Dear Mr. Kline:

Reference.  PennDOT Engineering District 2-0, Statement of Work, subj: Concept Design for Vehicle Bridge over Spring Creek along Puddintown Road in College Township, Centre County, PA, revision #1, dated February 10, 2014.

Statement of Problem.  Recent flooding has affected a structurally deficient vehicle bridge. The bridge was a necessary route to the Mount Nittany Medical Center located in State College, PA. Commuters now have a longer drive through a congested area.

Objective.  The objective is to design a new bridge that will satisfy the traffic flow and provide a quicker route to Mount Nittany Medical Center

Design Criteria.  Two bridge types will be analyzed: the Howe through truss and the Warren through truss. Both bridges will be constructed with medium strength concrete, and will the ability to support two 225kN trucks (one in each lane).

Technical Approach.

Phase 1: Economic Efficiency. This will be determined by the cost of each design. The cost will be measured by the West Point Bridge Designer 2013 software. In this program, the focus will be cost efficiency and the fulfillment of the requirements as stated above.

Phase 2: Structural Efficiency. A prototype Howe truss bridge and a prototype Warren truss bridge will each be constructed by the design team to compare structural efficiency of the two. Each truss prototype will be load tested until failure occurs. It must have the ability to support live loads. Each prototype will be designed using popsicle sticks and Elmers glue. Each bridge will be able to use 60 popsicle sticks maximum to keep the results consistent. The structural efficiency of both trusses will be determined by a simple equation. (Load test until failure weight/weight of prototype truss)
Results.

Phase 1: Economic Efficiency. We have found, using West Point Bridge Designer, that the Warren truss bridge is $21,938.34 cheaper than the Howe truss bridge.

Phase 2: Structural Efficiency. We have found from the testing of our prototypes that the Howe truss has the better structural efficiency. The actual weight of the bridge was lower while the weight supported was higher than the Warren truss.

Best Solution. After considering all the facts and comparing the structural efficiency and economic efficiency of the Warren through truss and Howe through truss bridge designs, we have decided that the Howe truss bridge design is the best solution for the necessary bridge replacement over Spring Creek.

Using the information from the structural efficiency testing of the two prototype bridges, we have concluded that the Howe bridge design is much more structurally sound than the Warren design. Both bridges obtained similar forensic analysis results and even so, the Warren withheld a higher live load.

The cost tabulation from both bridge designs showed us that the Warren truss would be about $20,000 dollars cheaper than the Howe, but regardless, as a group we have decided that a mere $20,000 in a close to $300,000 project would be insignificant when looking at structural efficiency and how the Howe truss trumps the Warren truss in this category.

Conclusions and Recommendations. The Howe through truss bridge is our recommendation for replacing the destroyed bridge across Spring Creek. We have taken into consideration structural efficiency and economic efficiency and believe the Howe truss design to be in the best interest for State College.

The next steps taken should include foundation inspection/possible reinstallation considering if the old foundation is structurally efficient or not. After this step, materials should be ordered to construct the bridge as recommended and construction companies employed in order to start construction as soon as possible.

Respectfully,

Anna George
Engineering Student
EDSGN100 Design Team # 7
College of Engineering
Penn State University

Chris Klarides
Engineering Student
EDSGN100 Design Team # 7
College of Engineering
Penn State University

Lenny Colome
Engineering Student
EDSGN100 Design Team # 7
College of Engineering
Penn State University
Phase 1: Economic Efficiency

**Howe Truss.** Our Howe Truss bridge on West Point Bridge Designer uses carbon steel bars of varying size for the top cords, end posts, and the diagonals. The bottom cords and verticals are all made of quenched and tempered steel tubes. The total cost of the bridge is $284,144.98

### Table 1: Cost Calculation

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Length (ft)</th>
<th>Width (in)</th>
<th>Depth (in)</th>
<th>Cross Section</th>
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</thead>
<tbody>
<tr>
<td>Steel Bar</td>
<td>100</td>
<td>4</td>
<td>2</td>
<td>(-)</td>
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</table>

### Table 2: Load Test Report

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Length (ft)</th>
<th>Width (in)</th>
<th>Depth (in)</th>
<th>Cross Section</th>
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<tbody>
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<td>Steel Tube</td>
<td>100</td>
<td>4</td>
<td>2</td>
<td>(-)</td>
</tr>
</tbody>
</table>
Table 3: Member Details

Figure 1: West Point Bridge Designer 2013 Howe Truss Bridge
Warren Truss. The Warren Truss Bridge on West Point Bridge Designer uses carbon steel bars of varying sizes for the end posts, the top cords, and the diagonals. The bottom cords are made of quenched and tempered steel tubes. The cost of the Warren truss bridge is $262,206.64

Table 4: Cost Calculation

Table 5: Load Test Report
Table 6: Member Details

Figure 2: West Point Bridge Designer 2013 Warren Truss Bridge
ATTACHMENT 2

Phase 2: Structural Efficiency

**Howe Truss.** The structural efficiency using the estimated weight of 88.78g is .340 lbs/g. The structural efficiency using the actual weight of 81.4g is .371 lbs/g. The estimated and actual weight is most likely off because of a misjudged glue use estimation.

**Prototype Bridge.** In constructing the prototype, 60 popsicles out of the 60 were used. The bridge included 12 vertical members, 4 end post members, 8 diagonal members, 10 top cord members, 16 bottom cord members, and had 4 struts and 4 floor beam members. The other two popsicle sticks were broken and used as support pieces for the top cords and bottom cords.

Figure 3: Howe before Failure

**Load Testing.** Average load test failure weight: 48.975lbs

Our bridge was below average by about

<table>
<thead>
<tr>
<th>Team No.</th>
<th>Howe Load Test Results (lbs.)</th>
<th>Howe Load Test Results (kg)</th>
<th>Howe Load Test Results (g)</th>
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Table 7: Howe Load Test Results
**Forensic Analysis.** The Howe truss prototype failed at 30.2lbs. The bridge fell over in a direction parallel to the struts. We believe this was due to poor attachment of the struts to the top cords. When testing, it was seen that a strut actually peeled off of top cord at one of the glue joints.

![Image of Howe Bridge Structural Efficiency](image)

**Figure 4: Howe after failure**

**Warren Truss.** The structural efficiency using the estimated weight of 88.78g is .322 lbs/g. The structural efficiency using the actual weight of 82.7g is .346 lbs/g. The estimated and actual weight is most likely off because of a misjudged glue use estimation.

![Image of Warren Bridge before Failure](image)

**Figure 5: Warren before Failure**

**Prototype Bridge.** In constructing the prototype, 60 popsicles out of the 60 were used. The 60 popsicle sticks were used as follows: 8 end post members, 16 diagonal members, 10 top cord members, 16 bottom cord members, 4 strut members, 4 floor beam members, and the other two popsicle sticks were used for reinforcement in the top and bottom cords.

**Load Testing.** Average load test failure weight: 47.2lbs
Our bridge was around 20lbs under the average load weight.
<table>
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<tr>
<th>Team No.</th>
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<tr>
<td>8</td>
<td>28.6</td>
<td>12.973</td>
<td>12972.742</td>
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</tbody>
</table>

Table 9: Warren Load Test Results

**Forensic Analysis.** The Warren truss prototype failed at 28.6lbs. The problem is assumed to be that the strut joints were very weakly connected to the top cords and this caused the bridge to topple over to the side (fell parallel to the struts). As you can see in Figure 6, the struts were the only piece to break on the prototype.

Figure 6: Warren after failure

![Warren Bridge Structural Efficiency](image.png)

Table 10: Warren Structural Efficiency