Prioritizing Stream Segments for Riparian Restoration Projects

2008 Report

In five salmon-bearing streams in Seattle, WA

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SUMMARY

OBJECTIVE Develop a list of the top 100 stream segments in terms of existing riparian quality versus threat to existing riparian quality

STUDY AREA Five salmon bearing streams in Seattle: Fauntleroy, Thornton, Pipers, Longfellow, and Taylor Creeks

ANALYSES

1) Riparian Quality: weighted linear combination model using 5 input metrics and weights derived via a pairwise comparison exercise
2) Riparian Threat: weighted linear combination model using with 3 input metrics derived via a pairwise comparison exercise

METHODS

Combine the two analyses (1 and 2, above) onto a graph and choose the segments plotted in the mid-range for both analyses as subjects for riparian restoration projects. All data transformed into a synthetic 1-9 scale with 1 being “worst” and 9 being “best” in terms of salmon habitat quality or threat. Conduct the calculations on all 768 segments for which there are riparian data. The mid range of the models was considered the best place to focus restoration efforts.

RESULTS

Because only 72 stream segments fell exactly within the mid range (i.e., having a quality score between 3 and 6 and a threat score between 3 and 6), the selection criteria were expanded, emphasizing the upper-right hand portion of the model results. Segments having quality and threat scores between 2.8 and 6.6 were therefore considered appropriate targets for restoration efforts. There were 101 of these segments.

PROJECT TEAM

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OVERVIEW

The study objective was to identify the top 100 stream segments that Seattle Public Utilities (SPU) can target for riparian restoration projects. To accomplish that task, a matrix combining riparian quality and threats to riparian habitat was envisioned. The stream segments sporting medium riparian quality and medium threat level were to have the highest priority for restoration.

The quality/threat matrix used in this study was adapted from a similar one described in the Green Seattle Partnership's 20 Year Plan (page 24). In this study, however, the matrix was modified, as shown in Figure 1.

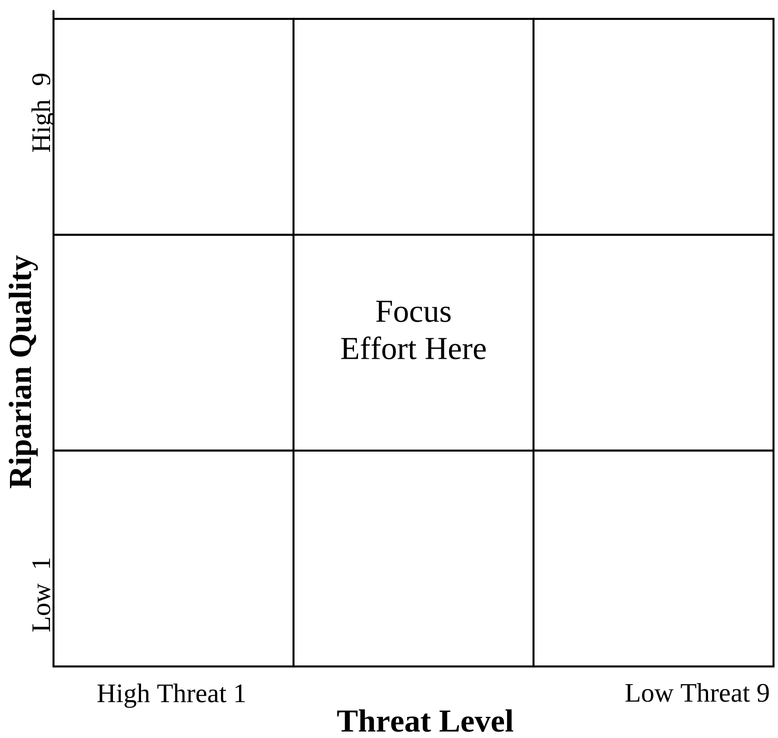

Figure 1. Modified quality/threat decision matrix

The 1-9 scale was designed so that 1 indicates "poor" conditions and 9 indicates "good" conditions for salmon habitat. A medium threat level and medium riparian quality were considered high priorities for restoration projects. The exact mid-range (threat between 3 and 6 and quality between 3 and 6) box contained only 72 stream segments so the selection range was expanded somewhat (to 2.8 and 6.6, respectively) to enable the selection of at least 100 stream segments. It should be noted, however, that there are other methods of deciding which stream segments receive priority, especially depending on the specific outcome. A low threat, medium riparian quality may be just as important for restoration if many of the mid-range box segments contain threats that can not be changed.

DATA

The metric data that were used to evaluate the segments were gathered in-the-field by SPU in 2004 as part of a riparian habitat survey. The data consist of segments of approximately 100 feet in length, with a separate set of data for each side of the stream.

During the data exploration phase of the project, it was decided that the canopy layer would be duplicitous in the threat model as landscape type and understory already alluded to canopy coverage. Additionally, the “vegetation type” layer, identified in the riparian analyte metadata as a layer, was not present in GIS format although it may have been part of the original field data collection effort. The amount of time that it would take to find and potentially export the vegetation type layer to GIS format was deemed too time consuming for the project at this time.

QUALITY MODEL

The quality model consisted of 4 habitat functions ranked via a pairwise comparison matrix in a group decision-making setting (see appendix A). The 4 habitat functions, referred to as criteria, were: shade, structure, nutrient inputs, and floodplain/filter. The pairwise comparison process resulted in a weight for each criterion that reflects its relative contribution to salmon habitat quality. The weights were:

Shade: 0.400 | Structure: 0.466 | Nutrient Inputs: 0.094 | Floodplain/Filter: 0.039

Furthermore, each criterion was made up of 2 or more metrics (i.e., GIS layers) that measured that criterion. They were:

Shade	**Structure**	**Nutrient Inputs**	**Floodplain/Filter**
canopy density	riparian width	riparian width	riparian width
stream cover	understory	understory	understory
	canopy density		
	Slope		

Weights for each metric were then computed based on the criteria weights and the number and type of metric in each criterion. For example, the Shade criterion is weighted at 0.400, which was divided by 2.0 since there are two metrics in the Shade criterion. Since 0.400 / 2.0 = canopy density and stream cover for the Shade metric are weighted at 0.2 and 0.2. The stream cover metric is only counted in the Shade criterion (i.e., it is not present in the Structure, Nutrient Inputs, or Floodplain/Filter criterion) so its final weight in the quality model is 0.2. Canopy density, however, is also in the Structure criterion. With Structure being weighted at 0.466 and consisting of 4 metrics, each of the metrics in that criterion are weighted at 0.466 / 4 = 0.117. Therefore, the stream cover metric is weighted at 0.2 + 0.117 = 0.317. The other metrics were computed in the same manner.

The final metric weights are shown in Table 1.

Table 1. Final metric weights for the quality model

Canopy Density	0.317
Stream Cover	0.200
Riparian Width	0.183
Understory	0.183
Slope	0.117

One additional step was taken before the model could be computed in the GIS. Each metric, or GIS layer, needed to be transformed to a standardized scale (again, 1-9 with 9 being “good”). The metrics and their standardized scales are found in Appendix B. At this point the standardized scales were applied to the raw GIS data and the model was run. In this model, a segment with the highest rating for all metrics receives a final model score of 9 and a segment with the lowest rating for all metrics receives a final model score of 1.

THREAT MODEL

The threat level model consisted of three input metrics: understory, encroachment, and landscape type. Although the understory metric is used in both the quality and threat models, the transformation from raw data values to synthetic was different for both (see Appendix B). The weights for this weighted linear combination model were also derived via pairwise comparison. The weights are shown in Table 2.

Table 2. Final metric weights for the threat model

Encroachment	0.690
Landscape Type	0.251
Undersory	0.059

In this model, as in the quality model, a segment with the highest rating, corresponding to the lowest threat, receives a final model score of 9. Therefore, the result of “9” can still be interpreted to mean “good” in terms of salmon habitat quality.

The encroachment metric was developed specifically for this project as a consistently applied encroachment metric could not otherwise be found. The layer was computed via GIS to include encroachment of 4 types: buildings, roads, culverts, and drainage outfalls. A stream segment would be assigned a value of “severe” encroachment (a 1 in the database) if any instance of one of the above 4 encroachments was within 25’ of the stream segment. If an encroachment was found between 25’ and 75’ of a stream segment, it was labeled “moderate” (or a 2 in the database) and any encroachment found between 75’ and 100’ of the stream segment was labeled “light” (a 3 in the database). These calculations were done iteratively so that any segment that already had a value of severe would not be evaluated further. Bank sides were kept separate for this analysis as well.

RESULTS

The calculations were performed on 768 segments of the 5 Seattle stream systems. The results were plotted (see Figure 2), with each square representing an individual stream segment.

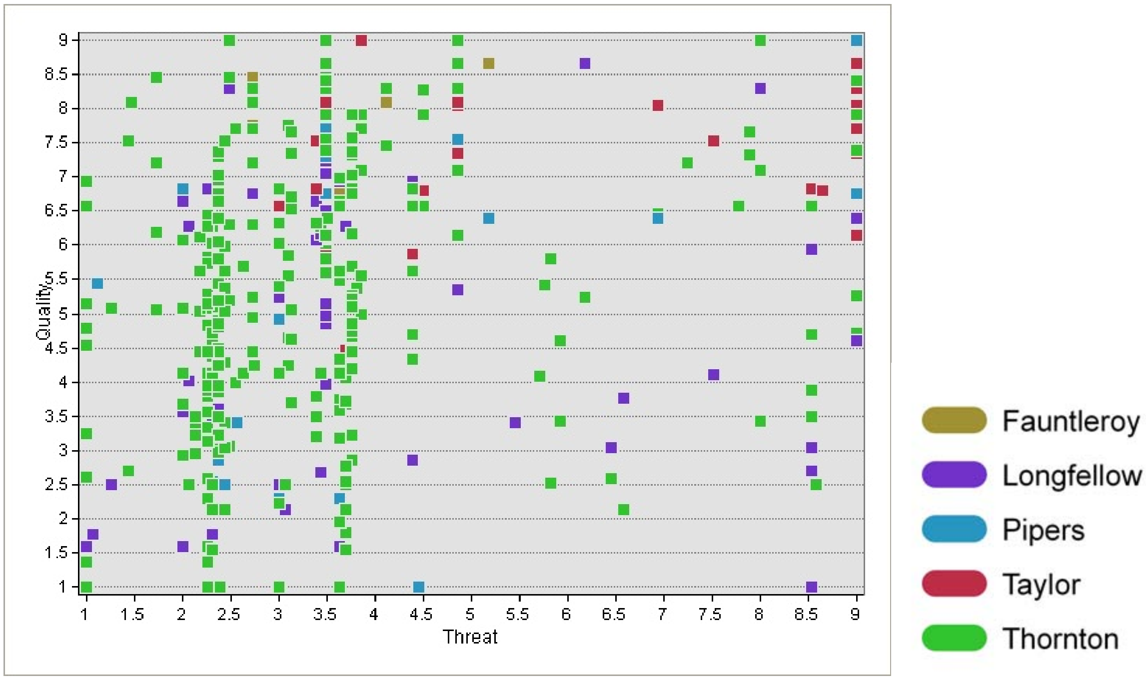

Figure 2. Result scatter plot, points are colored according to their stream location

One stream segment, on the Venema Tributary of Pipers Creek, got a score of 9 for both the quality and threat models. It is shown in figure 3.

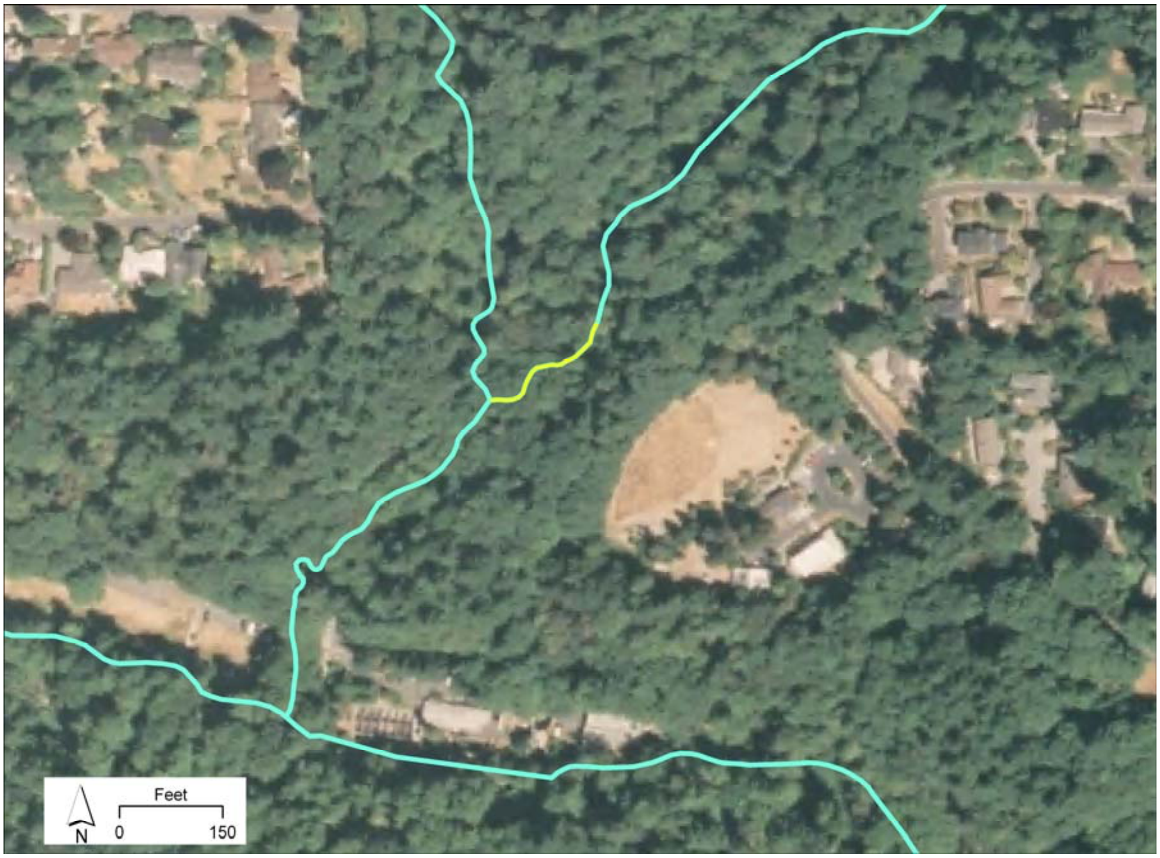

Figure 3. Pipers Creek, Venema tributary, final score of 9 for both quality and threats

There were 189 stream segments receiving the lowest scores, a 1 for quality and a 1 for threat. One of these segments, on the Longfellow Mainstem, is shown in Figure 4.

Figure 4. Longfellow Creek, Mainstem: final score of 1 for both quality and threats

Because the goal was to identify the top 100 stream segments for riparian restoration projects, and the mid-section of the graph only contains 72 segments, the selection criteria were expanded, emphasizing the upper-right hand portion of the model results. Specifically, 101 stream segments with quality scores between 3.9 and 6 and threat scores between 2.8 and 6.6 are reported below. These segments are recommended for priority stream restoration projects (see figure 5).

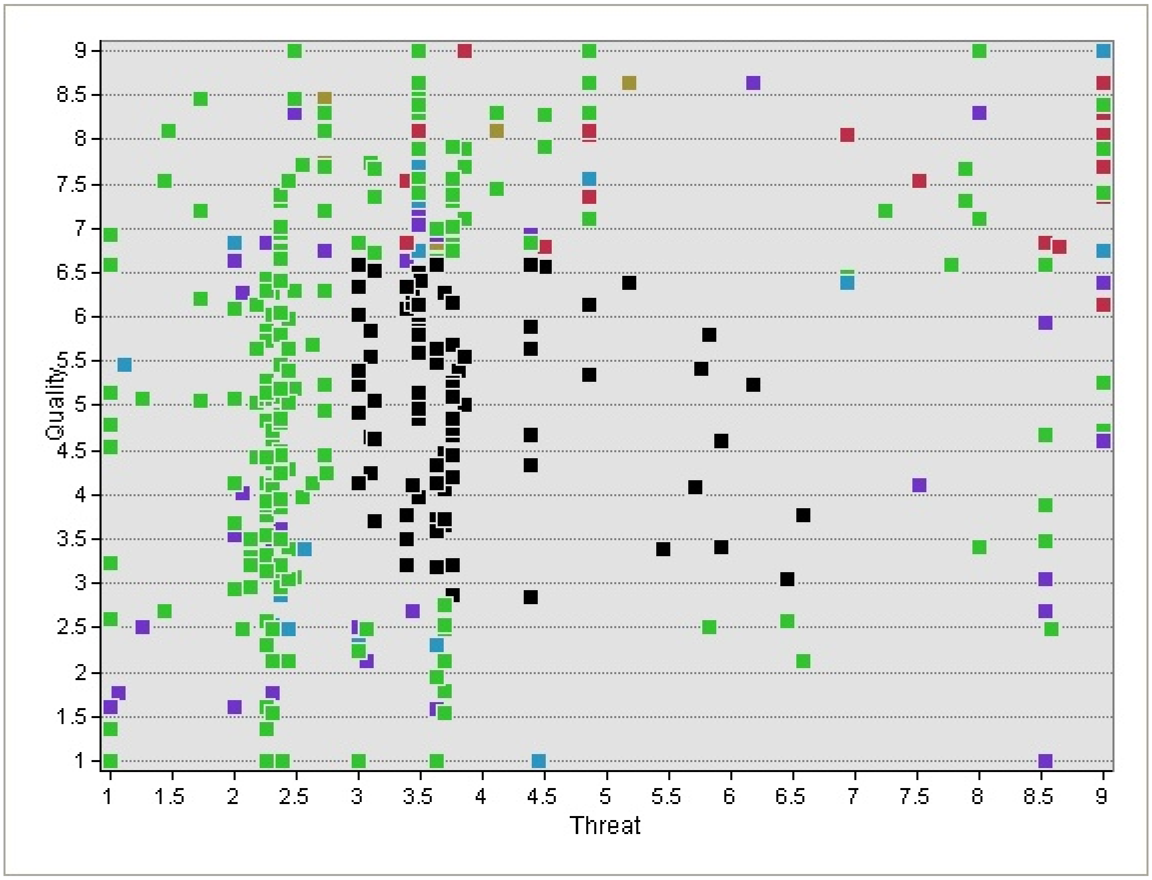

Figure 5. Scatter plot of results, with the 101 mid-range results highlighted in black (between 2.8 and 6.6 for quality and threats)

Those stream segments and their scores are reported in detail in table 3. Please note that there are also lengthy comments associated with each stream segment that were recorded during the riparian analyte data collection but, due to space constraints, not placed in this report. It may be helpful to read those comments along with these results when deciding on where to do the restoration work. The comments are included as a deliverable with this report. They are in spreadsheet format as an extra column in the table.

Figures 6 through 10 show the general stream segment locations in map format. For exact locations, see the beginning and ending feet columns in table 3.

Table 3. Prioritized stream segments for riparian restoration

MapID	Stream Name	From Feet	To Feet	Bank Side	Year Rest-ored	Riparian Width (Quality)	Canopy Density (Quality)	Stream Cover (Quality)	Under-story (Quality)	Slope (Quality)	Landscape Type (Threat)	Under-story (Threat)	Encroa-chment (Threat)	Quality Result	Threat Result
1	FAUNTLEROY - MAINSTEM	1760	1991	R		9	3	6	1	3	9	1	3	**4.332**	**4.388**
5	LONGFELLOW - MAINSTEM	3480	3740	R	1999	3	6	6	9	3	9	9	1	**5.649**	**3.480**
3	LONGFELLOW - MAINSTEM	4050	4650	R	2000	9	1	1	9	9	9	9	1	**4.864**	**3.480**
4	LONGFELLOW - MAINSTEM	4050	4650	L	2000	9	1	1	9	9	9	9	1	**4.864**	**3.480**
2	LONGFELLOW - MAINSTEM	4900	5200	L		9	1	1	1	6	9	1	6	**3.049**	**6.458**
20	LONGFELLOW - MAINSTEM	4900	5200	R		9	1	1	1	6	9	1	6	**3.049**	**6.458**
19	LONGFELLOW - MAINSTEM	6430	6900	L		9	9	1	1	3	9	1	1	**5.234**	**3.008**
17	LONGFELLOW - MAINSTEM	10500	10750	R		6	1	1	1	9	9	1	3	**2.851**	**4.388**
18	LONGFELLOW - MAINSTEM	10500	10750	L		6	1	1	6	9	9	3	6	**3.766**	**6.576**
15	LONGFELLOW - MAINSTEM	11875	13460	R	2002	9	3	1	9	6	9	9	1	**5.147**	**3.480**
16	LONGFELLOW - MAINSTEM	11875	13460	L	2002	9	3	1	9	6	9	9	1	**5.147**	**3.480**
13	LONGFELLOW - MAINSTEM	13460	13980	R	2002	9	6	3	9	6	9	9	1	**6.498**	**3.480**
14	LONGFELLOW - MAINSTEM	13460	13980	L	2002	9	6	3	9	6	9	9	1	**6.498**	**3.480**
12	LONGFELLOW - MAINSTEM	14750	15400	R	2002	6	1	1	9	6	9	9	1	**3.964**	**3.480**
10	LONGFELLOW - MAINSTEM	15490	15800	R	2002	6	3	3	9	9	9	9	3	**5.349**	**4.860**
11	LONGFELLOW - MAINSTEM	15490	15800	L	2002	9	3	3	9	1	9	9	1	**4.962**	**3.480**
9	LONGFELLOW - MAINSTEM	15900	16000	L		3	9	9	2	6	6	2	3	**6.270**	**3.694**

MapID	Stream Name	From Feet	To Feet	Bank Side	Year Rest-ored	Riparian Width (Quality)	Canopy Density (Quality)	Stream Cover (Quality)	Under-story (Quality)	Slope (Quality)	Landscape Type (Threat)	Under-story (Threat)	Encroa-chment (Threat)	**Quality Result**	**Threat Result**
8	LONGFELLOW - MAINSTEM	18220	18650	L		9	1	1	1	9	5	1	6	**3.400**	**5.454**
7	LONGFELLOW - MAINSTEM	18650	18820	L		9	9	3	2	6	5	2	3	**6.168**	**3.443**
6	LONGFELLOW - MAINSTEM	19350	19480	R		3	9	9	1	6	5	1	3	**6.087**	**3.384**
25	PIPER'S - MAINSTEM	4020	5400	L		9	3	9	9	3	9	9	1	**6.396**	**3.480**
24	PIPER'S - MAINSTEM	5400	5710	L		9	3	9	1	3	9	1	1	**4.932**	**3.008**
23	PIPER'S - MAINSTEM	6190	6350	L		9	3	9	9	3	9	9	1	**6.396**	**3.480**
22	PIPER'S - MAINSTEM	6190	7000	R		9	3	9	9	3	9	9	1	**6.396**	**3.480**
21	PIPER'S - MAINSTEM	6700	7000	L		9	3	9	9	3	2	9	6	**6.396**	**5.173**
26	TAYLOR - EAST FORK	776	1425	R		9	9	6	1	6	9	1	1	**6.585**	**3.008**
27	TAYLOR - EAST FORK	776	1425	L		9	9	6	1	6	9	1	1	**6.585**	**3.008**
31	TAYLOR - MAINSTEM	0	140	L		3	6	3	2	9	6	2	3	**4.470**	**3.694**
30	TAYLOR - MAINSTEM	0	160	R		3	6	3	2	9	6	2	3	**4.470**	**3.694**
32	TAYLOR - MAINSTEM	1235	1350	L	1999	6	3	9	9	3	9	9	1	**5.847**	**3.480**
28	TAYLOR - WEST FORK	1016	1225	R		9	6	9	1	3	9	1	3	**5.883**	**4.388**
29	TAYLOR - WEST FORK	1016	1225	L		9	6	9	1	3	9	1	3	**5.883**	**4.388**
46	THORNTON MAINSTEM	2040	2140	L		3	6	1	1	3	6	1	3	**3.185**	**3.635**
45	THORNTON MAINSTEM	2500	2680	R		6	3	1	2	9	6	2	3	**3.668**	**3.694**

MapID	Stream Name	From Feet	To Feet	Bank Side	Year Rest-ored	Riparian Width (Quality)	Canopy Density (Quality)	Stream Cover (Quality)	Under-story (Quality)	Slope (Quality)	Landscape Type (Threat)	Under-story (Threat)	Encroa-chment (Threat)	Quality Result	Threat Result
44	THORNTON MAINSTEM	2600	2800	L		3	1	1	6	9	6	3	3	**3.217**	**3.753**
43	THORNTON MAINSTEM	5350	5640	L		3	6	3	7	9	6	4	3	**5.385**	**3.812**
42	THORNTON MAINSTEM	6550	6750	R	1999	3	1	1	9	6	5	9	6	**3.415**	**5.926**
0	THORNTON MAINSTEM - MATTHEWS CREEK	125	420	R	1999	6	1	9	9	9	9	9	1	**5.915**	**3.480**
37	THORNTON NORTH - LITTLEBROOK TRIB	30	190	R		3	6	1	4	9	6	3	3	**4.436**	**3.753**
36	THORNTON NORTH - LITTLEBROOK TRIB	600	800	L		3	9	6	1	6	6	1	3	**5.487**	**3.635**
35	THORNTON NORTH - LITTLEBROOK TRIB	950	1825	L		9	3	6	1	3	6	1	3	**4.332**	**3.635**
34	THORNTON NORTH - LITTLEBROOK TRIB	2250	2540	R		9	3	6	1	3	9	1	3	**4.332**	**4.388**
33	THORNTON NORTH - LITTLEBROOK TRIB	3005	3190	L	2001	6	3	3	9	3	2	9	3	**4.647**	**3.103**
38	THORNTON NORTH - LITTLES TRIB	1640	1830	R		3	3	3	3	9	9	3	1	**3.702**	**3.126**
101	THORNTON NORTH BRANCH MAINSTEM	2590	2780	R		3	3	6	6	9	6	3	3	**4.851**	**3.753**
100	THORNTON NORTH BRANCH MAINSTEM	3020	3200	L		3	3	9	3	3	6	3	3	**4.200**	**3.753**
99	THORNTON NORTH BRANCH MAINSTEM	3200	3350	L		6	3	6	1	6	6	1	3	**4.134**	**3.635**
98	THORNTON NORTH BRANCH MAINSTEM	3820	4090	R		3	3	9	4	6	6	3	3	**4.734**	**3.753**
97	THORNTON NORTH BRANCH MAINSTEM	4090	4200	R	2001	6	9	3	5	6	6	3	3	**6.168**	**3.753**
96	THORNTON NORTH BRANCH MAINSTEM	4500	5090	L		9	9	3	1	9	5	1	3	**6.336**	**3.384**
95	THORNTON NORTH BRANCH MAINSTEM	5040	5325	R		9	9	6	1	6	6	1	3	**6.585**	**3.635**

MapID	Stream Name	From Feet	To Feet	Bank Side	Year Rest-ored	Riparian Width (Quality)	Canopy Density (Quality)	Stream Cover (Quality)	Under-story (Quality)	Slope (Quality)	Landscape Type (Threat)	Under-story (Threat)	Encroa-chment (Threat)	Quality Result	Threat Result
94	THORNTON NORTH BRANCH MAINSTEM	5950	6290	L		3	3	9	6	6	6	3	3	**5.100**	**3.753**
93	THORNTON NORTH BRANCH MAINSTEM	7080	7350	L		3	6	6	6	9	6	3	6	**5.802**	**5.823**
90	THORNTON NORTH BRANCH MAINSTEM	7300	8150	R		3	9	6	6	6	5	3	3	**6.402**	**3.502**
89	THORNTON NORTH BRANCH MAINSTEM	8450	8750	L		3	6	1	2	6	6	2	3	**3.719**	**3.694**
92	THORNTON NORTH BRANCH MAINSTEM	9570	9725	R		3	6	1	6	6	6	3	3	**4.451**	**3.753**
91	THORNTON NORTH BRANCH MAINSTEM	9725	10050	L		3	1	1	6	9	6	3	3	**3.217**	**3.753**
83	THORNTON NORTH BRANCH MAINSTEM	11975	12400	R	2000	9	3	6	9	6	9	9	1	**6.147**	**3.480**
81	THORNTON NORTH BRANCH MAINSTEM	12400	12590	R		9	3	6	1	6	9	1	3	**4.683**	**4.388**
82	THORNTON NORTH BRANCH MAINSTEM	12400	12590	L		9	9	6	1	6	9	1	3	**6.585**	**4.388**
88	THORNTON NORTH BRANCH MAINSTEM	15750	16260	L		6	3	6	1	6	9	1	1	**4.134**	**3.008**
87	THORNTON NORTH BRANCH MAINSTEM	18475	19000	R		6	3	6	1	3	5	1	3	**3.783**	**3.384**
86	THORNTON NORTH BRANCH MAINSTEM	19000	19150	L		6	3	1	9	6	5	9	6	**4.598**	**5.926**
85	THORNTON NORTH BRANCH MAINSTEM	19000	19290	R		3	6	1	9	6	5	9	3	**5.000**	**3.856**
84	THORNTON NORTH BRANCH MAINSTEM	19150	19290	L		6	6	1	9	6	5	9	3	**5.549**	**3.856**
102	THORNTON NORTH BRANCH MAINSTEM	20200	20750	L		6	9	1	1	9	9	1	1	**5.387**	**3.008**
80	THORNTON SOUTH - VICTORY TRIB	0	90	R		6	9	6	1	6	9	1	1	**6.036**	**3.008**
79	THORNTON SOUTH - VICTORY TRIB	925	1130	R		6	3	6	5	9	6	3	3	**5.217**	**3.753**

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78	THORNTON SOUTH - VICTORY TRIB	1500	1600	L		3	6	3	6	6	6	3	3	**4.851**	**3.753**
41	THORNTON SOUTH - WILLOW TRIB	350	700	R	1999	6	3	9	9	3	2	9	3	**5.847**	**3.103**
40	THORNTON SOUTH - WILLOW TRIB	1805	2000	R		3	1	9	1	3	5	1	3	**3.200**	**3.384**
39	THORNTON SOUTH - WILLOW TRIB	2880	3650	L		6	3	6	1	3	5	1	3	**3.783**	**3.384**
76	THORNTON SOUTH BRANCH MAINSTEM	1150	1510	R		3	6	1	2	6	6	2	3	**3.719**	**3.694**
75	THORNTON SOUTH BRANCH MAINSTEM	1300	1400	L		3	9	3	2	9	6	2	6	**5.421**	**5.764**
74	THORNTON SOUTH BRANCH MAINSTEM	1400	1510	L		3	6	1	2	6	6	2	3	**3.719**	**3.694**
73	THORNTON SOUTH BRANCH MAINSTEM	1790	1980	R		3	3	6	1	6	6	1	3	**3.585**	**3.635**
72	THORNTON SOUTH BRANCH MAINSTEM	2420	2580	L		3	9	9	2	6	5	2	3	**6.270**	**3.443**
71	THORNTON SOUTH BRANCH MAINSTEM	3300	3400	L		9	6	6	1	6	6	1	3	**5.634**	**3.635**
70	THORNTON SOUTH BRANCH MAINSTEM	3300	3700	R		9	6	6	1	6	9	1	3	**5.634**	**4.388**
69	THORNTON SOUTH BRANCH MAINSTEM	3400	4000	L	2000	9	3	6	9	6	9	9	3	**6.147**	**4.860**
68	THORNTON SOUTH BRANCH MAINSTEM	4000	4150	L		9	3	6	1	3	9	1	3	**4.332**	**4.388**
67	THORNTON SOUTH BRANCH MAINSTEM	4150	4385	L	2003	9	3	3	9	6	2	9	3	**5.547**	**3.103**
65	THORNTON SOUTH BRANCH MAINSTEM	4210	4385	R	2003	6	3	1	9	3	2	9	3	**4.247**	**3.103**
64	THORNTON SOUTH BRANCH MAINSTEM	4900	5000	L		3	6	3	2	6	5	2	3	**4.119**	**3.443**
63	THORNTON SOUTH BRANCH MAINSTEM	4900	5050	R		9	3	3	1	1	5	1	3	**3.498**	**3.384**

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62	THORNTON SOUTH BRANCH MAINSTEM	5000	5200	L		6	3	3	1	3	6	1	3	**3.183**	**3.635**
61	THORNTON SOUTH BRANCH MAINSTEM	5050	5200	R		9	3	3	1	3	6	1	3	**3.732**	**3.635**
60	THORNTON SOUTH BRANCH MAINSTEM	5200	5350	R		9	3	6	9	3	9	9	1	**5.796**	**3.480**
59	THORNTON SOUTH BRANCH MAINSTEM	7490	7625	L		3	1	1	6	6	6	3	3	**2.866**	**3.753**
58	THORNTON SOUTH BRANCH MAINSTEM	7850	7950	L		3	9	6	4	3	6	3	3	**5.685**	**3.753**
57	THORNTON SOUTH BRANCH MAINSTEM	8025	8200	R		9	3	6	5	3	9	3	1	**5.064**	**3.126**
56	THORNTON SOUTH BRANCH MAINSTEM	8200	8575	R		6	3	6	9	3	6	9	6	**5.247**	**6.177**
55	THORNTON SOUTH BRANCH MAINSTEM	8425	8625	L		9	3	3	1	6	6	1	6	**4.083**	**5.705**
54	THORNTON SOUTH BRANCH MAINSTEM	8625	8975	L		3	6	3	5	6	6	3	3	**4.668**	**3.753**
53	THORNTON SOUTH BRANCH MAINSTEM	8975	9425	L		3	6	6	5	6	6	3	3	**5.268**	**3.753**
51	THORNTON SOUTH BRANCH MAINSTEM	10275	10810	R		9	9	3	1	9	9	1	1	**6.336**	**3.008**
52	THORNTON SOUTH BRANCH MAINSTEM	10300	10400	L		3	9	6	5	9	9	3	3	**6.570**	**4.506**
50	THORNTON SOUTH BRANCH MAINSTEM	10810	10910	R		6	9	3	5	9	9	3	1	**6.519**	**3.126**
49	THORNTON SOUTH BRANCH MAINSTEM	11200	11300	L		3	6	1	2	9	6	2	3	**4.070**	**3.694**
47	THORNTON SOUTH BRANCH MAINSTEM	11600	11990	R	2003	6	3	3	5	9	9	3	1	**4.617**	**3.126**
48	THORNTON SOUTH BRANCH MAINSTEM	11600	11990	L	2003	6	3	6	9	6	9	9	1	**5.598**	**3.480**

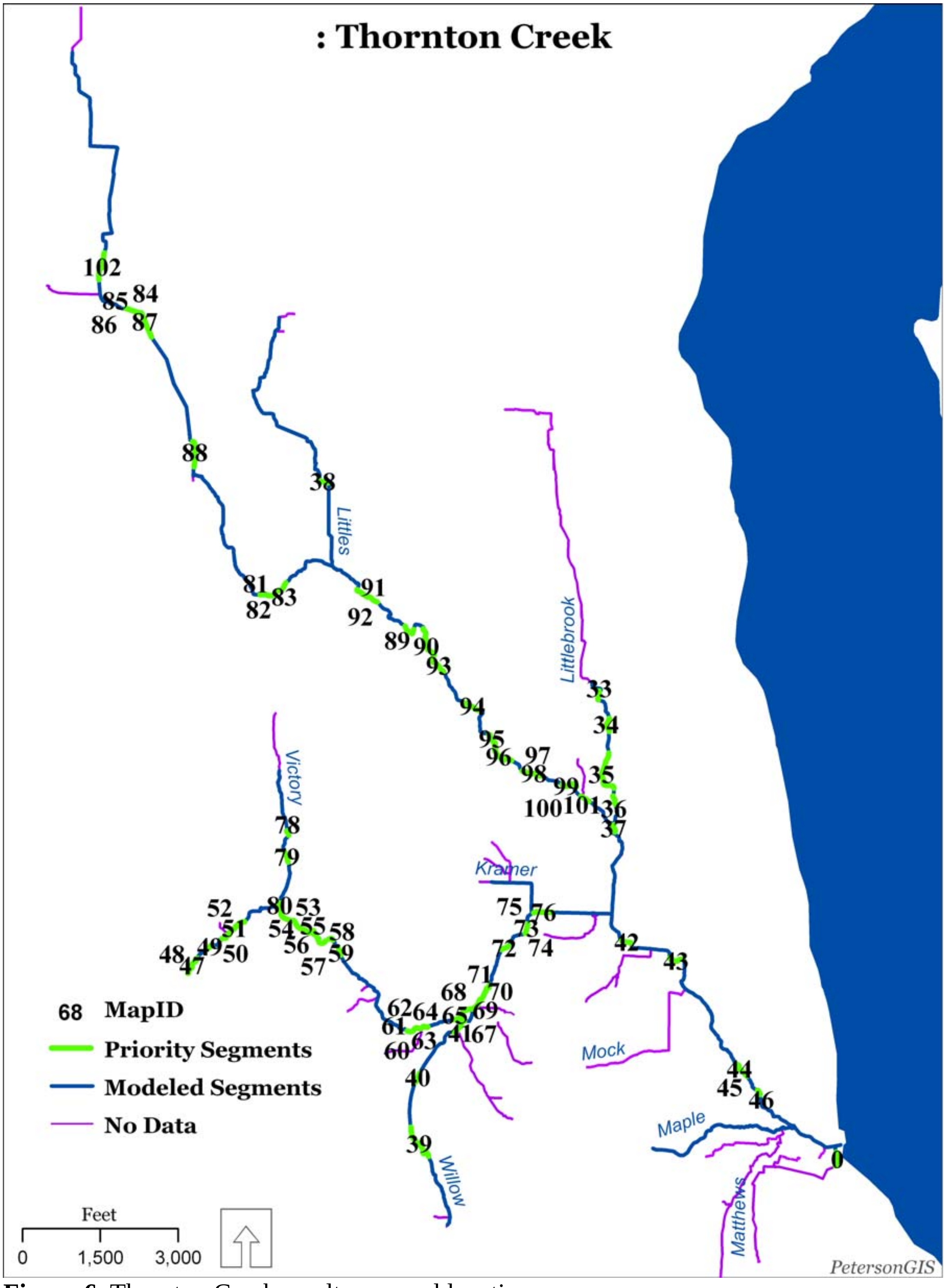

Figure 6. Thornton Creek results, general locations

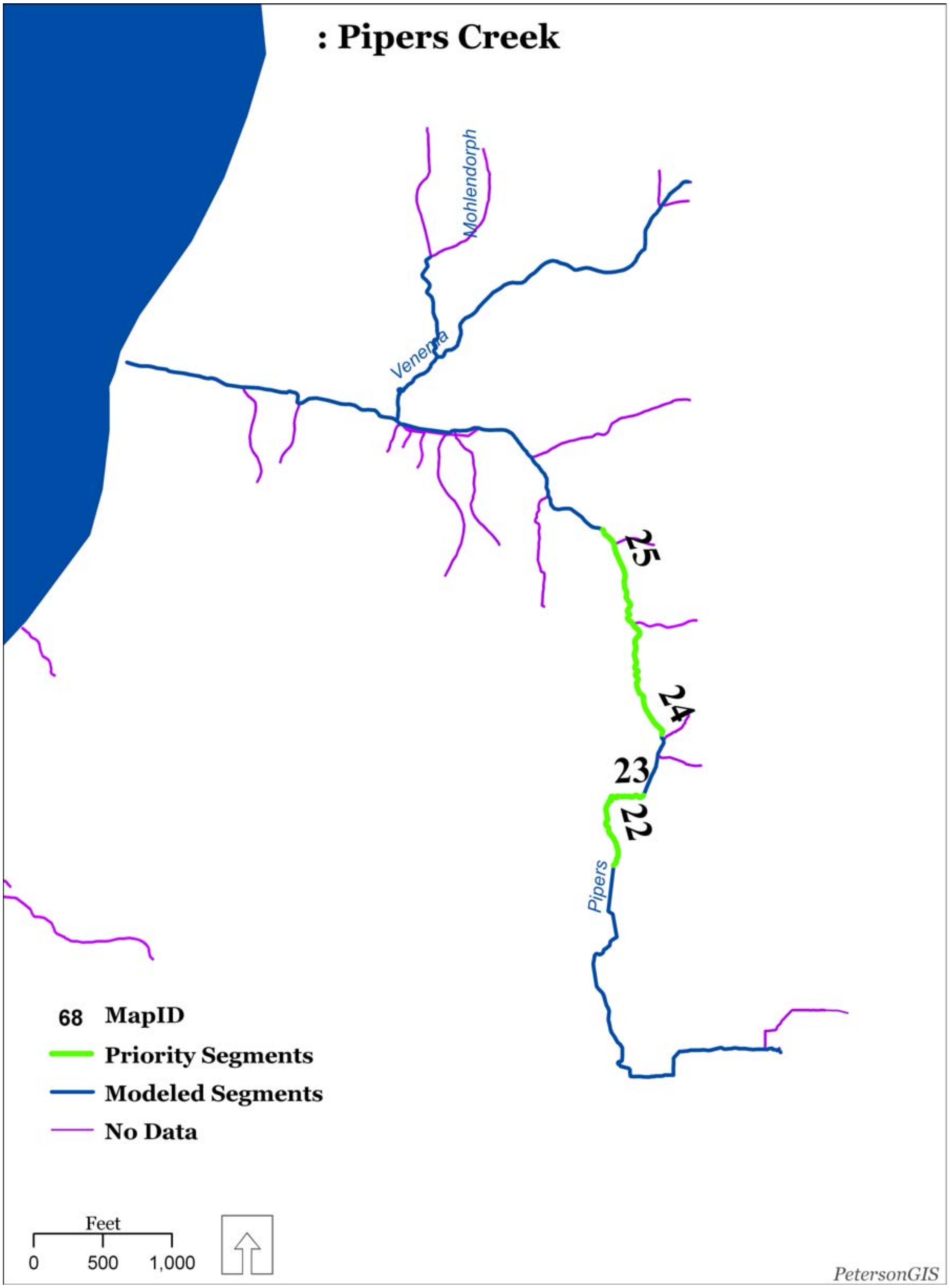

Figure 7. Pipers Creek results, general locations

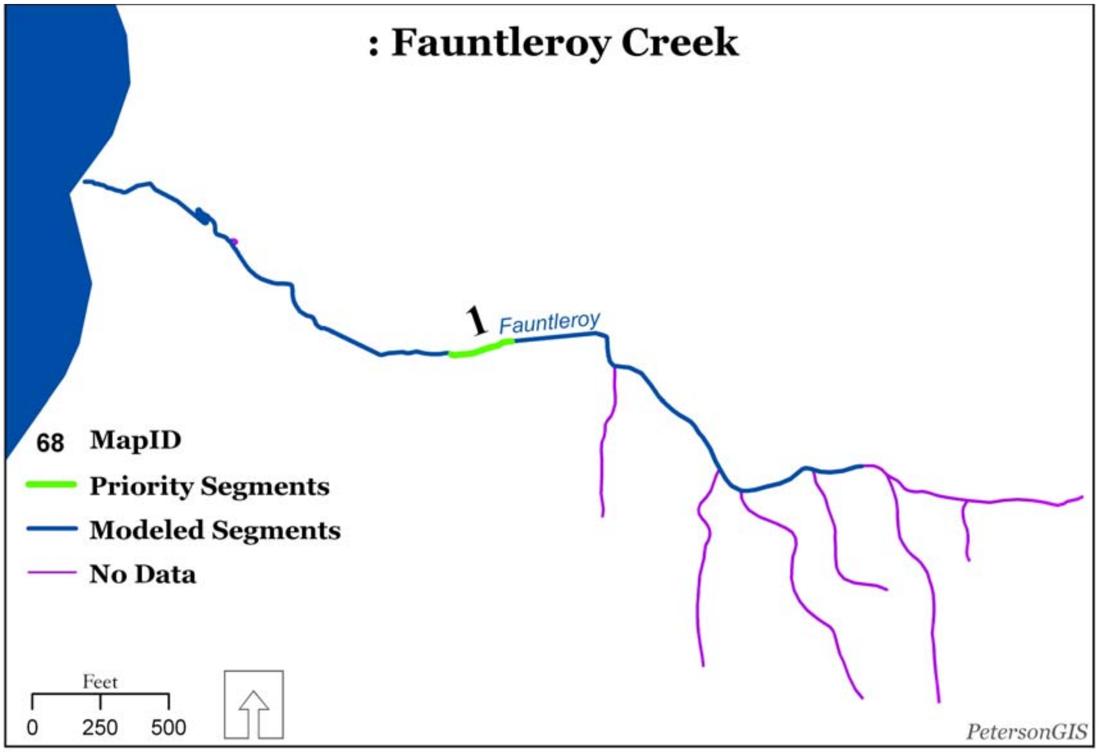

Figure 8. Fauntleroy Creek results

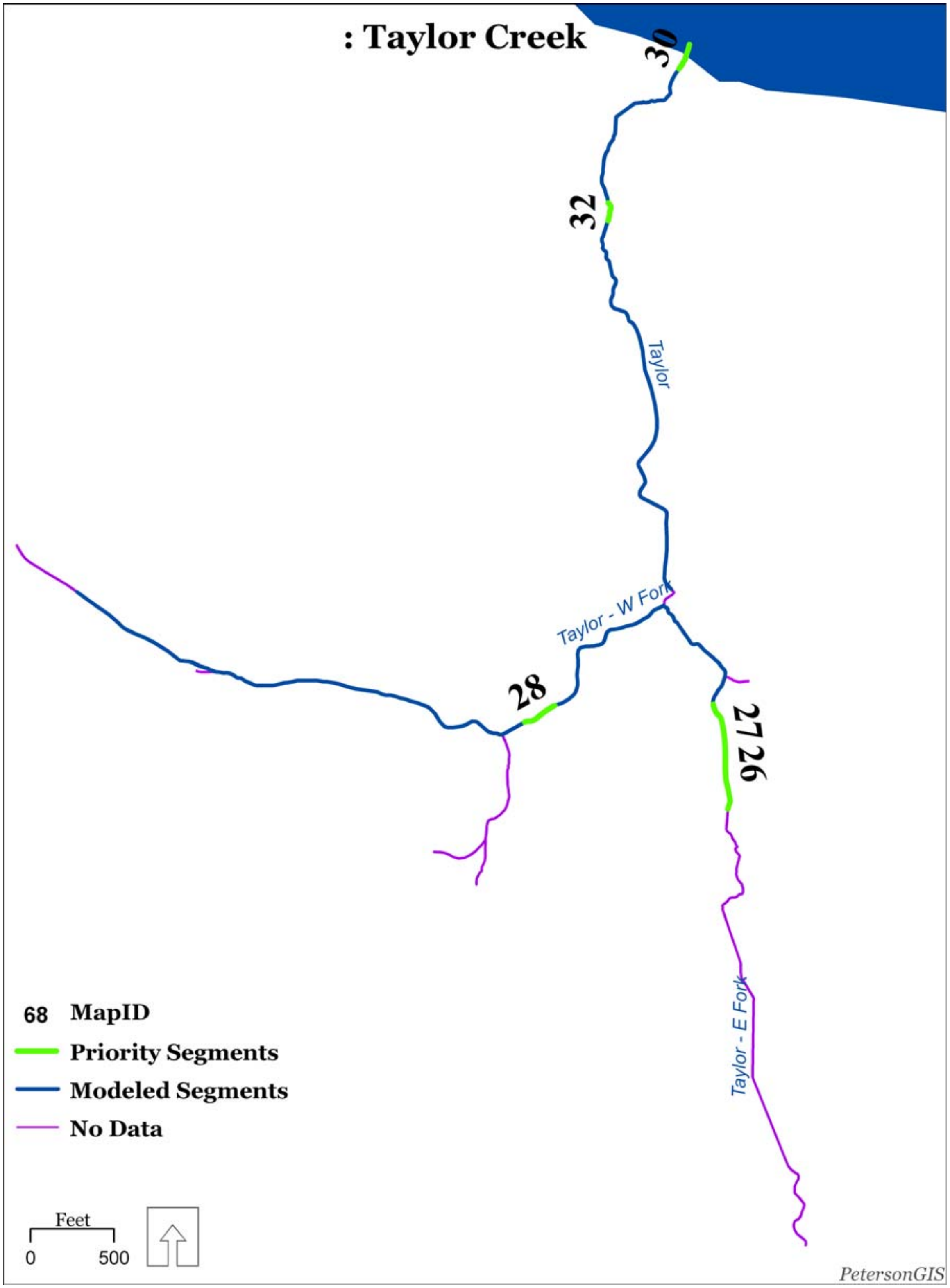

Figure 9. Taylor Creek results, general locations

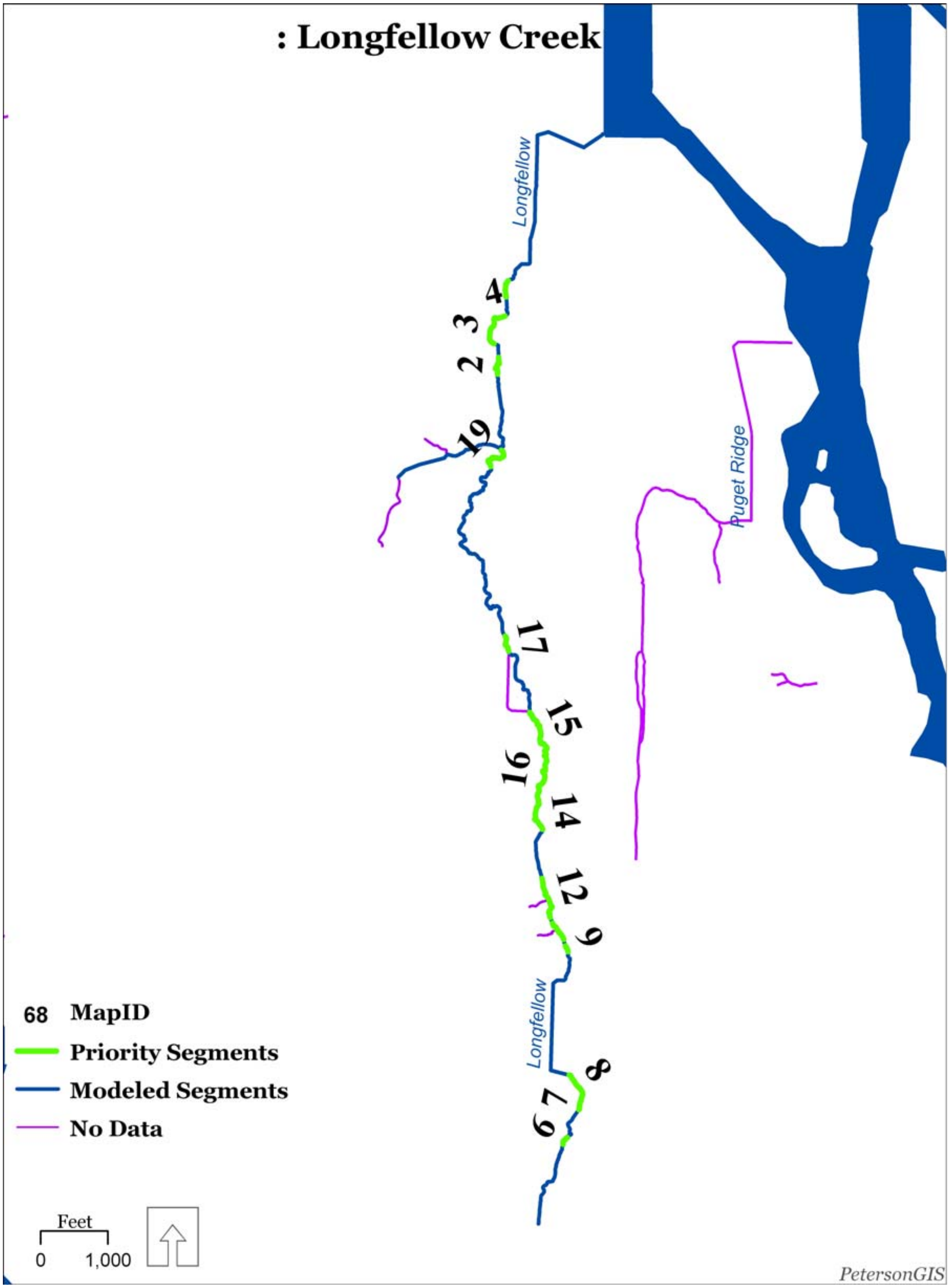

Figure 10. Longfellow Creek results, general locations

APPENDIX A

The scale used in the pairwise comparison is from Saaty 1980 as cited in Malczewski 1999:

Intensity of Importance	Definition
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance

The following shows the calculations used to obtain the criteria weights in the quality analysis (see Malczewksi 1999 for how to do a pairwise comparison):

Step 1) Convert numbers from meeting to alternate scale where 1 means the pair are equal in importance and 9 means the horizontal criteriu is of extreme importance compared with the vertical criterion

	Shade/Temperature Control	Structure (LWD Recruit)	Nutrient Inputs	Floodplain/filter
Shade/Temperature Control	1.000	1.000	5.000	9.000
Structure (LWD Recruit)	1.000	1.000	9.000	9.000
Nutrient Inputs	0.200	0.111	1.000	4.000
Floodplain/filter	0.111	0.111	0.250	1.000
Row Totals	2.311	2.222	15.250	23.000

Step 2) Create a normalized paiwise comparison matrix					Step 3) average each row of step 2	
	Shade/Temperature Control	Structure (LWD Recruit)	Nutrient Inputs	Floodplain/filter	**Weight**	
Shade/Temperature Control	0.433	0.450	0.328	0.391	0.400	(weight is the average of all possible ways of comparing the criteria)
Structure (LWD Recruit)	0.433	0.450	0.590	0.391	0.466	
Nutrient Inputs	0.087	0.050	0.066	0.174	0.094	
Floodplain/filter	0.048	0.050	0.016	0.043	0.039	

Step 4) Calculate the weighted sum vectors					5) sum	6) consistency vectors:
	0.400	0.466	0.470	0.355	1.692	4.225
	0.400	0.466	0.846	0.355	2.068	4.437
	0.080	0.052	0.094	0.158	0.384	4.083
	0.044	0.052	0.024	0.039	0.159	4.033
7) lambda	4.195					
8) consistency index	0.065					
9) consistency ratio	0.072	(0.9 is a constant from random inconsistency matrix-Saaty 1980 and Malczewski 1999)				
10) compare step 9 result with 0.10		0.072 < 0.10, indicating a reasonable level of consistency in the pairwise comparisons				

Step 11) Use the calculated weights from step 3 to determine the weight for each attribute in that criterion		
criteria	*number of attributes*	*attribute weight*
Shade/Temperature Control	2	0.200
Structure (LWD Recruit)	4	0.117
Nutrient Inputs	2	0.047
Floodplain/filter	2	0.020

Step 12) Use the attribute weights calculated in step 11 to determine each attribute's weight in total, these will become their map layer's respective weights in the GIS Quality model		
canopy density	0.317	
stream cover	0.200	
riparian width	0.183	
understory	0.183	
slope	0.117	
	1.000	*sum*

APPENDIX B

Synthetic scales were developed to transform the raw data into a commensurate scale of measurement. The scale used here is a 1-9 scale where raw data values representing “best” quality habitat or “lowest threat” were assigned a 9 and where raw data values representing “poor” quality habitat or “highest threat” were assigned a 1. One metric was used both in the quality and the threat models but with different synthetic data values assigned to the raw data.

Metric/GIS Layer	**Quality**	**Threat**
Riparian Width		
Raw	Synthetic	
1 (<20’)	3	
2 (20-50’)	6	
3 (>50’)	9	
99 (Pipe)	1	
100 (Not present)	1	
0	1	
Canopy Density		
Raw	Synthetic	
4	1	
6	1	
Full	9	
Intermittent	6	
Not Present	1	
Partial	3	
	1	
Stream Cover		
Raw	Synthetic	
0 - 24%	1	
25 - 50%	3	
51 - 75%	6	
76 - 100%	9	
	1	
Understory		
Raw	Synthetic	Synthetic
Native Shrubs	9	9
Mixed (Landscape/Native Shrub)	8	6
Landscape Shrubs	7	4
Mixed (Lawn/Landscape Shrub)	6	3
Mixed (Native Shrubs /Invasives)	5	3
Mixed (Landscape Shrub/Invasive)	4	3
Mixed (Lawn/Invasives)	3	3
Lawn	2	2

Non-Native Invasives	1	1
No Vegetation	1	1
	1	1

Slope

Raw	Synthetic
Flat	9
Medium	6
Steep	3
N/A	1
	1

Landscape Type

Raw	Synthetic
Open Space	9
School	6
Vacant	5
Commercial	2
Industrial	1
Multi-Family	5
N/A	1
ROW	1
Single-Family	6
	1

Encroachment	Synthetic
None, greater than 100’ (4)	9
Light, between 75’ and 100’ (3)	6
Moderate, between 25’ and 75’ (2)	3
Severe, less than 25’	1