Landscape Approaches: Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings

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Stream Simulation Spreadsheets

Four spreadsheets designed to support the US Forest Service

*Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings.*

US Dept. of Agriculture, Forest Service Stream-Simulation Working Group, May 2008

Mark Jordan, P.E.
Jordan Environmental Engineering

Robert Gubernick, R.G.
US Forest Service
Stream Simulation Spreadsheets

- Short Introduction to USFS Stream Simulation
- Overview of each Spreadsheet
- Update on Development & Distribution

Live demo during break!
What is Stream Simulation?

A structure with a constructed streambed (cross sections and profile) that mimics the natural conditions in a reference reach of the stream that maintains geomorphic and ecological continuity through the road-stream crossing.

Tongass N.F.
Southeast Alaska
Stream Simulation Design Elements

• Site assessment and reference reach conditions
  • Simulate natural channel and materials (particle size spreadsheet)
  • Bankfull cross section shape and dimensions (cross section spreadsheet)
  • Channel slope – (long profile spreadsheet)
  • Channel structure with dimensions and spacing (Roughness element spreadsheet)

• Geomorphic design
  • Fits with and in equilibrium with adjacent reaches (long profile and roughness element spreadsheets)
  • Dynamically sustained over a broad range of flows
  • “Mobile bed in stable channel” that is sustainable via natural sediment transport
Four Spreadsheets

1. Field Data Review
2. Long Profile Analysis
3. Roughness Elements Schematic
4. Particle Count Analysis
Four Spreadsheets

1. **Field Data Review**
   Takes raw field data and very quickly creates several charts and data tables.

2. **Long Profile Analysis**

3. **Roughness Elements Schematic**

4. **Particle Count Analysis**
Four Spreadsheets

1. Field Data Review
2. Long Profile Analysis
   Help identify reference reach, UVAP, LVAP & LPS.
3. Roughness Elements Schematic
4. Particle Count Analysis
Four Spreadsheets

1. Field Data Review
2. Long Profile Analysis
3. Roughness Elements Schematic
   Creates a schematic drawing of macro roughness elements.
4. Particle Count Analysis
Four Spreadsheets

1. Field Data Review
2. Long Profile Analysis
3. Roughness Elements Schematic
4. Particle Count Analysis
   USFS method
Stream Simulation

Spreadsheets

All the **charts and tables** displayed in this presentation are “**canned**” charts and tables that are automatically generated while you conduct the appropriate analysis.

Note: Some of the charts and tables have had additional formatting applied to them using Excel’s standard formatting tools.
Field Data Review

Spreadsheet has been designed to be used in the field with digital data collection (total station or tablet).

Objectives:

• Quickly visualize key parameters such as stream Thawleg, Cross-sections and Macro Roughness Elements (future).
• Help determine if sufficient field data has been collected for the site.
• Creates data tables to transfer data to other spreadsheets or software without re-entering data.
Field Data Review
4 steps from field data to charts & tables
(Example: Total Station).

1. Collect field data
2. Transfer data from “Total Station Data Logger” to data stick as an ACII file.
3. “Copy/Paste” or “Import” from data stick into Spreadsheet.
4a. Enter a small amount of info about your site.
4b. Then click one button to make several charts and tables.
Field Data Review

Site Map:
- Thawleg
- Culvert
- Etc.

Field Data

<table>
<thead>
<tr>
<th>Point No.</th>
<th>N-S</th>
<th>E-W</th>
<th>Z</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5000.00</td>
<td>5000.00</td>
<td>100.00</td>
<td>OCC1</td>
</tr>
<tr>
<td>2</td>
<td>5047.20</td>
<td>5000.00</td>
<td>95.87</td>
<td>NORTH</td>
</tr>
<tr>
<td>3</td>
<td>4969.61</td>
<td>5045.52</td>
<td>97.74</td>
<td>BM1</td>
</tr>
<tr>
<td>29</td>
<td>5084.92</td>
<td>5011.27</td>
<td>96.14</td>
<td>TW ST CB MS</td>
</tr>
<tr>
<td>30</td>
<td>5086.03</td>
<td>5008.68</td>
<td>97.26</td>
<td>BKF</td>
</tr>
<tr>
<td>31</td>
<td>5080.79</td>
<td>5011.86</td>
<td>95.40</td>
<td>TW</td>
</tr>
<tr>
<td>32</td>
<td>5075.91</td>
<td>5012.77</td>
<td>95.44</td>
<td>TW ST BL HS</td>
</tr>
<tr>
<td>33</td>
<td>5057.83</td>
<td>5008.73</td>
<td>94.84</td>
<td>TW</td>
</tr>
<tr>
<td>34</td>
<td>5047.04</td>
<td>5005.79</td>
<td>94.49</td>
<td>TW</td>
</tr>
<tr>
<td>35</td>
<td>5029.93</td>
<td>5002.13</td>
<td>94.41</td>
<td>TW</td>
</tr>
<tr>
<td>36</td>
<td>5021.56</td>
<td>5001.63</td>
<td>93.85</td>
<td>TW</td>
</tr>
<tr>
<td>37</td>
<td>5013.13</td>
<td>4995.82</td>
<td>93.74</td>
<td>TW</td>
</tr>
<tr>
<td>38</td>
<td>5011.50</td>
<td>4995.55</td>
<td>93.41</td>
<td>STR1 INVERT</td>
</tr>
<tr>
<td>39</td>
<td>5011.50</td>
<td>4995.75</td>
<td>97.30</td>
<td>STR1 TOC</td>
</tr>
</tbody>
</table>
Field Data Review

Quickly visualize key parameters.

Cross-Sections:

**Type 1.**
All XS on a single chart centered on thawleg.

**Type 2.**
Individual charts for each XS.
Field Data Review

Long-Profile:

Field data point numbers.
Field Data Review

Long-Profile:

- Slope Calculator
Field Data Review

Hopefully the 3 charts will help determine if sufficient field data has been collected.

• Possible Tie Points?
• How does the existing culvert lie compared to the historical stream bed?
• Where should the new culvert inverts be located?
• Possible Reference Reach?
Create data tables to transfer data to other spreadsheets or software without re-entering data. For example: Long-Profile Analysis spreadsheet.

**Table 1. Field Data**

<table>
<thead>
<tr>
<th>Pt. No.</th>
<th>Station</th>
<th>Thawleg Elev.</th>
<th>Bankfull Elev.</th>
<th>Grade Control Notes</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>106.49</td>
<td></td>
<td>Step - high</td>
<td>Boulder</td>
</tr>
<tr>
<td>2</td>
<td>13.3</td>
<td>105.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>26.17</td>
<td>105.14</td>
<td>Step - high</td>
<td>Bedrock</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>48.8</td>
<td>103.82</td>
<td>Step - high</td>
<td>Bedrock</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>65.98</td>
<td>100.94</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>74.93</td>
<td>100.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>86.33</td>
<td>101.08</td>
<td>Step - high</td>
<td>Bedrock</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>95.11</td>
<td>100.63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>103.55</td>
<td>99.59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>116.55</td>
<td>100.15</td>
<td>Step - high</td>
<td>Boulder</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>117.77</td>
<td>101.29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>122.95</td>
<td>98.58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>130.65</td>
<td>98.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>140.09</td>
<td>98.79</td>
<td>Step - high</td>
<td>Boulder</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>143.35</td>
<td>98.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>151.34</td>
<td>98.8</td>
<td>Step - high</td>
<td>Boulder</td>
<td></td>
</tr>
</tbody>
</table>
Long Profile Analysis

Focus of this spreadsheet is to conduct a Long Profile Analysis. The charts are interactive tools.

Getting Started:

Table 1. Field Data

<table>
<thead>
<tr>
<th>Pt. No.</th>
<th>Station</th>
<th>Thawleg Inv. Elev.</th>
<th>Bankfull Elevation</th>
<th>Grade Control Notes</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>106.49</td>
<td></td>
<td>Step - high</td>
<td>Boulder</td>
</tr>
<tr>
<td>2</td>
<td>13.3</td>
<td>105.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>26.17</td>
<td>105.14</td>
<td></td>
<td>Step - high</td>
<td>Bedrock</td>
</tr>
<tr>
<td>4</td>
<td>48.8</td>
<td>103.82</td>
<td></td>
<td>Step - high</td>
<td>Bedrock</td>
</tr>
<tr>
<td>5</td>
<td>65.98</td>
<td>100.94</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>74.93</td>
<td>100.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Instructions:
- Enter data into "Table 1. Field Data".
- Click button "Make Data Tables and Charts".

Make Data Tables & Charts
Long Profile Analysis

4 interactive charts to identify or develop:

- Slope Segments
- Reference Reach
- Upper Vertical Adjustment Potential Line
- Lower Vertical Adjustment Potential Line
- Long Profile Shape
Long Profile Analysis

A “Slope Segment” is a stretch of stream that has a consistent slope.

Add “Breakpoints” to establish start & stop points of the “Slope Segment”.
Long Profile Analysis

To continue to add “Slope Segment Lines”, add additional “Break Points”.

Mouse Brook at Route 9, Downeast, ME
IDF Test
Long Profile Analysis

Mouse Brook at Route 9, Downeast, ME
Interactive Chart Demonstration

<table>
<thead>
<tr>
<th>Seg.</th>
<th>Slope</th>
<th>% diff. in Slope between Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.0653</td>
<td>Sta. 49 to 66</td>
</tr>
<tr>
<td>B</td>
<td>0.065</td>
<td>Sta. 60 to 84</td>
</tr>
</tbody>
</table>

Adjust Tails or Delete Break Point

Delete Break Point

Or, Adjust Tail Lengths at Sta. 70

Current Upstream Tail Length: [Enter Value]

Enter New Upstream Tail Length: [Enter Value]

Current Downstream Tail Length: [Enter Value]

Enter New Downstream Tail Length: [Enter Value]

Apply New Tail Lengths

Cancel
Long Profile Analysis

Mouse Brook at Route 9, Downeast, ME
Interactive Chart Demonstration
Long Profile Analysis

Table 5. Slope Segment Table

<table>
<thead>
<tr>
<th>Segment</th>
<th>Elevation Change (ft or m)</th>
<th>Segment Length (ft or m)</th>
<th>Gradient (ft/ft or m/m)</th>
<th>% grad. diff. between successive segments (%)</th>
<th>Maximum residual pool depth (ft or m)</th>
<th>Number of intermediate grade controls</th>
<th>Avg. dist. between grade controls (ft or m)</th>
<th>Distance between grade controls (ft or m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>---</td>
<td>(ft or m)</td>
<td>(ft or m)</td>
<td>(m/m)</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>B</td>
<td>1.28</td>
<td>12.5</td>
<td>0.102</td>
<td>163%</td>
<td>0.81</td>
<td>0</td>
<td>12.5</td>
<td>12.5</td>
</tr>
<tr>
<td>C</td>
<td>3.41</td>
<td>57</td>
<td>0.0598</td>
<td>42%</td>
<td>0.72</td>
<td>2</td>
<td>19</td>
<td>17 18 22</td>
</tr>
<tr>
<td>E**</td>
<td>3.72</td>
<td>60.5</td>
<td>0.0615</td>
<td>83%</td>
<td>0.5</td>
<td>0</td>
<td>60.5</td>
<td>60.5</td>
</tr>
<tr>
<td>G</td>
<td>2.16</td>
<td>37</td>
<td>0.0584</td>
<td>19%</td>
<td>0.66</td>
<td>2</td>
<td>12.33</td>
<td>8 12 17</td>
</tr>
</tbody>
</table>

Notes:
[1] ** Indicates Segment contains a culvert.

• The above information is used later in the Long Profile analysis, or
• Used to design the new crossing once the Reference Reach has been identified.
Long Profile Analysis

For each chart, the information you need to conduct the analysis associated with that chart, is located adjacent to it.

Example: The chart for identifying the Vertical Adjustment Potential Line requires:

- Max Pool Depth
- Max Pool Depth Multiplier
Long Profile Analysis

Mouse Brook at Route 9, Downeast, ME
Culvert Replacement - Preliminary Design
Roughness Elements Schematic

Plot of roughness elements within the Reference Reach to help identify:

- What types of Roughness Elements occur?
- What sizes are they?
- At what frequency do they occur?
- How are they laid out (relative position)?
- To what extent do they contribute to the overall roughness of the channel?

Use the reference reach schematic as a template for designing the roughness elements in the new crossing.
Roughness
Elements Schematic

Types of Roughness *.

- Shorelines
- **Sinuosity** (See Field Data Review)
- Contraction-Expansion
- Large Rocks (Key Pieces)
- Rock Steps (Step-Pool Morphology)
- Wood (Individual Trees)
- Wood Jambs

* In addition to grain size (skin friction)
Roughness Elements Schematic

Field Data to Plot

1. Field data collection (identify location and size of roughness elements).
2. Field Data Review Spreadsheet
   • Create output files.
3. Copy/Paste output files
4. Roughness Elements Schematic Spreadsheet
   • Select options.
   • Click “Plot” button.

Tree is above Bankfull elev.
Roughness Elements Schematic

- Shorelines
- Sinuosity
- Contraction-Expansion
- Large Rocks
- Rock Steps
- Wood
- Wood Jambs

Large Rocks:
Circle size is proportional to rock size.
Rock color (gray scale) is proportional to protrusion.
Roughness Elements Schematic

- Shorelines
- Sinuosity
- Contraction-Expansion
- Large Rocks
- Rock Steps
- Wood (Trees)
- Wood Jambs
### Particle Count

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>No. of Particles</th>
<th>% by Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>d&lt;2</td>
<td>0.0%</td>
</tr>
<tr>
<td>2 &lt;= d &lt; 2.8</td>
<td>4</td>
<td>0.0%</td>
</tr>
<tr>
<td><strong>Fine Gravel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 &lt;= d &lt; 5.7</td>
<td>2</td>
<td>3.8%</td>
</tr>
<tr>
<td>5.7 &lt;= d &lt; 8</td>
<td>3</td>
<td>9.8%</td>
</tr>
<tr>
<td><strong>Med. Gravel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 &lt;= d &lt; 11.3</td>
<td>5</td>
<td>9.8%</td>
</tr>
<tr>
<td>11.3 &lt;= d &lt; 16</td>
<td>8</td>
<td>9.8%</td>
</tr>
<tr>
<td><strong>Coarse Gravel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 &lt;= d &lt; 22.6</td>
<td>11</td>
<td>19.5%</td>
</tr>
<tr>
<td>22.6 &lt;= d &lt; 32</td>
<td>15</td>
<td>30.9%</td>
</tr>
</tbody>
</table>

Gravel = 68.4%

D<sub>16</sub> = 13.8 mm

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>No. of Particles</th>
<th>% by Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sm. Boulder</td>
<td>362 &lt;= d &lt; 512</td>
<td>2</td>
</tr>
<tr>
<td>Med. Boulder</td>
<td>512 &lt;= d &lt; 724</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>724 &lt;= d &lt; 1024</td>
<td></td>
</tr>
<tr>
<td>Lg. Boulder</td>
<td>d &gt;= 1024</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D&lt;sub&gt;5&lt;/sub&gt;</th>
<th>D&lt;sub&gt;90&lt;/sub&gt;</th>
<th>D&lt;sub&gt;99&lt;/sub&gt;</th>
<th>D&lt;sub&gt;99.9&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>16%</td>
<td>13.8</td>
<td>0.544</td>
<td>0.045</td>
</tr>
<tr>
<td>10%</td>
<td>8.86</td>
<td>0.349</td>
<td>0.029</td>
</tr>
<tr>
<td>5%</td>
<td>3.86</td>
<td>0.152</td>
<td>0.013</td>
</tr>
</tbody>
</table>
Particle Count Analysis

- 84% Finer = 112 mm
- 50% Finer = 39.3 mm
- 35% Finer = 25.2 mm
- 16% Finer = 8.24 mm

**Cumulative Percent**

- \( d_{98} = 387 \text{ mm} \)
- \( d_{84} = 110 \text{ mm} \)
- \( d_{50} = 42.2 \text{ mm} \)

**Percent of Total Per Bin**

- \( 3\% \)
- \( 2.2\% \)
- \( 3.7\% \)
- \( 8.2\% \)
- \( 11.2\% \)
- \( 15\% \)
- \( 5\% \)
- \( 3\% \)
- \( 1.5\% \)
- \( 0.7\% \)

**Particle Size (mm)**

- \( 0 \) to \( 1 \)
- \( 10 \) to \( 20 \)
- \( 50 \) to \( 100 \)
- \( 1000 \) to \( 2000 \)
Target Users

Anyone trained in the USFS Stream Simulation methodology, including:

• Hydrologists
• Fisheries Biologists
• Geologists
• Foresters
• Engineers
• Etc.
Current Status of Development

Useable, but not done!

• Preliminary versions of Field Data Review and Roughness Elements Schematic in use for about one year.
• Current version of spreadsheets available for limited distribution.
Distribution

• Basic spreadsheets will be free to non-profits organizations and government agencies.

• Distribute spreadsheets at USFS Stream Simulation training courses.

• Distribute at other training venues.

• Updates to be available once or twice a year.
Credits:
Thanks to Bob Gubernick, USFS and Steve Koenig, Project SHARE, for their support.

Thanks to:
• Alex Abbott, USF&WS
• Serena Dose, USF&WS
• Jed Wright, USF&WS
for photos, data, testing & support.
Software Demo
During upcoming break in this room.

If interested in learning more or testing the spreadsheets:

• Leave me your business card, or

• Send me a text at: (207) 838 – 8091