North Atlantic Aquatic Connectivity Collaborative (NAACC)

Aquatic Passability Scoring Systems for Tidal Stream Crossings

June 4, 2021

The aquatic passability assessment protocol and scoring systems were developed to complement an existing protocol developed for road-stream crossings on non-tidal streams. It is particularly challenging to assess aquatic passability for tidal streams because daily fluctuations in water levels and flow characteristics mean that, for some streams, barrier effects may vary greatly throughout a single day. Conditions that would be impassable at low tide might be fine at high tide.

The Technical Advisory Committee that guided the development of the tidal stream crossing assessment protocol and scoring system weighed the costs and benefits of basing assessments on a single visit vs. multiple visits (e.g. to assess conditions at multiple points in the tide cycle). The consensus of the group was that a protocol based on a single visit would be more likely to be used, and used more widely, than a multiple-visit protocol. Thus, the metrics used in these scoring systems utilize data that can be reasonably gathered during a single visit at low tide. Some variables are estimates of conditions at high tide, based on water staining observable at low tide in and around the crossing structures.

There are two scoring systems in use for tidal stream crossings: 1) a coarse screen that assigns each crossing to one of four classifications (No AOP, Poor AOP, Moderate AOP, Good AOP) and 2) a numeric scoring system that scores crossings on a continuous scale ranging from 0 (no passage) to 1 (full passage).

Coarse Screen

The Tidal Crossings Coarse Screen is a method for identifying those crossings that provide good passage for aquatic organisms (“Good AOP”) and those that essentially provide no aquatic organism passage (“No AOP”) or that provide reduced AOP. Crossings that are classified as “Good AOP” are assumed to provide passage for a wide range of species throughout the year (e.g. during periods of low and high flows). Those classified as “No AOP” are assumed to provide little or no passage for aquatic species at any point in the year. There are two categories that are intermediate between good passage and no passage: “Poor AOP” and “Moderate AOP.”

		Crossing Classification			
		Good AOP	**Moderate AOP**	**Poor AOP**	**No AOP**
Metric	**Flow Condition**	*If all are true*	*If not RED or Orange and any are true*	*If not RED and any are true*	*If any are true*
Constriction ratio		≥ 1.5	≤ 1.5		
Tidal constriction		≥ 1.0	≤ 1.0		
Water depth	High tide	≥ 1.0	0.4 – 0.99	< 0.4	
Inlet perch	Low tide	0 ft.	≤ 1.0 ft.		
Inlet perch	High tide	0 ft.	0 ft.	0 < x < 2.5 ft.	> 2.5 ft.
Outlet perch	Low tide	0 ft.	< 0.25 ft.		
Outlet perch	High tide	0 ft.	0 ft.	0 < x < 2.5 ft.	> 2.5 ft.
Tide gate barrier severity		No tide gate	Minor or moderate	Severe	No aquatic passage
Other physical barrier severity		No barrier	Minor or moderate	Severe	No aquatic passage

Numeric Scoring System

The Tidal Crossings Numeric Score is a continuous range of scores from 0 (no passage) to 1 (full passage). Passability is a function of three elements that are difficult to measure but that make up the conceptual basis for the numeric scoring system: 1) proportion of species able to pass, 2) proportion of individuals able to pass (includes variability in size and life stage), and 3) proportion of the year that the crossing is passable.

The numeric scoring algorithm is based on the opinions of experts who decided both the relative importance of all the available predictors of passability as well as a way to score each predictor. Scoring involves five steps:

(1) generating a component score for each predictor variable,
(2) selecting which of the predictor variables to include in the scoring algorithm for each type of tidal stream,
(3) combining the selected predictor variables with a weighted average to generate a composite score for the crossing,
(4) determining predictor variables that will be considered limiting, and
(5) assigning a final score based on the minimum score from among the composite score and each of the component scores for limiting variables.

The numeric scoring system uses many variables and most variables have only a limited effect on the overall passability score. Some variables, such as outlet drop and physical barriers, directly relate to passability. Others are indirect indicators of conditions at other points in the tide cycle or other seasons of the year. For example, the presence of scour pools or armoring suggests that high flows may be present at mid-tide or during periods of high freshwater discharge.

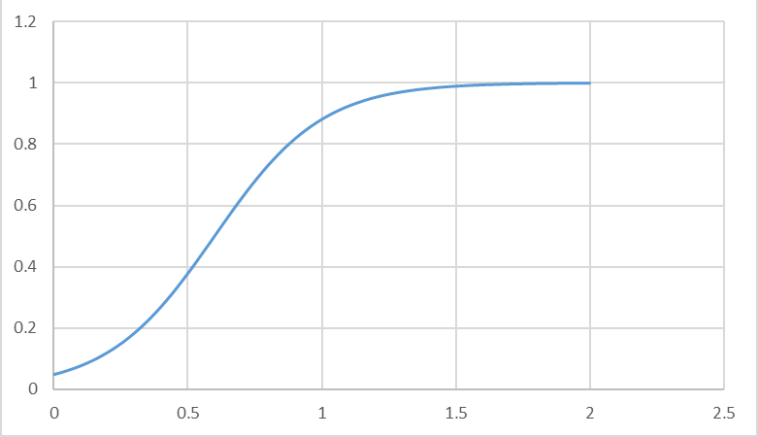
It is recognized that with so many variables, there will be a significant amount of correlation among them. The Technical Advisory Committee took this into account when assigning weights to the metrics for computing composite scores. We believe that redundancies in the metrics help to ensure that mistakes made in assessing individual metrics will not radically alter the final passability scores.

Four metrics are considered "limiting variables" and do have the potential to significantly affect the final passability score. These variables (inlet perch at high tide, outlet perch at high tide, tide gate severity, and other physical barrier severity) are considered so important for determining passabiltity that if any one of them has a component score lower than the composite score, the lowest component score will be used to score the structure.

This numeric scoring approach aims to identify an ideal crossing (one that scores 1.0 for each of the selected variables) so that, for crossings that lack a fatal flaw (e.g. a tide gate that presents a severe barrier or blocks all aquatic passage) a weighted average of component scores will serve to quantify how much each crossing deviates from the ideal. The selection of limiting variables serves to identify fatal flaws that should result in low overall scores even if the composite score is not that bad.

Step 1: Following are the component scoring systems for each of the predictor variables (metrics). These are variables that were identified by the Technical Advisory Committee as having some direct or indirect relationship with aquatic passability.

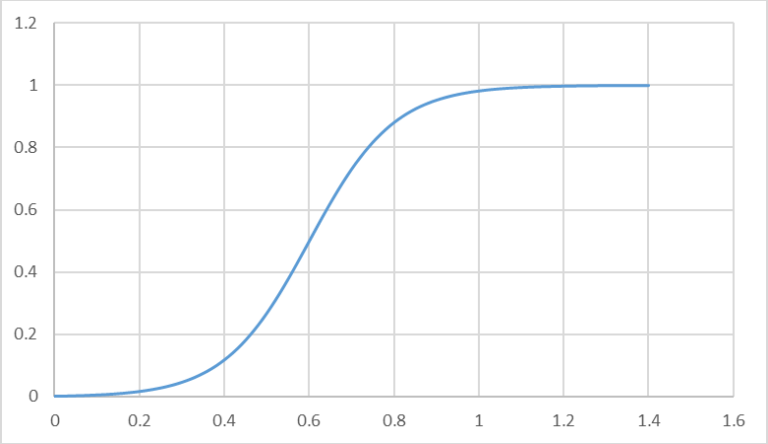
1. Constriction ratio: combined structure width divided by channel width (an indirect indicator of tidal restriction and potential velocity problems; tidal restrictions may indicate potential for biochemical barriers, such as salinity, dissolved oxygen, temperature, or pH)



$$Y = \frac{1}{1 + e^{(-5.0\ (X - 0.6))}}$$

Constriction ratio (continuous)	Score
0.3	0.18
0.6	0.50
1.0	0.88
1.5	0.99

2. Tidal constriction: upstream tidal range divided by downstream tidal range (an indicator of tidal restriction, which may also indicate potential biochemical barriers, such as salinity, dissolved oxygen, temperature, or pH).



$$Y = \frac{1}{1 + e^{(-10.0\ (X - 0.6))}}$$

Tidal Constriction (continuous)	Score
0.25	0.03
0.50	0.27
0.75	0.82
1.00	0.98

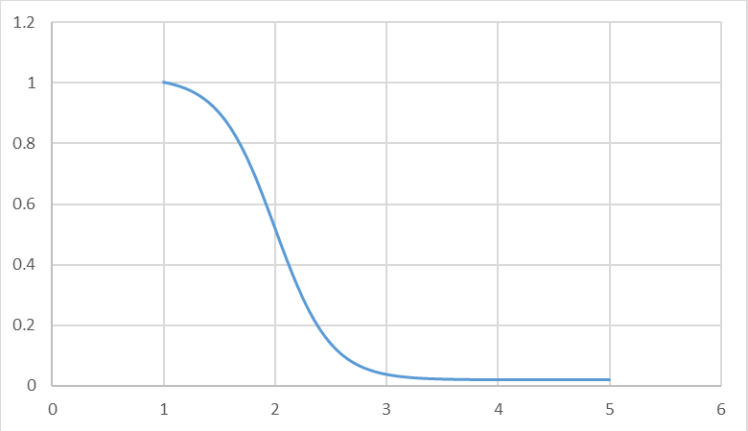
3. Vegetation change: upstream vs. downstream (an indirect indicator of tidal restriction, which may also indicate potential biochemical barriers, such as salinity, dissolved oxygen, temperature, or pH)

Vegetation change (categorical)	Score
Comparable	1.0
Slightly different	0.8
Moderately different	0.4
Very different	0.0
Unknown	No score

4. Ratio of high tide water depth in the structure relative to water depth in the downstream channel (water depth influences which species or what size organisms are able to pass through the structure)

High Tide Water Depth (categorical)	Score
< 0.10	0.0
0.10 – 0.24	0.2
0.25 – 0.49	0.4
0.50 – 0.74	0.6
0.75 – 0.99	0.8
≥ 1.0	1.0

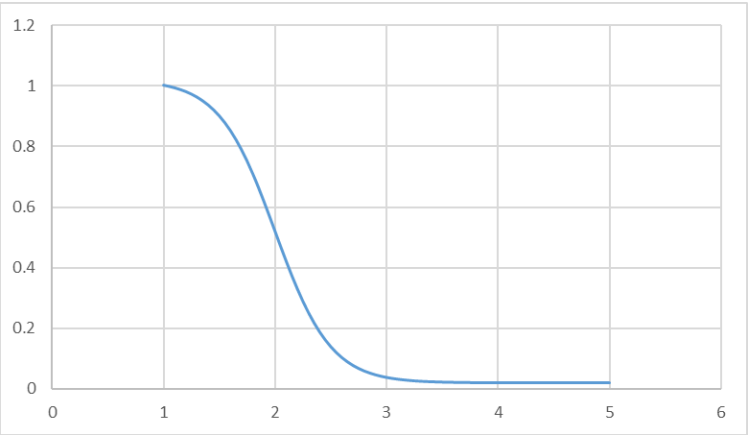
5. Downstream scour: downstream pool width divided by downstream channel width (an indirect indicator of potential velocity problems)



$$Y = \frac{1}{1 + e^{(4.0\ (X - 2.0))}}$$

Downstream scour (continuous)	Score
1.0	1.00
2.0	0.50
2.5	0.14
3.0	0.04
4.0	0.02

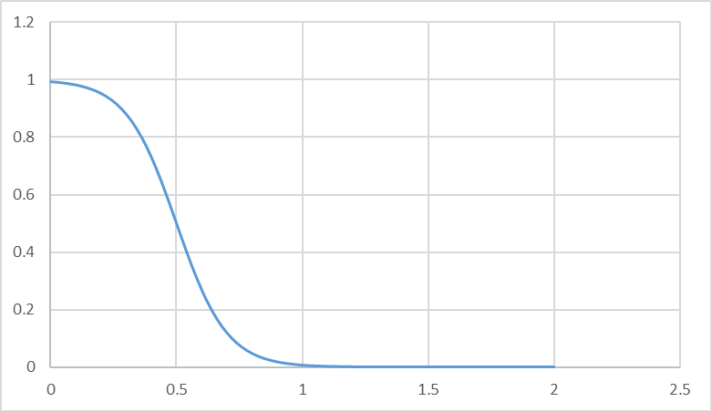
6. Upstream scour: upstream pool width divided by upstream channel width (an indirect indicator of potential velocity problems)



$$Y = \frac{1}{1 + e^{(4.0\ (X - 2.0))}}$$

Upstream scour (continuous)	Score
1.0	1.00
2.0	0.50
2.5	0.14
3.0	0.04
4.0	0.02

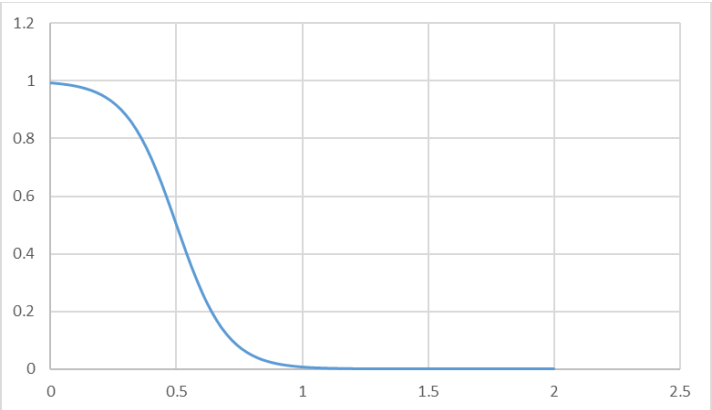
7. Inlet perch at low tide relative to tidal range (such a perch would likely prevent downstream movement at low tide)



$$Y = \frac{1}{1 + e^{(10.0\ (X - 0.5))}}$$

Low tide inlet perch (continuous)	Score
0.00	0.99
0.25	0.92
0.50	0.50
0.75	0.07
1.00	0.01

8. Outlet perch at low tide relative to tidal range (an outlet perch at low tide would create a barrier to upstream passage at or around slack tide, a time when water velocities would be low)



$$Y = \frac{1}{1 + e^{(10.0\ (X - 0.5))}}$$

Low tide outlet perch (continuous)	Score
0.00	0.99
0.25	0.92
0.50	0.50
0.75	0.07
1.00	0.01

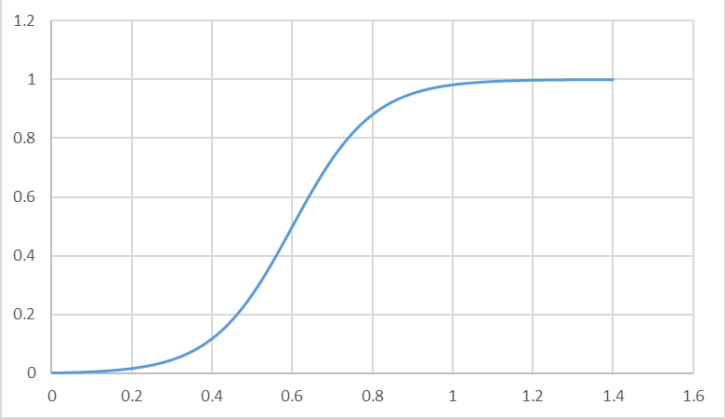
9. Inlet armoring (an indirect indicator of potential velocity problems at higher flows; armoring is often used to prevent scour due to high velocity flows)

Inlet armoring (categorical)	Score
None	1.0
Not extensive	0.5
Extensive	0.0

10. Outlet armoring (an indirect indicator of potential velocity problems at higher flows; armoring is often used to prevent scour due to high velocity flows)

Outlet armoring (categorical)	Score
None	1.0
Not extensive	0.5
Extensive	0.0

11. Crossing openness: cross-sectional area of the structure opening at low tide, divided by structure length (some organisms can be affected by darkness or how confining a structure feels when openness is low)



$$Y = \frac{1}{1 + e^{(-10.0\ (X - 0.6))}}$$

Openness (continuous)	Score
0.3	0.05
0.6	0.50
0.9	0.95
1.0	0.98

12. Substrate comparability (for benthic organisms)

Substrate comparability (categorical)	Score
Comparable	1.0
Contrasting	0.5
Not appropriate	0.0
None	0.0
Unknown	No score

13. Substrate coverage (for benthic organisms and as an indirect indicator of potential velocity problems)

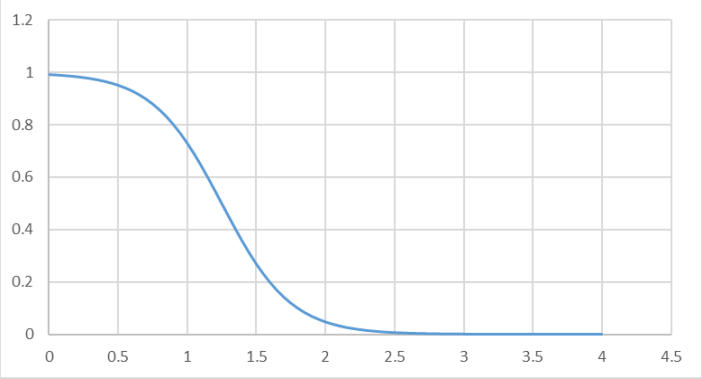
Substrate coverage (categorical)	Score
100 %	1.0
75-99 %	0.8
50-75 %	0.5
25-50 %	0.2
None	0.0
Unknown	No score

Steps 2 & 3: Selecting and Weighting Variables. For each of the tidal crossing types, the table below identifies variables for inclusion in the scoring system and how they are weighted to create a composite score. The weights are based on best professional judgement and assigned by members of the Technical Advisory Committee. Weights from individual Advisory Committee members were averaged and are listed to two decimal places, not because we have confidence in values to that level of precision, but to avoid additional errors/uncertainty in the scoring model due to rounding.

Variable	Salt marsh creek	Salt/brackish flow-through river/stream	Freshwater tidal river/stream
Constriction ratio	11.84	14.93	18.18
Tidal constriction	19.58	20.04	10.49
Vegetation change: upstream vs. downstream	14.32	8.07	4.90
Water depth at high tide	2.41	2.55	2.45
Downstream scour	5.84	6.22	6.64
Upstream scour	5.84	6.22	4.90
Inlet perch at low tide	3.51	5.45	5.94
Outlet perch at low tide	9.81	10.95	11.19
Inlet armoring	4.01	1.47	3.15
Outlet armoring	3.53	1.11	4.20
Crossing openness	9.97	9.51	16.08
Substrate comparability	4.88	7.31	5.94
Substrate coverage	4.47	6.18	5.94
Total	**100**	**100**	**100**

Step 4: Limiting Variables. A limiting variable is one that is so important that its score should take precedence if it is lower than the composite score (weighted average). Limiting variable were identified by consensus of the Technical Advisory Committee. All three tidal crossing types have the same four limiting variables.

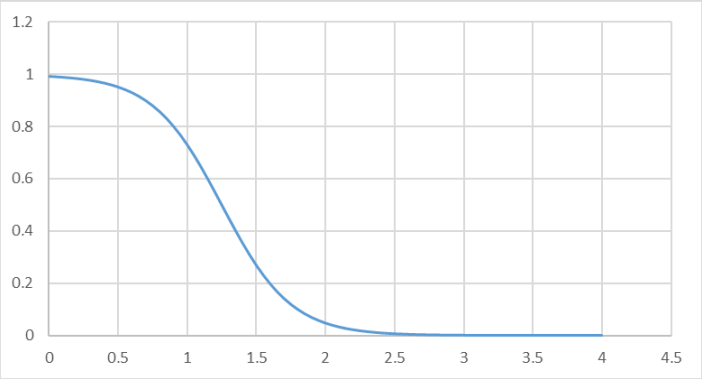
14. Inlet perch at high tide (an inlet perch at high tide would be expected to prevent downstream movement throughout the tide cycle)



$$Y = \frac{1}{1 + e^{(4.0\ (X - 1.25))}}$$

High tide inlet perch (continuous)	Score
0.50 ft.	0.95
1.00 ft.	0.73
1.25 ft.	0.50
2.00 ft.	0.05
2.50 ft.	0.01

15. Outlet perch at high tide (an outlet perch at high tide indicates that the structure is a barrier to upstream passage throughout the tide cycle)



$$Y = \frac{1}{1 + e^{(4.0\ (X - 1.25))}}$$

High tide outlet perch (continuous)	Score
0.50 ft.	0.95
1.00 ft.	0.73
1.25 ft.	0.50
2.00 ft.	0.05
2.50 ft.	0.01

16. Tide gate barrier severity (tide gates often present significant physical barriers, blocking upstream movement of aquatic organisms). Coordinator review and approval/revision is required for tide gate severity.

Tide gates (categorical)	Score
No tide gate	1.0
Minor	0.8
Moderate	0.5
Severe	0.2
No aquatic passage	0.0

17. Other physical barrier severity (other physical barriers can block upstream and/or downstream movement of aquatic organisms)

Physical barriers (categorical)	Score
No physical barrier	1.0
Minor	0.8
Moderate	0.5
Severe	0.2
No aquatic passage	0.0

Step 5: Final Passability Score. The final passability score for all three tidal crossing types is the lowest among the component scores for limiting variables and the composite score.

Final Score = Min[composite score, inlet perch at high tide score, outlet perch at high tide score, tide gate barrier severity score, other physical barrier severity score]

Appendix A: Comparison Tidal Scoring Systems with the Aquatic Passability Scoring Systems for Non-tidal Stream Crossings

Non-tidal Aquatic Organism Passage Coarse Screen

Metric	Flow Condition	Crossing Classification		
		Full AOP	Reduced AOP	No AOP
		If all are true	*If any are true*	*If any are true*
Inlet Grade		At Stream Grade	Inlet Drop or Perched	
Outlet Grade		At Stream Grade		Cascade, Free Fall onto Cascade
Outlet Drop to Water Surface		= 0		≥ 1 ft
Outlet Drop to Water Surface/ Outlet Drop to Stream Bottom				> 0.5
Inlet or Outlet Water Depth	Typical-Low	> 0.3 ft		< 0.3 ft w/Outlet Drop to Water Surface > 0
	Moderate	> 0.4 ft		< 0.4 ft w/Outlet Drop to Water Surface > 0
Structure Substrate Matches Stream		Comparable or Contrasting		
Structure Substrate Coverage		100%	< 100%	
Physical Barrier Severity		None	Minor or Moderate	Severe

Tidal Aquatic Organism Passage Coarse Screen

Metric	Flow Condition	Crossing Classification			
		Good AOP	Moderate AOP	Poor AOP	No AOP
		If all are true	*If not RED or Orange and any are true*	*If not RED and any are true*	*If any are true*
Constriction ratio		≥ 1.5	≤ 1.5		
Tidal constriction		≥ 1.0	≤ 1.0		
Water depth	High tide	≥ 1.0	0.4 – 0.99	< 0.4	
Inlet perch	Low tide	0 ft.	≤ 1.0 ft.		
Inlet perch	High tide	0 ft.	0 ft.	0 < x < 2.5 ft.	> 2.5 ft.
Outlet perch	Low tide	0 ft.	< 0.25 ft.		
Outlet perch	High tide	0 ft.	0 ft.	0 < x < 2.5 ft.	> 2.5 ft.
Tide gate barrier severity		No tide gate	Minor or moderate	Severe	No aquatic passage
Other physical barrier severity		No barrier	Minor or moderate	Severe	No aquatic passage

Variables included in numeric scoring models, and their weights, for three classes of tidal crossings and for crossings on non-tidal streams.

Variable	Salt marsh creek	Salt/brackish flow-through river/stream	Freshwater tidal river/stream	Non-tidal streams
Constriction ratio	11.84	14.93	18.18	9.00
Tidal constriction	19.58	20.04	10.49	
Vegetation change: upstream vs. downstream	14.32	8.07	4.90	
Water depth at high tide	2.41	2.55	2.45	
Water depth (non-tidal)				8.20
Downstream scour	5.84	6.22	6.64	7.10
Upstream scour	5.84	6.22	4.90	
Inlet perch at low tide	3.51	5.45	5.94	
Inlet perch (non-tidal)				8.80
Outlet perch at low tide	9.81	10.95	11.19	
Outlet drop (non-tidal)				16.10
Other physical barrier severity				13.50
Inlet armoring	4.01	1.47	3.15	
Outlet armoring	3.53	1.11	4.20	3.70
Crossing height				4.50
Crossing openness	9.97	9.51	16.08	5.20
Substrate comparability	4.88	7.31	5.94	7.00
Substrate coverage	4.47	6.18	5.94	5.70
Water velocity				8.00
Internal structures				3.20
Total	**100**	**100**	**100**	**100**

Non-tidal Crossings Limiting Variables

- Outlet drop
- Other physical barrier severity (optional; coordinator's choice)

Tidal Crossings Limiting Variables

- Inlet perch at high tide
- Outlet perch at high tide
- Tide gate severity
- Other physical barrier severity