2	1	C	good	9.02	N	0.06	0.57	8.04	7.92	0	51.00	3.00
KNF188-0.2	2	C	good	9.02	N	1.02	0.57	1.68	0.12	0	51.00	52.00
KNF188-0.8	1	C	fair	7.87	N	0.02	0.71	34.32	16.92	0	51.00	1.00
KNF202-0.1	1	B	fair	12.27	N	1.31	0.82	41.04	32.64	0	75.00	98.00
KNF202-0.1	2	B	fair	12.27	N	1.32	0.82	41.40	33.00	0	75.00	99.00
KNF212-2.3	1	C	good	6.10	N	4.44	0.87	13.68	10.56	0	32.00	142.00
KNF212-2.8	1	C	fair	19.72	N	0.18	0.25	-0.72	-1.20	0.12	28.00	5.00
KNF212-2.8	2	C	fair	19.72	N	1.04	0.25	-1.20	-1.68	0	28.00	29.00
KNF212-2.9	1	C	good	14.97	N	0.12	0.30	-1.08	-0.12	0.60	33.00	4.00
KNF212-2.9	2	C	good	14.97	N	0.15	0.30	-1.80	-0.84	2.40	33.00	5.00
KNF247-2.4	1	C	fair	10.87	N	0.73	0.55	6.36	5.88	0	15.00	11.00
KNF247-2.4	2	C	fair	10.87	N	1.93	0.55	8.64	3.00	0	15.00	29.00
KNF257-0.6	1	C	poor	11.60	N	4.39	0.30	0.72	-3.72	14.04	28.00	123.00
KNF257-0.6	2	C	poor	11.60	N	2.25	0.30	-15.36	-9.72	22.92	28.00	63.00
KNF269-1.3	1	C	good	9.25	N	0.82	0.65	4.80	-4.08	0	66.00	54.00

Table continued on next page…

Table F5 (*continued*). Description of crossings surveyed on the Kisatchie National Forest in Louisiana, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, F= ford, and O= Other. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site Id	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe Slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
KNF556-0.3	1	C	fair	2.93	N	2.47	0.68	6.48	0.36	0	40.00	99.00
KNFC008G-0.1	1	C	fair	7.08	N	2.08	0.28	-5.52	4.08	11.52	24.00	50.00
KNFC024A-0.7	1	C	fair	4.98	N	0.00	0.68	NA	0.36	0	24.00	0.00
KNFC026A-0.1	1	C	good	10.72	N	0.40	0.56	NA	0.84	0	63.00	25.00
KNFC026C-0.1	1	C	fair	5.28	N	0.48	0.74	17.16	-3.00	0	54.00	26.00
KNFC057S-0.2	1	C	fair	5.18	N	0.22	0.39	21.12	36.48	0	36.00	8.00
KNFC071A-0.5	1	PA	fair	7.97	N	2.21	0.78	-1.56	2.04	11.88	39.00	86.00
KNFC083X-0.1	1	C	fair	15.50	N	0.46	0.50	-0.84	-4.44	0	24.00	11.00
KNFE018A-0.4	1	C	fair	7.02	N	3.32	0.43	3.36	-4.80	0	25.00	83.00
KNFE038C-0.2	1	C	good	6.55	N	0.81	0.69	2.64	-0.48	0.84	36.00	29.00
KNFE038C-0.2	2	C	good	6.55	N	0.31	0.69	2.52	-0.60	0	36.00	11.00
KNFE040B-0.4	1	C	fair	10.45	N	0.16	0.32	-12.24	-7.56	11.76	24.70	4.00
KNFE040B-0.4	2	C	fair	10.45	N	1.42	0.32	-9.00	-2.28	13.20	24.70	35.00
KNFE046O-0.2	1	C	poor	6.70	N	3.26	0.79	11.88	17.04	0	66.00	215.00
KNFJ09-0.2	1	C	fair	4.87	N	0.25	1.23	-0.12	16.32	1.20	36.00	9.00
KNFJ09-0.2	2	C	fair	4.87	N	0.89	1.23	1.44	-2.88	0	37.00	33.00

Appendix G: Results for the George Washington-Jefferson National Forest

We completed surveys at 12 (100%) of 12 documented crossings on the Eastern Divide Ranger District in 2007 (Figure G1, Tables G1 and G2). Filter A (strong swimmers and leapers) classified 66% (n=8) of crossings as impassable, 17% (n=2) as passable, and 17% (n=2) as indeterminate (Figure G2, Table G2). Filter B (moderate swimmers and leapers) classified 92% (n=11) of crossings as impassable, 8% (n=1) as passable, and 0% (n=0) as indeterminate (Figure G2, Table G2). Filter C (weak swimmers and leapers) classified 100% (n=12) of crossing as impassable, 0% (n=0) as passable, and 0% (n=0) as indeterminate (Figure G2, Table G2). Characteristics and filter classifications for each crossing are presented in Tables G3-G5.

The majority of the crossings surveyed were circular culverts (100%, n=12). Box culverts, pipe arches, vented fords, fords and open bottom arches were not encountered during surveys conducted in 2007. Filter A classified 66% of circular culverts, as impassable (Figure F3). Filter B classified 98% of circular culverts as impassable (Figure F3). Filter C classified 39% of circular culverts, 67% of box culverts, and 60% of pipe arches as impassable (Figure F3). The mean crossing width to channel width ratio (excluding fords, vented fords, and multiple structure crossings) was 0.53 ± 0.17 (mean ± SD) (n=10) (Figure F4). The mean crossing width to channel width ratio for surveyed crossings classified impassable by Filter A was 0.57 ± 0.20 (n=6). The mean ratio for crossings classified impassable by Filter B was 0.53 ± 0.17 (n=10), and was 0.53 ± 0.17 (n=10) for Filter C (Figure F5). The sample size was insufficient to calculate mean crossing width to channel width ratio for surveyed crossings classified passable by Filter A, Filter B, and Filter C (Figure F5).

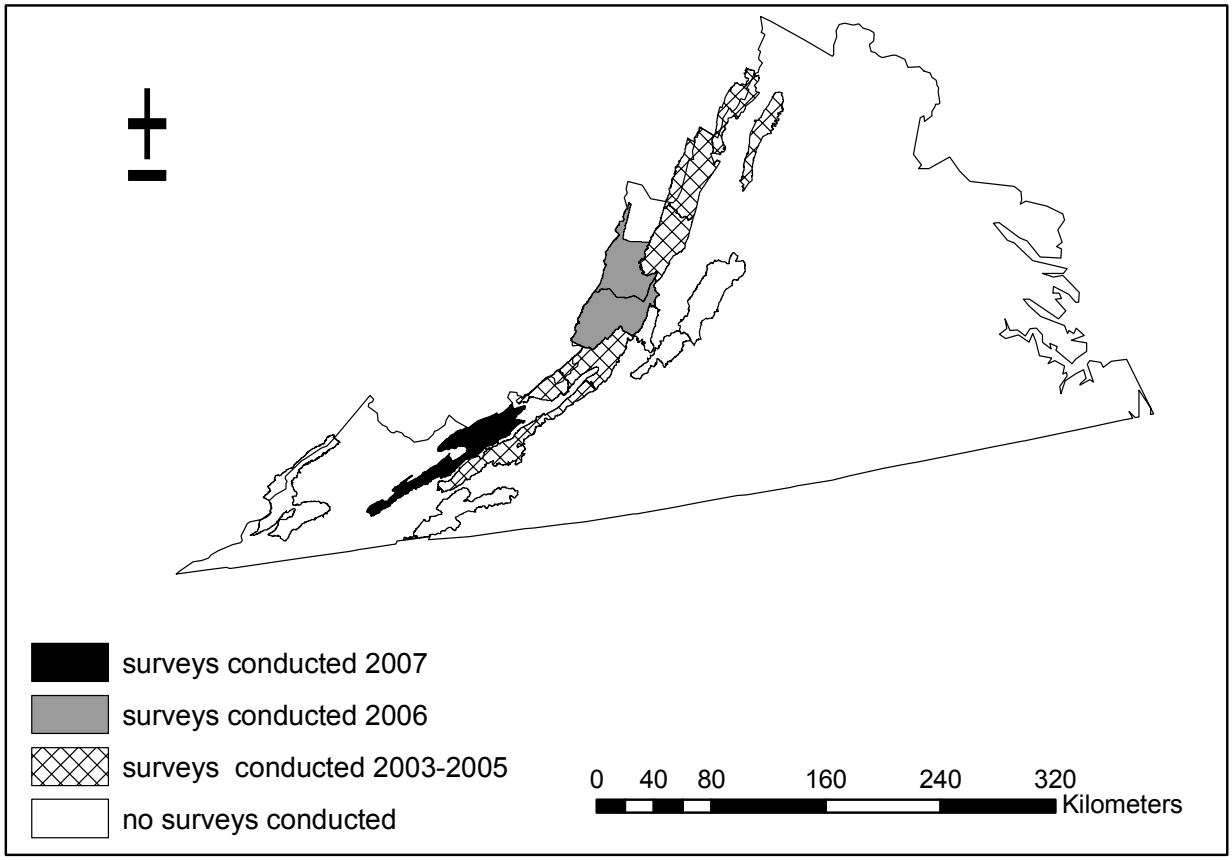

Figure G1. Districts on the George Washington-Jefferson National Forest, Virginia where road-stream crossing surveys were conducted from 2003 to 2006. (Previous data can be found in Coffman et al. 2005 and Coffman et al. 2006)

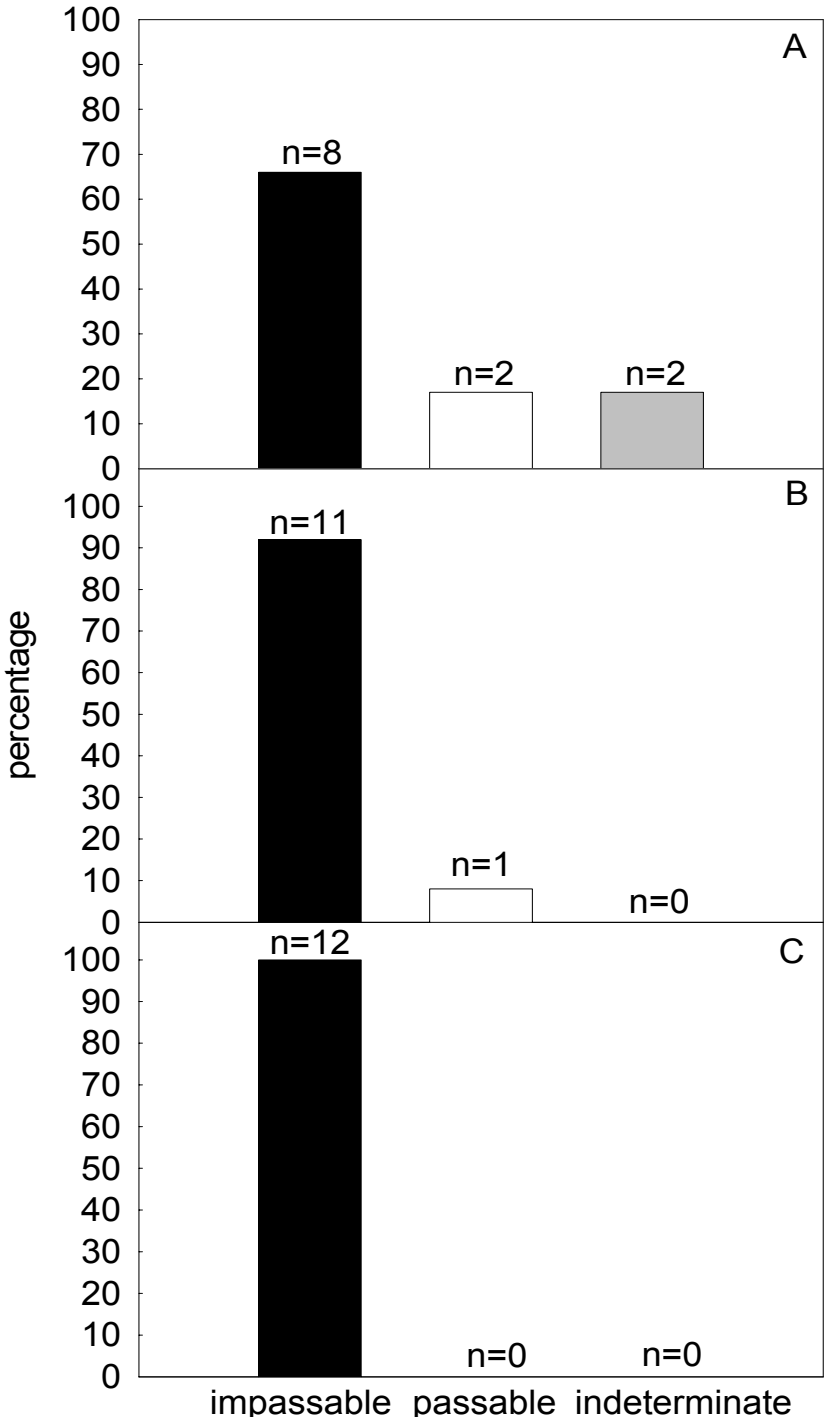

Figure G2. Percentage of crossings classified as impassable, passable, or indeterminate for Filter A, B, and C; George Washington-Jefferson National Forest, Virginia, summer 2007 (N=12).

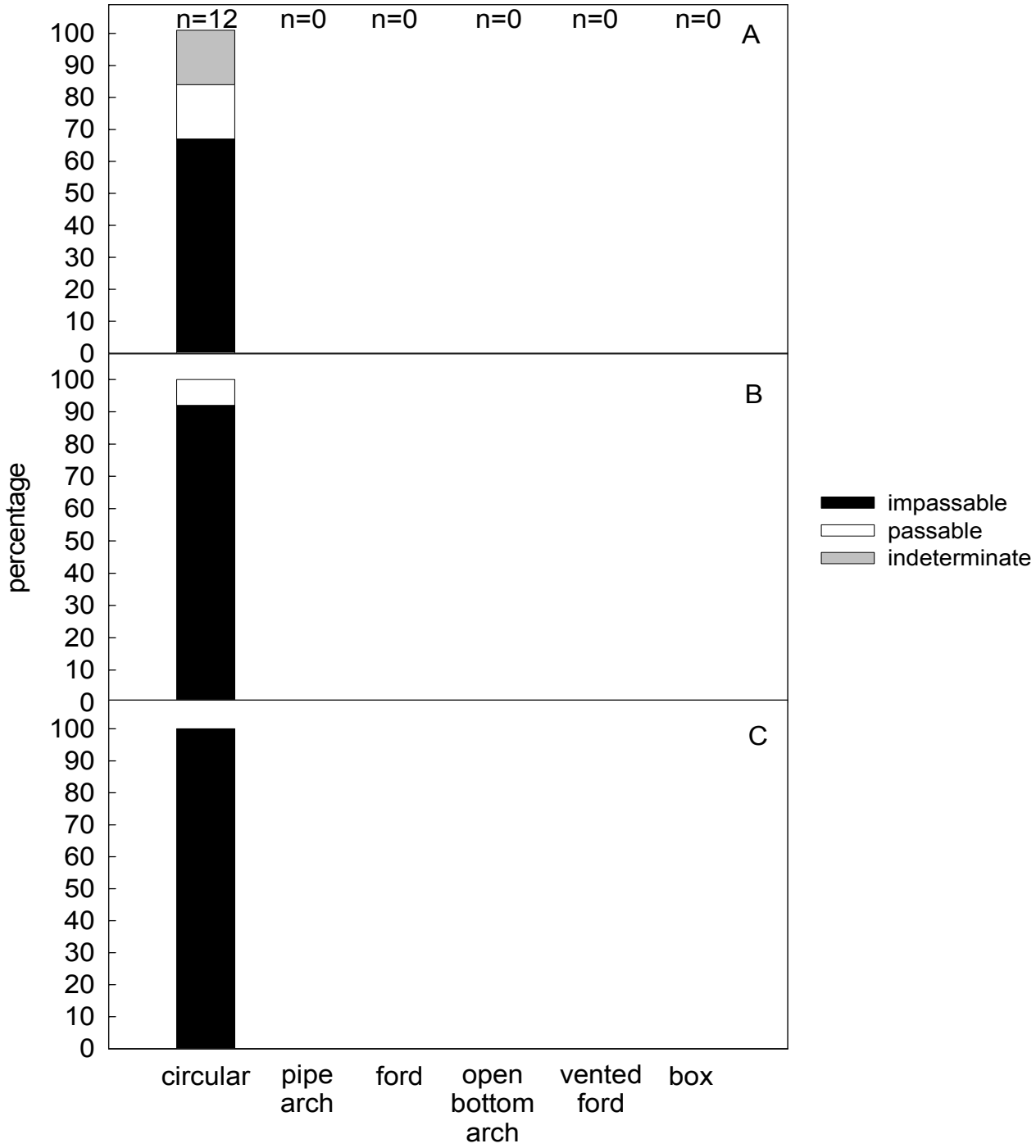

Figure G3. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter A, B, and C; George Washington-Jefferson National Forest, Virginia, summer 2007 (N=12).

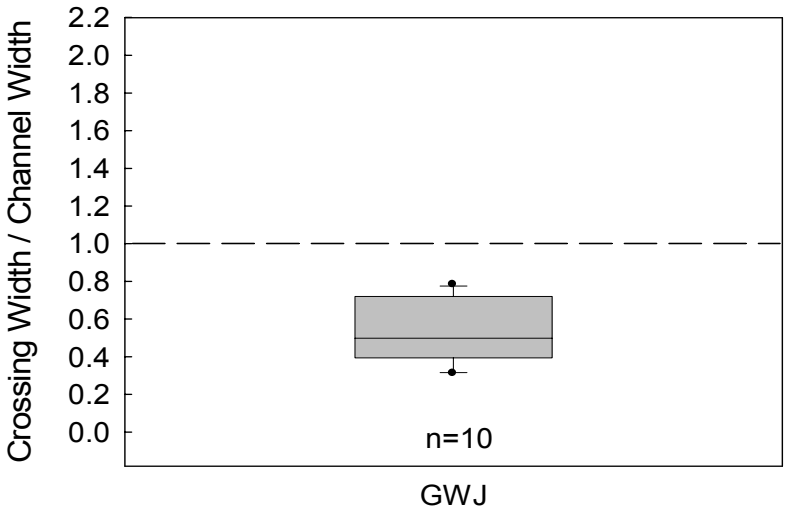

Figure G4. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2007 on the George Washington-Jefferson National Forest in Virginia (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

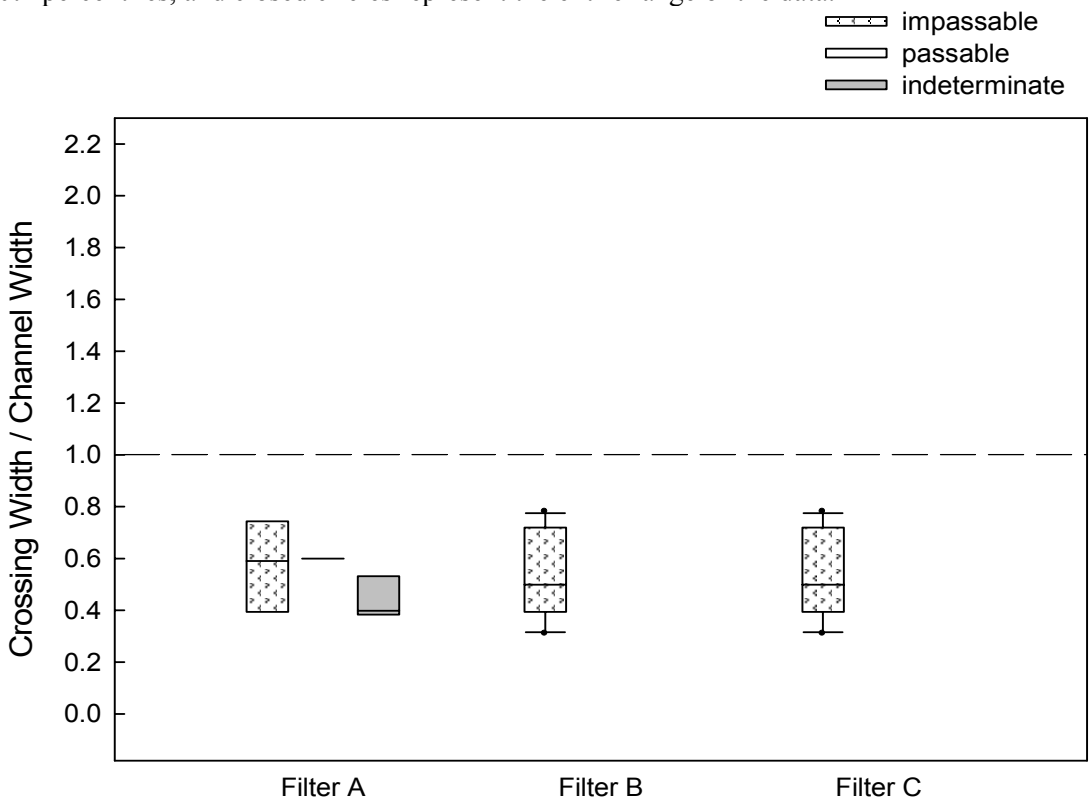

Figure G5. Crossing width to bankfull channel width ratio for crossings classified impassable, passable, or indeterminate in summer 2007 on the George Washington-Jefferson National Forest in Virginia (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The symbol inside each set of whiskers represents the median, and the top and bottom of the whiskers represent the maximum and minimum values.

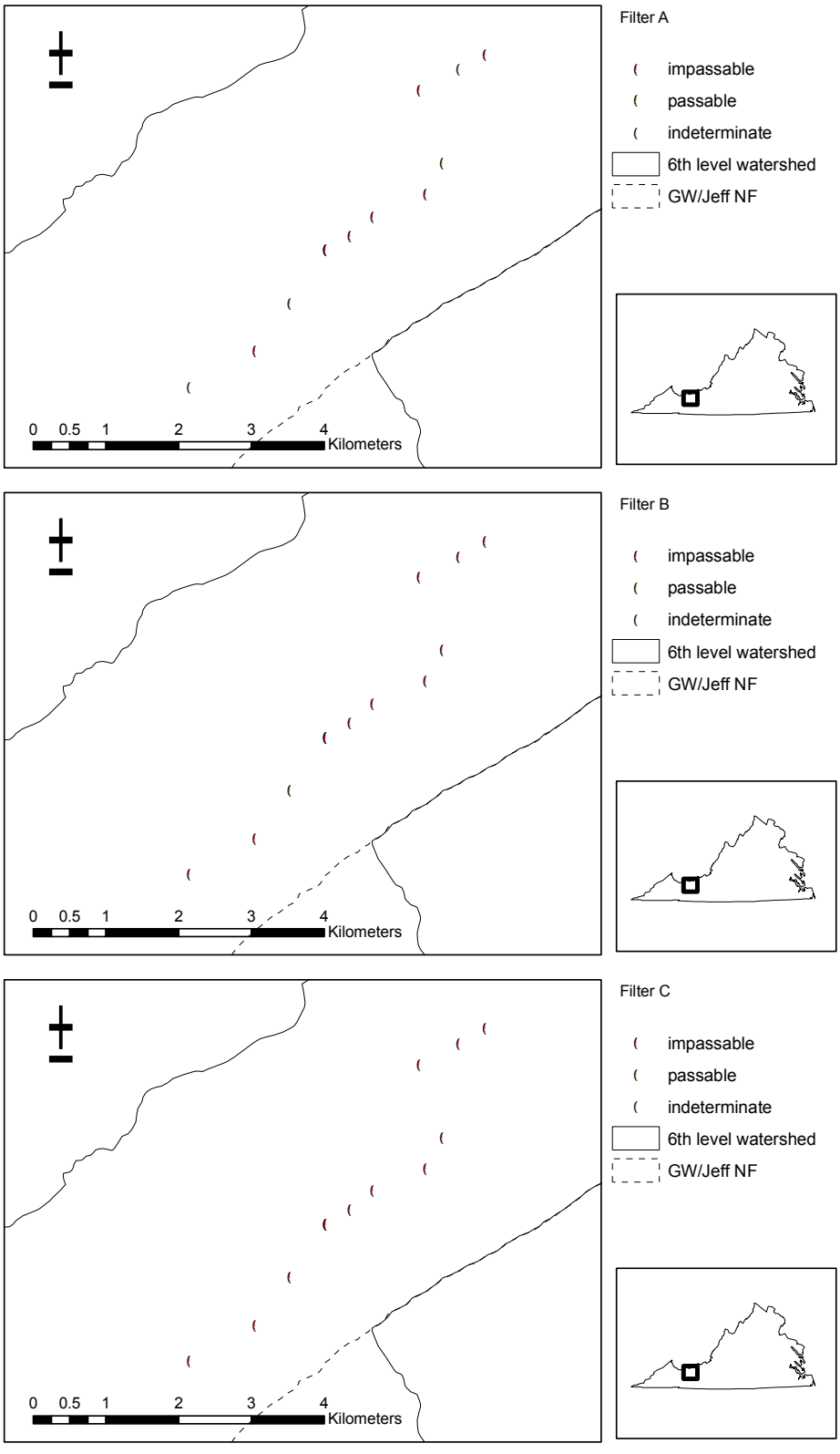

Figure G6. Location of crossings classified for fish passage by coarse filters A, B, and C within 6th level watersheds on the George Washington-Jefferson National Forest, summer 2007.

Table G1. Number of crossings documented (Total crossings documented) and not surveyed (Crossings not surveyed) on the George Washington-Jefferson National Forest in Virginia, summer 2007. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossings documented	Crossings not surveyed (n,[%])				
		NH	NA	NF	BR	Total not surveyed
GWJ	12	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table G2. Number of crossings surveyed (Total surveyed) with coarse filter results for the George Washington-Jefferson National Forest in Virginia, summer 2007. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse Filter Results								
		Impassable (n,[%])			Passable (n,[%])			Indeterminate (n,[%])		
		A	B	C	A	B	C	A	B	C
GWJ	12	8 (66)	11 (92)	12 (100)	2 (17)	1 (8)	0 (0)	2 (17)	0 (0)	0 (0)

Table G3. Location of crossings surveyed on the George Washington-Jefferson National Forest in Virginia, summer of 2007. Site ID consists of the Forest abbreviation (GWJ), road the crossing is on (1015), and the distance (miles) from the junction road (1.7).

Site ID	# Pipes	District	Junction Road	Stream Name	Quad	6th Level Watershed
GWJ1015-1.7	2	Eastern Divide	201	Unnamed tributary of Dismal Creek	White Gate	050500020105
GWJ201-1.2	1	Eastern Divide	606	Dismal Creek	Mechanicsburg	050500020105
GWJ201-1.9	1	Eastern Divide	606	Standrock Branch	Mechanicsburg	050500020105
GWJ201-3.2	1	Eastern Divide	606	Dismal Creek	Mechanicsburg	050500020105
GWJ201-3.3	1	Eastern Divide	606	Unnamed tributary of Dismal Creek	Mechanicsburg	050500020105
GWJ201-3.5	1	Eastern Divide	606	Tributary 7	Mechanicsburg	050500020105
GWJ201-3.8	1	Eastern Divide	606	Tributary 8	White Gate	050500020105
GWJ201-4.3	1	Eastern Divide	606	Tributary 9	White Gate	050500020105
GWJ606-4.0	1	Eastern Divide	606	Unnamed tributary of Dismal Creek	White Gate	050500020105
GWJ606-5.8	1	Eastern Divide	606	Unnamed tributary of Dismal Creek	White Gate	050500020105
GWJ606-6.3	1	Eastern Divide	606	Unnamed tributary of Dismal Creek	White Gate	050500020105
GWJ606-6.7	2	Eastern Divide	606	Unnamed tributary of Dismal Creek	White Gate	050500020105

Table G4. Coarse filters A, B, and C, classifications for surveyed crossings on the George Washington-Jefferson National Forest in Virginia, summer 2007. At sites with multiple pipes, data are grouped by site ID and given the most favorable passage rating for each filter to determine passage status.

Site ID	Filter A	Filter B	Filter C
GWJ1015-1.7	passable	passable	impassable
GWJ201-1.2	impassable	impassable	impassable
GWJ201-1.9	indeterminate	impassable	impassable
GWJ201-3.2	indeterminate	impassable	impassable
GWJ201-3.3	impassable	impassable	impassable
GWJ201-3.5	impassable	impassable	impassable
GWJ201-3.8	passable	impassable	impassable
GWJ201-4.3	indeterminate	impassable	impassable
GWJ606-4.0	impassable	impassable	impassable
GWJ606-5.8	impassable	impassable	impassable
GWJ606-6.3	impassable	impassable	impassable
GWJ606-6.7	impassable	impassable	impassable

Table G5. Description of crossings surveyed on the George Washington-Jefferson National Forest in Virginia, summer 2007. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, F= ford, and O= Other. Channel width is the mean bankfull channel width. 0= no natural substrate, 1= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
GWJ1015-1.7	1	circular	good	8.63	N	4.08	0.17	-2.64	-2.58	12.72	20.60	84.00
GWJ1015-1.7	2	circular	good	8.63	N	2.92	0.17	-3.06	-3.00	10.38	20.90	61.00
GWJ201-1.2	1	circular	good	14.92	N	14.47	0.31	12.24	9.48	0	76.10	1101.50
GWJ201-1.9	1	circular	good	11.73	N	4.14	0.38	21.12	19.26	0	63.30	262.00
GWJ201-3.2	1	circular	good	7.53	N	3.95	0.40	18.48	16.32	0	66.90	264.00
GWJ201-3.3	1	circular	fair	5.15	N	9.33	0.47	13.32	13.80	0	75.42	703.50
GWJ201-3.5	1	circular	good	4.73	N	7.09	0.42	8.88	4.38	0	53.00	376.00
GWJ201-3.8	1	circular	good	5.92	N	0.68	0.60	16.08	12.72	0	56.90	38.50
GWJ201-4.3	1	circular	good	7.33	N	3.42	0.53	-1.98	-5.64	0	58.90	201.50
GWJ606-4.0	1	circular	good	4.10	N	7.64	0.73	3.36	1.80	0	45.30	346.00
GWJ606-5.8	1	circular	other	6.42	N	11.29	0.78	NA	34.44	0	50.10	565.50
GWJ606-6.3	1	circular	good	8.38	N	7.95	0.72	37.26	30.00	0	44.30	352.00
GWJ606-6.7	1	circular	poor	6.85	N	8.45	0.58	11.76	9.24	0	40.70	344.00
GWJ606-6.7	2	circular	poor	6.85	N	7.05	0.58	14.22	10.92	0	40.00	282.00