Stream Instability Countermeasures Applied at KDOT Highway Structures

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KU CEAE Dept
Acknowledgments

- Brad Rognlie
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- KDOT Bridge Section
This project considered stream instability countermeasures used by KDOT to protect the highway infrastructure at stream crossings from changes due to the dynamic nature of streams. The following countermeasure types were observed in the field at several locations in Kansas.

- Bend way Weirs
- Jetties (or spurs)
- Drop Structures
- Hard Points
- Gabion Baskets
- Bank Protection
Do Streams Change?
Site #4 – Rock Jetties, Little Blue River
Hanover, KS, Washington County
Site #1 – Sheet Pile Jetties
Arlington, KS, Reno County
Site #17 - Sand Tube Bendway Weirs
Kingman, KS, Reno County
Stream Instability

Stream instability can be due to natural environmental changes and/or human activities. The following are a few human activities that can cause stream instability.

- Loss of riparian vegetation due to overgrazing, development or farm practices.
- Channel degradation downstream from man-made reservoirs.
- Change in sediment load due to development and farm practices.
- Increase or decrease of stream runoff due to development or farm practices.
Lateral migration of a stream does not necessarily classify the stream is unstable – it only confirms that it is a dynamic stream.

The location of the meanders, pools and riffles for a stable channel may change over time even though the general geometric characteristics of the stream will remain constant.
Stream Stability

HDS 6 River Engineering for Highway Encroachments, p 1.7

(http://isddc.dot.gov/OLPFiles/FHWA/010589.pdf)

“In summary, archaeological, botanical, geological, and geomorphic evidence supports the conclusion that most rivers are subject to constant change as a normal part of their morphologic evolution.”
Stream Stability

Rosgen, D.


“When the stream laterally migrates, but maintains its bankfull width and width/depth ratio, stability is achieved even though the river is considered to be an “active” and “dynamic” system.”
References for the Design of Scour Countermeasures

HDS 6  River Engineering for Highway Encroachments
(http://isddc.dot.gov/OLPFiles/FHWA/010589.pdf)

HEC-11  Design of Riprap Revetment
(http://isddc.dot.gov/OLPFiles/FHWA/009881.pdf)

HEC-18  Evaluating Scour at Bridges
(http://isddc.dot.gov/OLPFiles/FHWA/010590.pdf)

HEC-20  Stream Stability at Highway Structures
(http://isddc.dot.gov/OLPFiles/FHWA/010591.pdf)

HEC-23  Bridge Scour and Stream Instability Countermeasures
(http://isddc.dot.gov/OLPFiles/FHWA/010592.pdf)
Locations of KDOT Stream Instability Countermeasure Sites
<table>
<thead>
<tr>
<th>Number</th>
<th>Kansas County Name</th>
<th>Nearby City Name</th>
<th>Kansas Bridge Serial #</th>
<th>Problem</th>
<th>Solution</th>
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<tbody>
<tr>
<td>1</td>
<td>Reno</td>
<td>Arlington</td>
<td>82</td>
<td>River encroachment-Meander</td>
<td>Steel Sheetpile Jetties, Rock Bank Protection.</td>
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<td>2</td>
<td>Riley</td>
<td>Manhattan</td>
<td>-</td>
<td>River encroachment</td>
<td>Bendway weirs</td>
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<td>Pottowatomie</td>
<td>Wamego</td>
<td>8</td>
<td>River encroachment-Meander</td>
<td>Guide Bank (East Abut. Berm) + Rock Jetties</td>
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<td>Washington</td>
<td>Hanover</td>
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<td>5</td>
<td>Sumner</td>
<td>Riverdale</td>
<td>132</td>
<td>River encroachment-Meander</td>
<td>Steel Sheetpile Jetties</td>
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<td>6</td>
<td>Atchison</td>
<td>Arrington</td>
<td>46</td>
<td>Channel Erosion-Meander</td>
<td>Rock Hard Points</td>
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<tr>
<td>7</td>
<td>Hodgeman</td>
<td>Jetmore</td>
<td>10</td>
<td>Vertical Degrading</td>
<td>Steel Sheetpile Basin-Drop Structure</td>
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<td>8</td>
<td>Decatur</td>
<td>Oberlin</td>
<td>9</td>
<td>Vertical Degrading</td>
<td>Steel Sheetpile Basin-Drop Structure</td>
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<td>Finney</td>
<td>Garden City</td>
<td>15</td>
<td>River encroachment-Meander</td>
<td>Sec-14 COE-Buried Rock Trench + Riprap</td>
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<tr>
<td>10</td>
<td>Neosho</td>
<td>Porterville</td>
<td>57</td>
<td>Stream encroachment-Meander</td>
<td>Rock Slope Protection at Abutment</td>
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<td>Atchison</td>
<td>54</td>
<td>Stream encroachment-Vert. &amp; Horiz.</td>
<td>Gabion protection at abutment berm</td>
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<td>Wyandotte</td>
<td>Bonner Springs</td>
<td>84 &amp; 85</td>
<td>Stream encroachment- Horiz.</td>
<td>Gabion protection at abutment berm</td>
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<td>Manhattan</td>
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<td>RCB Wing Erosion</td>
<td>Gabion protection at RCB wing</td>
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<td>Nemaha</td>
<td>Goff</td>
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<td>St. George</td>
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<td>Vertical headcut</td>
<td>Drop structure</td>
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<td>Wabaunsee</td>
<td>Alma</td>
<td>-</td>
<td>Lateral migration</td>
<td>Bendway Weirs</td>
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<tr>
<td>17</td>
<td>Kingman</td>
<td>Kingman</td>
<td>-</td>
<td>Lateral migration</td>
<td>Bendway Weirs</td>
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Bendway Weirs

- Low elevation sills
- Constructed of stones
- Water flows over a sill perpendicular to the longitudinal sill axis
- Reduce outer bank velocities
- Promote deposition between bendway weirs
Bendway Weir - Typical Plan View (HEC 23)
Bendway Weir - Typical Cross-Section (HEC 23)

H = 0.3 to 0.5 mean annual high water elevation depth

SIDE SLOPES SET AT ANGLE OF REPOSE OR FLATTER
Site #2  Tuttle Creek Reservoir Park Bridge
Manhattan, KS, Riley County
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Manhattan, KS, Riley County
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Manhattan, KS, Riley County
Site #2  Tuttle Creek Reservoir Park Bridge
Manhattan, KS, Riley County
Site #2 Tuttle Creek Reservoir Park Bridge
Manhattan, KS, Riley County
Site #2  Tuttle Creek Reservoir Park Bridge  
Manhattan, KS, Riley County
Site #16 - South Alma K-99
Alma, KS, Wabaunsee County
Site #16 - South Alma K-99
Alma, KS, Wabaunsee County
Site #16 - South Alma K-99
Alma, KS, Wabaunsee County
Site #16 - South Alma K-99
Alma, KS, Wabaunsee County
Site #17 - RS1704 Sand Sock
Kingman, KS, Kingman County
Site #17 - RS1704 Sand Sock
Kingman, KS, Kingman County
Site #17 - RS1704 Sand Sock
Kingman, KS, Kingman County
Site #17 - RS1704 Sand Sock
Kingman, KS, Kingman County
Site #17 - RS1704 Sand Sock
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Site #17 - RS1704 Sand Sock
Kingman, KS, Kingman County
Site #17 - RS1704 Sand Sock
Kingman, KS, Kingman County
Site #17 - RS1704 Sand Sock
Kingman, KS, Kingman County
Site #17 - RS1704 Sand Sock
Kingman, KS, Kingman County
Jetties (or Spurs)

- Stone or steel construction materials
- Water flows around jetties
- Jetties control meandering by
  - Redirecting velocities through bends
  - Breaking up secondary currents
  - Promoting deposition between jetties
Extent of Protection Required at a Channel Bend Design (HEC 23)
Initial Installation of Jetty System
Equilibrium Conditions for Jetty System
Example of Spur Dike Design (HEC 23)

NOTE: SOLID LINES REPRESENT EXISTING CONDITIONS. DASHED LINES REPRESENT SOLUTIONS
Site #3 - K24 Vermillion River, Rock Jetties
Wamego, KS, Pottowatomie County
Site #3 - K24 Vermillion River, Rock Jetties, Wamego, KS, Pottowatomie County

Toe of jetty
Site #3 - K24 Vermillion River, Rock Jetties
Wamego, KS, Pottowatomie County
Site #3 - K24 Vermillion River, Rock Jetties
Wamego, KS, Pottowatomie County
Site #3 - K24 Vermillion River, Rock Jetties
Wamego, KS, Pottowatomie County
Site #4 - Rock Jetties, Little Blue River
Hanover, KS, Washington County
Site #4 - Rock Jetties, Little Blue River
Hanover, KS, Washington County
Site #4 – Rock Jetties, Little Blue River
Hanover, KS, Washington County

May 2001

March 2006
Site #4 – Rock Jetties, Little Blue River
Hanover, KS, Washington County
Site #4 – Rock Jetties, Little Blue River
Hanover, KS, Washington County
Site #1 – Sheet Pile Jetties
Arlington, KS, Reno County
Site #1 - Sheet Pile Jetties
Arlington, KS, Reno County
Site #1 - Sheet Pile Jetties (looking DS)
Arlington, KS, Reno County
Site #1 - Sheet Pile Jetties
Arlington, KS, Reno County
Site #1 - Sheet Pile Jetties (looking US)

Arlington, KS, Reno County
Site #1 – Sheet Pile Jetties (looking US)
Arlington, KS, Reno County
Site #5 – Sheet Pile Jetties
Riverdale, KS, Sumner County
Site #5 - Sheet Pile Jetties
Riverdale, KS, Sumner County
Site #5 - Sheet Pile Jetties
Riverdale, KS, Sumner County
Site #5 – Sheet Pile Jetties
Riverdale, KS, Sumner County
Site #5 – Sheet Pile Jetties
Riverdale, KS, Sumner County
Site #5 - Sheet Pile Jetties
Riverdale, KS, Sumner County
Site #5 - Sheet Pile Jetties
Riverdale, KS, Sumner County
Site #5 - Sheet Pile Jetties
Riverdale, KS, Sumner County
Drop Structures

Headcutting can pose serious threats to roads, culverts and bridges. Since headcutting is prevalent in Kansas, a major effort has been made to address protecting our highway system from the damage it could cause by the use of check dams or drop structures.

(a) $t_1$

(b) $t_2 > t_1$
Causes of Headcutting

- Channel straightening
- Increased discharge
- Drop of water surface at a tributary confluence
- Gravel mining
- Channelization
- Loss of riparian buffer zone
Check Dam

![Diagram of a check dam with labels for various dimensions and energy gradient lines. The diagram includes symbols for velocity ($V$), height ($H$), and other geometric properties such as $V_u/2g$, $V_d/2g$, $V^2_u/2g$, $V^2_d/2g$, $Y_d$, and $Z$ dimensions.]
Site #14 - Sheet Pile Sill, Rip Rap
Goff, KS, Nemaha County
Site #14 - Sheet Pile Sill, Rip Rap
Goff, KS, Nemaha County
Site #14 - Sheet Pile Sill, Rip Rap
Goff, KS, Nemaha County
Site #14 – Sheet Pile Sill, Rip Rap
Goff, KS, Nemaha County
Site #15 - Concrete Drop Structure, Rip Rap
St. George, KS, Pottowatomie County
Site #15 - Concrete Drop Structure, Rip Rap
St. George, KS, Pottowatomie County
Site #15 - Concrete Drop Structure, Rip Rap
St. George, KS, Pottowatomie County
Site #15 - Downstream View
St. George, KS, Pottowatomie County
Site #15 - Upstream View
St. George, KS, Pottowatomie County
Hard Points

Hard points are locations on an erodible stream bank that are resistant to erosion. They can be either man-made or can occur naturally.

Hard points protect an existing bank line from further migration or degradation. They are used effectively in relatively straight stream reaches.
Perspective View of Hardpoint Installation with Section Detail (HEC 23)

NORMAL WATER SURFACE

TOPSOIL & SEEDED

FLOW

STONE FILL

TYPICAL SECTION

SPUR

STONE ROOT

VARIES 38 - 50'
Site #6 – Hard Points
K166, Delaware River Bridge 3(46)
Arrington, KS, Atchison County
Site #6 - Hard Points
K166, Delaware River Bridge 3(46)
Arrington, KS, Atchison County
Site #6 - Hard Points
K166, Delaware River Bridge 3(46)
Arrington, KS, Atchison County

Can’t see them.
Gabion Baskets

Gabion baskets are rectangular-shaped wire mesh baskets filled with cobbles or rocks. They are effective in controlling erosion in streams.
Site #11 - Gabion Baskets, US59 White Clay Creek Bridge 3(054)
Atchison, KS, Atchison County
Site #11 - After Countermeasures
Atchison, KS, Atchison County
Site #12 - K32 Mission Creek, Bridge 105(84-85)
Bonner Springs, KS, Wyandotte County
Site #12 – Before Countermeasures
Bonner Springs, KS, Wyandotte County
Site #12 – Before Countermeasures
Bonner Springs, KS, Wyandotte County
Site #12 – Sketch of Countermeasures
Bonner Springs, KS, Wyandotte County
Site #12 – Sketch of Countermeasures
Bonner Springs, KS, Wyandotte County
Site #12 – After Countermeasures
Bonner Springs, KS, Wyandotte County
Site #12 – After Countermeasures
Bonner Springs, KS, Wyandotte County
Site #13 - K18 RCB Gabion, Bridge 81(033)  
Manhattan, KS, Riley County
Bridge 63-66-14.31033
Nemahah County
Bridge 63-66-14.31033
Nemahah County
Summary and Conclusions

Rosgen states that even streams classified as stable are “dynamic” and “active” and experience lateral migration (6, p 1-3). The degree of a stream’s stability and the appropriate method of determining it are still being debated. **What is not being debated is the inherent dynamic nature of streams whether they are stable or unstable.**
Summary and Conclusions

As engineers, we will continue to be responsible for protecting our roadways and the public from the failure of our highway infrastructure due to stream instability.

The projects sited in this study were comprehensive solutions to complicated problems. KDOT did not elect to use “band-aid” solutions. As a result, all the stream instability countermeasure projects considered herein were quite successful.