2013 Colorado Flood Recovery: A Case Study in Riverine/Fluvial NNBF Applications

Randy Mandel
Vice President, Technical Services, Great Ecology
Revegetation Lead, CWCB Emergency Watershed Protection Program
rmandel@greatecology.com
Outline

• Background on Colorado’s 2013 Floods
• The Colorado Stream Bioengineering Guide
• The Colorado Revegetation Matrix
• Example Restoration Projects
• Insights on NNBF Riverine/Fluvial Applications
• Insights on Community & Stakeholder Engagement
Colorado’s Catastrophic 2013 Floods

- Nearly $4 billion in damage
- CO’s costliest natural disaster
- Caused damage across 24 counties
- Displaced 18,000 people
- Destroyed 1,800 homes

Photos: J. Giordanengo & Denver Post
The Response: Colorado Water Conservation Board (CWCB)

“THIS WAS A NEW WAY OF DOING BUSINESS. WE TOOK A DIFFERENT, MORE HOLISTIC APPROACH AND WE’RE EXCITED TO SEE THE RESULTS ON THE GROUND.”

-KEVIN HOUCK, CWCB
Colorado Emergency Watershed Protection (EWP) Program

- EWP funds were allocated to NRCS
- Program was administered and managed by CWCB
- Federal funds provided reimbursement for 75% of construction
- CWCB’s management of the $70 million program began in 2015 and ended in 2018
The Response:
A Bioengineering Guide
for Colorado Streams

Submitted To: State of Colorado, Colorado Water Conservation Board
1313 Sherman St, Room 718
Denver, CO 80201

Submitted By: AloTerra Restoration Services, LLC, and
Golder Associates, Inc.

Primary Authors:
John H. Giordanengo
Randy H. Mandel
William J. Spitz
Matthew C. Bostler
Michael J. Blazevic
Steven E. Yochum
Kate R. Jagt
William J. LaBarre
Grant E. Gurnee
Robert Humphries
Kelly T. Uhing

4. Round River Design, LLC; 5. USFS, National Stream and Aquatic Ecology Center;
6. Watershed Science and Design, PLLC; 7. Ecosystem Services, LLC; 8. Denver Parks -
Natural Resources Division

DRAFT Date: April 12, 2016
A Bioengineering Guide for Colorado Streams

**Bioengineering:** the integration of living woody and herbaceous materials along with organic and inorganic materials to increase the strength and structure of the soil


**Purpose of Guide:** to provide restoration practitioners with guidelines for planning, design, and construction of streambank protection optimized for the conditions specific to Colorado’s watersheds.
A Bioengineering Guide for Colorado Streams

- Intent of Guide
  - Provide guidelines for comprehensive restoration strategy
  - Incorporate design elements that impart site stability
  - Include recommendations that minimize risks during vulnerable periods
The Colorado Revegetation Matrix

- Includes prioritized woody, forb, and graminoid species based on feedback from multiple agencies and groups
- Incorporates 51 searchable parameters
  - Nomenclature
  - County
  - Hydrology/physiographic preference
  - Morphology
  - Germination data
The Colorado Revegetation Matrix

- Included within morphology are root parameters that allow better incorporation in bioengineering techniques.

- Also includes germination protocols, average seed weights, storage recommendations, and implementation preferences.
### Search Criteria:

This form is used to search for plant species in flood affected areas that are found in Colorado by occurrence. Enter the search criteria in the boxes below. Click the filter button to apply the criteria. Click the remove filter button to remove all criteria values. If no criteria is applied for a specific topic, then all options for that topic will be included in the results. A list of the results is provided under Summary of Results and a table with all of data table columns can be exported to Excel by clicking "Export Results to Excel."

#### Search for Plant(s) that meet the following criteria:

- **Native Status:**
  - Leave blank if yes or no.

- **Elevation Range (feet):**

- **County Occurrence:**
  - Adams
  - Alamosa
  - Arapahoe
  - Archuleta
  - Baca
  - Bent
  - Boulder
  - Broomfield
  - Clear Creek
  - Conejos
  - Costilla
  - Crowley
  - Custer
  - Delta
  - El Paso
  - Elbert
  - Eagle
  - Garfield
  - Gilpin
  - Grant
  - Gunnison
  - Hinsdale
  - Huerfano
  - Jefferson
  - Kit Carson
  - Lake
  - Las Animas
  - Lincoln
  - Logan
  - Moffat
  - Montgomery
  - Morgan
  - Mesa
  - Morey
  - Montezuma
  - Prowers
  - Park
  - Otero
  - Phillips
  - Pueblo
  - Pitkin
  - Rio Blanco
  - Rio Grande
  - Rio Grande
  - San Juan
  - Sangre de Cristo
  - San Miguel
  - Saguache
  - San Luis
  - Sedgwick
  - Sheridan
  - Sierrita
  - Siskiyou
  - Smith River
  - Spearhead
  - Teller
  - Weld
  - Washington
  - Whetstone
  - Whitewater
  - Willows
  - Winsted
  - Yuma
  - Yuma

### Summary of Results:

The exported data table includes all columns of data, not just the subset of the table columns shown below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>PLANTS Code</th>
<th>Native Status</th>
<th>Elevation Range (ft)</th>
<th>County Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woody Species</td>
<td>Acer glabrum Torr.</td>
<td>Rocky Mountain maple</td>
<td>ACGL</td>
<td>yes</td>
<td>5,200 to 10,500</td>
<td>Alamosa, Archuleta, Boulder, Chaffee, Clear Creek, Conejos, Costilla, Custer, Delta, Denver, Dolores, Douglas, Eagle, El Paso, Fremont,</td>
</tr>
<tr>
<td>Woody Species</td>
<td>Acer negundo L. ssp. interius (Britton) Sarg.</td>
<td>boxelder</td>
<td>ACNEI2</td>
<td>yes or no</td>
<td>4,800 to 7,900</td>
<td>Adams, Alamosa, Arapahoe, Archuleta, Baca, Bent, Boulder, Chaffee, Clear Creek, Costilla, Custer, Delta, Denver, Dolores, Douglas, Eagle,</td>
</tr>
<tr>
<td>Forb</td>
<td>Achillea millefolium L. var. occidentalis DC.</td>
<td>western yarrow; common yarrow</td>
<td>ACMIO</td>
<td>yes</td>
<td>4,800 to 13,200</td>
<td>Adams, Alamosa, Arapahoe, Archuleta, Boulder, Chaffee, Cheyenne, Clear Creek, Conejos, Costilla, Custer, Denver, Dolores, Douglas, Eagle,</td>
</tr>
<tr>
<td>Graminoid</td>
<td>Achnatherum hymenoides (Roemer &amp; Schultes)</td>
<td>Indian ricegrass; Indian mountain</td>
<td>ACHY</td>
<td>yes</td>
<td>3,400 to 10,000</td>
<td>Adams, Alamosa, Arapahoe, Archuleta, Baca, Bent, Boulder, Chaffee, Cheyenne, Clear Creek, Conejos, Costilla, Custer, Delta, Dolores, Douglas, Eagle,</td>
</tr>
<tr>
<td>Graminoid</td>
<td>Achnatherum lettermanii (Vasey)</td>
<td>Letterman's needlegrass</td>
<td>ACLE9</td>
<td>yes</td>
<td>6,000 to 12,500</td>
<td>Boulder, Chaffee, Costilla, Delta, Dolores, Eagle, Garfield, Gilpin, Grand, Gunnison, Hinsdale, Jackson, Larimer, Las Animas, Mesa,</td>
</tr>
<tr>
<td>Graminoid</td>
<td>Achnatherum polaris</td>
<td>Columbia needlegrass</td>
<td>ACLE9</td>
<td>yes</td>
<td>6,000 to 12,000</td>
<td>Alamosa, Archuleta, Boulder, Chaffee, Clear Creek, Conejos, Costilla, Delta, Dolores, Eagle,</td>
</tr>
<tr>
<td>Graminoid</td>
<td>Achnatherum pilosella</td>
<td>Columbia needlegrass</td>
<td>ACLE9</td>
<td>yes</td>
<td>6,000 to 12,000</td>
<td>Alamosa, Archuleta, Boulder, Chaffee, Clear Creek, Conejos, Costilla, Delta, Dolores, Eagle,</td>
</tr>
</tbody>
</table>
Search for Plant(s) that meet the following criteria:

<table>
<thead>
<tr>
<th>Habitat contains:</th>
<th>Ecological Zone:</th>
<th>Successional Tier:</th>
<th>Aspect Preference:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrologic preference contains:</td>
<td>bank</td>
<td>mesic to upland</td>
<td>early-serial</td>
</tr>
<tr>
<td>Soil texture contains:</td>
<td>overbank</td>
<td>toe</td>
<td>transitional</td>
</tr>
<tr>
<td>pH Range (std. units):</td>
<td>upland</td>
<td>intolerant</td>
<td></td>
</tr>
<tr>
<td>Nitrogen Fixer:</td>
<td>leave blank if yes or no.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Summary of Results:

<table>
<thead>
<tr>
<th>Type</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>PLANTS Code</th>
<th>Habitat</th>
<th>Ecological Zone</th>
<th>Hydrologic Preference</th>
<th>Successional Tier</th>
<th>pH Preference</th>
<th>Aspect Preference</th>
<th>Soil Texture</th>
<th>Acidic Tolerance</th>
<th>Alkalinity Tolerance</th>
<th>Sodicity Tolerance</th>
<th>Drought Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>woody</td>
<td>Acer glabrum Torr.</td>
<td>Rocky Mountain maple</td>
<td>ACGL</td>
<td>Along streams,</td>
<td>overbank zone;</td>
<td>mesic to upland;</td>
<td>overbank zone;</td>
<td>mesic; early-serial sub-dominant</td>
<td>5.8 to 7.5</td>
<td>northern aspect optimal;</td>
<td>silty, loamy, sandy, gravelly, and rocky</td>
<td>tolerant</td>
<td>moderate</td>
<td>intolerant</td>
</tr>
<tr>
<td>woody</td>
<td>Acer negundo L. ssp.</td>
<td>boxelder</td>
<td>ACNEI2</td>
<td>Riparian areas,</td>
<td>overbank zone;</td>
<td>mesic; early-serial sub-dominant;</td>
<td>5.2 to 7.0</td>
<td>non-specific;</td>
<td>gravelly to clay soils, but prefers deep</td>
<td>moderate</td>
<td>moderate</td>
<td>intolerant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>forb</td>
<td>Achillea millefolium L. var.</td>
<td>western yarrow, common yarrow</td>
<td>ACMIO</td>
<td>Common in gravelly;</td>
<td>transitional zone; upland</td>
<td>mesic to xeric; early-serial sub-dominant</td>
<td>6.0 to 8.0</td>
<td>southern and western;</td>
<td>coarse to medium-coarse textured</td>
<td>intolerant</td>
<td>moderate</td>
<td>intolerant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>graminoid</td>
<td>Achineratherum hymenoides (Roemer &amp; K. Schultes)</td>
<td>Indian ricegrass; Indian mountain</td>
<td>ACHY</td>
<td>Desert, plains,</td>
<td>upland zone</td>
<td>xeric; early-serial, mid-seral or late-seral;</td>
<td>6.6 to 8.6</td>
<td>southern and western;</td>
<td>medium coarse to silt loam, clay loam, or</td>
<td>intolerant</td>
<td>moderate</td>
<td>intolerant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>graminoid</td>
<td>Achineratherum lettermanii (Vasey)</td>
<td>Letterman's needlegrass</td>
<td>ACLE9</td>
<td>Common in</td>
<td>upland zone</td>
<td>xeric to mesic; early-serial, mid-seral or late-seral;</td>
<td>6.0 to 7.6</td>
<td>non-specific;</td>
<td>fine, medium, and coarse textured</td>
<td>intolerant</td>
<td>moderate</td>
<td>intolerant</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Search Criteria:

This form is used to search for plant species in flood affected areas that are found in Colorado by growth form and attributes. Enter the search criteria in the boxes below. Click the filter button to apply the criteria. Click the remove filter button to remove all criteria values. If no criteria is applied for a specific topic, then all options for that topic will be included in the results. A list of the results is provided under Summary of Results and a table with all of data table columns can be exported to Excel by clicking "Export Results to Excel."

**Search for Plant(s) that meet the following criteria:**

- Growth Form: 
  - [ ] subshrub
  - [ ] shrub
  - [ ] shrub to small tree
  - [ ] large shrub to small tree
  - [ ] tree
  - [ ] small tree
  - [ ] graminoid
  - [ ] herbaceous dicot
  - [ ] herbaceous monocot

- Duration: 
  - [ ] annual
  - [ ] biennial
  - [ ] perennial

- Season: 
  - [ ] cool
  - [ ] warm

### Summary of Results:

The exported data table includes all columns of data, not just the subset of the table columns shown below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>PLANTS Code Growth Form</th>
<th>Duration</th>
<th>Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>woody</td>
<td>Acer glabrum Torr.</td>
<td>Rocky Mountain maple</td>
<td>ACGL</td>
<td>shrub to small tree</td>
<td>perennial</td>
</tr>
<tr>
<td>woody</td>
<td>Acer negundo L. ssp. interius (Britton) Sarg.</td>
<td>box elder</td>
<td>ACNET2</td>
<td>tree</td>
<td>perennial</td>
</tr>
<tr>
<td>forb</td>
<td>Achillea millefolium L. var. occidentalis DC.</td>
<td>western yarrow; common yarrow</td>
<td>ACMIO</td>
<td>herbaceous dicot</td>
<td>perennial</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum hymenoides (Roemer &amp; J.A. Schultes) Barkworth</td>
<td>Indian ricegrass; Indian mountain ricegrass</td>
<td>ACHY</td>
<td>graminoid</td>
<td>perennial</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum lettermanii (Vasey) Barkworth</td>
<td>Letterman's needlegrass</td>
<td>ACLE9</td>
<td>graminoid</td>
<td>perennial</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum nelsonii (Scribn.) Barkworth</td>
<td>Columbia needlegrass</td>
<td>ACNE9</td>
<td>graminoid</td>
<td>perennial</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum nelsonii (Scribn.) Barkworth ssp. dorei (Barkworth &amp; McCloskey)</td>
<td>Dore's needlegrass; Columbia needlegrass</td>
<td>ACNED</td>
<td>graminoid</td>
<td>perennial</td>
</tr>
<tr>
<td>forb</td>
<td>Agastache urticifolia(Benth.) Kuntze</td>
<td>nettleleaf giant hyssop; field</td>
<td>AGUR</td>
<td>herbaceous dicot</td>
<td>perennial</td>
</tr>
</tbody>
</table>
# Search Plant Species by Wetland Status

This form is used to search for plant species in flood-affected areas that are found in Colorado by wetland status. Enter the search criteria in the boxes below. Click the filter button to apply the criteria. Click the remove filter button to remove all criteria values. If no criteria is applied for a specific topic, then all options for that topic will be included in the results. A list of the results is provided under Summary of Results and a table with all of data table columns can be exported to Excel by clicking "Export Results to Excel."

## Search for Plant(s) that meet the following criteria:

<table>
<thead>
<tr>
<th>Status:</th>
<th>AW (FAC)</th>
<th>AW (FACU)</th>
<th>AW (FACW)</th>
<th>AW (OBL)</th>
<th>AW (UPL)</th>
<th>AW ( - )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GP (FAC)</td>
<td>GP (FACU)</td>
<td>GP (FACW)</td>
<td>GP (OBL)</td>
<td>GP (UPL)</td>
<td>GP ( - )</td>
</tr>
<tr>
<td></td>
<td>WMVC (FAC)</td>
<td>WMVC (FACU)</td>
<td>WMVC (FACW)</td>
<td>WMVC (OBL)</td>
<td>WMVC (UPL)</td>
<td>not listed</td>
</tr>
</tbody>
</table>

### USACE Regions:
- AW = Arid West
- GP = Great Plains
- WMVC = Western Mountains, Valleys, and Canyons

### Indicator Codes:
- OBL = Obligate Wetland (designated hydrophyte), almost always occurs in wetlands
- FACW = Facultative Wetland (designated hydrophyte), usually occurs in wetlands, but may occur in non-wetlands
- FAC = Facultative (designated hydrophyte), occurs in wetlands and non-wetlands
- FACU = Facultative Upland (designated non-hydrophyte), usually occurs in non-wetlands, but may occur in wetlands

## Summary of Results:

The exported data table includes all columns of data, not just the subset of the table columns shown below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>PLANTS Code</th>
<th>USACE National Wetland Plant List Indicator Stat</th>
</tr>
</thead>
<tbody>
<tr>
<td>woody species</td>
<td><em>Acer glabrum</em> Torr.</td>
<td>Rocky Mountain maple</td>
<td>ACGL</td>
<td>AW (FAC), GP (FAC), WMVC (FACU)</td>
</tr>
<tr>
<td>woody species</td>
<td><em>Acer negundo</em> L. ssp. interius (Britton) Sarg.</td>
<td>box elder</td>
<td>ACNEI2</td>
<td>AW (FACW), GP (FAC), WMVC (FAC)</td>
</tr>
<tr>
<td>forb</td>
<td><em>Achillea millefolium</em> L. var. occidentalis DC.</td>
<td>western yarrow; common yarrow</td>
<td>ACMLO</td>
<td>AW (FACU), GP (FACU), WMVC (FACU)</td>
</tr>
<tr>
<td>graminoid</td>
<td><em>Achnatherum hymenoides</em> (Roemer &amp; J.A. Schultes) Barkworth</td>
<td>Indian ricegrass; Indian mountain ricegrass</td>
<td>ACHY</td>
<td>AW (UPL), GP (FACU), WMVC (UPL)</td>
</tr>
<tr>
<td>graminoid</td>
<td><em>Achnatherum lettermanii</em> (Vasey) Barkworth</td>
<td>Letterman's needlegrass</td>
<td>ACL9E</td>
<td>not listed</td>
</tr>
<tr>
<td>graminoid</td>
<td><em>Achnatherum polare</em> (Grun.) Barkworth</td>
<td>Columbian needlegrass</td>
<td>ACNP07</td>
<td>AW (FACU), GP (UPL), WMVC (UPL)</td>
</tr>
<tr>
<td>Type</td>
<td>Scientific Name</td>
<td>Common Name</td>
<td>PLANTS Code</td>
<td>Project Implementation Plant Materials</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------</td>
<td>--------------------------------------</td>
<td>-------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>woody species</td>
<td>Acer glabrum Torr.</td>
<td>Rocky Mountain maple</td>
<td>ACGL</td>
<td>container</td>
</tr>
<tr>
<td>woody species</td>
<td>Acer negundo L. ssp. Interius (Britton) Sarg.</td>
<td>boxelder</td>
<td>ACNE12</td>
<td>container</td>
</tr>
<tr>
<td>forb</td>
<td>Achillea millefolium L. var. occidentalis DC.</td>
<td>western yarrow; common yarrow</td>
<td>ACMIO</td>
<td>seed, container</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum hymenoides (Roemer &amp; J.A. Schultes) Barkworth</td>
<td>Indian ricegrass; Indian mountain ricegrass</td>
<td>ACHY</td>
<td>seed</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum lettermanii (Vasey) Barkworth</td>
<td>Letterman's needlegrass</td>
<td>ACLE9</td>
<td>seed</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum nelsonii (Scribn.) Barkworth</td>
<td>Columbia needlegrass</td>
<td>ACNE9</td>
<td>seed</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum nelsonii (Scribn.) Barkworth ssp. dorei (Barkworth &amp; Maze) Dorn</td>
<td>Dore's needlegrass; Columbia needlegrass</td>
<td>ACNED</td>
<td>seed</td>
</tr>
<tr>
<td>forb</td>
<td>Agastache urticifolia(Benth.) Kuntze var. urticifolia</td>
<td>nettleleaf giant hyssop; field horsemint</td>
<td>AGUR</td>
<td>container</td>
</tr>
<tr>
<td>forb</td>
<td>Allium acuminatum Hook.</td>
<td>tazacito onion</td>
<td>ALAC4</td>
<td>container</td>
</tr>
</tbody>
</table>
### Search Plant Species by Root System

**Search Criteria:**

This form is used to search for plant species in flood affected areas that are found in Colorado by root system. Enter the search criteria in the box below. Click the filter button to apply the criteria. Click the remove filter button to remove all criteria values. If no criteria is applied, then all options for that topic will be included in the results. A list of the results is provided under Summary of Results and a table with all of data table columns can be exported to Excel by clicking "Export Results to Excel."

**Search for Plant(s) that meet the following criteria:**

- **Root System:**  
  - [ ] cespitose (non-spreading)  
  - [ ] spreading  
  - [ ] rhizomatous/rhizomes/stoloniferous  
  - [ ] taproot/caudex  
  - [ ] hemiparastic  
  - [ ] bulb  
  - [ ] unknown

### Summary of Results:

The exported data table includes all columns of data, not just the subset of the table columns shown below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>PLANTS Code Root System</th>
<th>Root System</th>
</tr>
</thead>
<tbody>
<tr>
<td>forb</td>
<td>Achillea millefolium L. var. occidentalis DC.</td>
<td>western yarrow; common yarrow</td>
<td>ACM10</td>
<td>Shallow with extensive rhizomes.</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum hymenoides (Roemer &amp; J.A. Schultes) Barkworth</td>
<td>Indian ricegrass; Indian mountain ricegrass</td>
<td>ACHY</td>
<td>Cespitose with extensive fibrous roots.</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum lettermanii (Vasey) Barkworth</td>
<td>Letterman's needlegrass</td>
<td>ACL59</td>
<td>Cespitose with extensive fibrous roots (up to 3 ft in depth).</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum nelsonii (Scribn.) Barkworth</td>
<td>Columbia needlegrass</td>
<td>ACNE9</td>
<td>Cespitose with extensive fibrous roots (up to 3 ft in depth).</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum nelsonii (Scribn.) Barkworth ssp. dorei (Barkworth &amp;</td>
<td>Dore's needlegrass; Columbia needlegrass</td>
<td>ACNE15</td>
<td>Cespitose with extensive fibrous roots (up to 3 ft in depth).</td>
</tr>
<tr>
<td>forb</td>
<td>Agastache urticifolia(Denth.) Kuntze var. urticifolia</td>
<td>nettleleaf giant hyssop; field horsemint</td>
<td>AGUR</td>
<td>Lateral, spreading roots.</td>
</tr>
<tr>
<td>forb</td>
<td>Allium acuminatum Hook.</td>
<td>tapertip onion</td>
<td>ALAC4</td>
<td>Lateral, spreading roots.</td>
</tr>
</tbody>
</table>
### Search Criteria:

This form is used to search for plant species in flood-affected areas that are found in Colorado by nursery propagation. Enter the search criteria in the boxes below. Click the filter button to apply the criteria. Click the remove filter button to remove all criteria values. If no criteria is applied for a specific topic, then all options for that topic will be included in the results. A list of the results is provided under Summary of Results and a table with all data table columns can be exported to Excel by clicking "Export Results to Excel."

#### Search for Plant(s) that meet the following criteria:

- **Nursery Propagule:**
  - cutting
  - division
  - rhizome
  - seed
  - plantlet

- **Relative Difficulty to Propagate:**
  - easy
  - moderate
  - intermediate
  - difficult

- **Project Implementation Plant Materials Type:**
  - container
  - cutting
  - rhizome
  - seed
  - vegetative planting

- **Seed Collection Time:**
  - [ ]

- **Seed Periodicity (years):**
  - [ ]

- **Average Cleaned Seed Weight (seeds/lb):**
  - [ ]

- **Minimum Seed Viability in Proper Storage* (years):**
  - [ ]

- **Germination/Vegetative Protocol contains:**
  - [ ]

---

### Summary of Results:

The exported data table includes all columns of data, not just the subset of the table columns shown below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>PLANTS Code</th>
<th>Nursery Propagule</th>
<th>Relative Difficulty to Propagate</th>
<th>Project Impl. Plant Materials</th>
<th>Seed Collection</th>
<th>Seed Periodicity</th>
<th>Average Cleaned Seed Weight</th>
<th>Seed Viability in Proper Storage*</th>
<th>Germination/Vegetative Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>woody</td>
<td>Acer glabrum Torr.</td>
<td>Rocky Mountain maple</td>
<td>ACGL</td>
<td>seed</td>
<td>intermediate</td>
<td>container</td>
<td>mid-September to late-October</td>
<td>1 to 3 years</td>
<td>7,820 to 20,300 seeds/lb (avg. 13,430)</td>
<td>2 years</td>
<td>Seed: 75°F distilled H2O (4h); 70°F</td>
</tr>
<tr>
<td>woody</td>
<td>Acer negundo L. ssp. interius (Britton) Sarg.</td>
<td>boxelder</td>
<td>ACNE12</td>
<td>seed</td>
<td>easy</td>
<td>container</td>
<td>mid-September</td>
<td>annually</td>
<td>8,200 to 20,400 seeds/lb (avg. 13,400)</td>
<td>2 years</td>
<td>Seed: 75°F distilled H2O (4h); 40°F cold</td>
</tr>
<tr>
<td>forbs</td>
<td>Achillea millefolium L. var. occidentalis DC.</td>
<td>western yarrow; common yarrow</td>
<td>ACMIO</td>
<td>seed</td>
<td>easy</td>
<td>seed, container</td>
<td>August through September</td>
<td>annually</td>
<td>2,740,670 to 4,124,000 seeds/lb</td>
<td>2 years</td>
<td>Seed: Dry sow seed; 80°F</td>
</tr>
<tr>
<td>graminoid</td>
<td>Achnatherum hymenoides (Common R. &amp; H. Schult.)</td>
<td>Indian ricegrass; Indian feather grass</td>
<td>ACHY</td>
<td>seed</td>
<td>difficult</td>
<td>seed</td>
<td>July through August</td>
<td>annually</td>
<td>128,482 to 235,000 seeds/lb</td>
<td>5 to 10 years</td>
<td>Seed: 212°F distilled H2O (2h); 78°F</td>
</tr>
</tbody>
</table>
The Colorado Revegetation Matrix

Matrix incorporates over 419 documents:

- PLANTS Database
- Biota of North America Project (BONAP)
- NWPL/Lichvar/Army Corps of Engineers
- Flora of Colorado (Ackerfield)
- Colorado Flora (Weber and Whitman)
Stream Bioengineering Equations

Root parameters can be applied to:

- Annandale Erodibility Index (2006)

\[ K = M_s \times K_b \times K_d \times J_a \]

Where: \( M_s \) - mass strength; \( K_b \) - block size; \( K_d \) - discontinuity bond shear strength; and \( J_a \) - relative ground structure.

\[ K_b = 1000D^3 \]

Block size = 1000 * root dimension\(^3\)
Stream Bioengineering Equations

The simple perpendicular model is based on the Coulomb equation:

$$S_r = \dot{c} + (\sigma - \mu) \tan \varphi'$$

Root parameters can be applied to:

- Waldron Model (1977), as modified by Wu, McKinnell, & Swanston (1979) (as described in Simon et al. 2006)

- Where: $S_r$ = shear strength (kPa), $\dot{c}$ = effective cohesion (kPa), $\sigma$ = normal stress (kPa), $\mu$ = pore pressure (kPa), and $\varphi'$ = angle of internal friction in degrees
As such, the shear strength of the roots ($\Delta S$) is calculated through use of the root tensile strength and the cross section of the roots relative to the area of the shear surface:

$$\Delta S = T_r \left( \frac{A_R}{A} \right) 1.2$$

- Where: $T_r =$ root tensile strength (kPa), $A_R/A =$ root area ratio (dimensionless), $A =$ soil area (m$^2$), $A_R =$ root area (m$^2$), and $1.2 =$ value that accounts for the angle of shear distortion and soil friction in degrees (Wu et al., 1979; Simon et al., 2006)
Development of the Germination Protocols

Photo courtesy of E. Schmidt
<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Project Implementation Plant Materials Type</th>
<th>Seed Collection Time</th>
<th>Seed Periodicity</th>
<th>Average Cleaned Seed Weight</th>
<th>Seed Viability in Proper Storage (approx. 40°F and under 10% humidity)</th>
<th>Germination/Vegetative Protocol</th>
<th>C-Value</th>
<th>pH preference</th>
<th>Aspect Preference</th>
<th>Soil Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Soli</em> geyeriana Anderss.</td>
<td>container, vegetative planting</td>
<td>mid-spring as cotton is appearing on female catkins (April through May)</td>
<td>annually</td>
<td>estimated at 11,500,000 cleaned seeds/lb</td>
<td>recalcitrant (little to no shelf-life)</td>
<td>Seed: Seed must be fresh-collected and direct sowed, as it has minimal shelf life. 75°F distilled H2O(2h); 80°F greenhouse (8-10 d emergence). Seed should be lightly covered with germination mix. Cutting - semi-hardwood: no pre-soak; gel rooting mix 70°F greenhouse (30 d). Cutting - hardwood: (dormant stems ½ to 1¾” width, 12-24” length, bottom diagonally cut); soak 5-10 d; gel rooting mix 35-60°F (30 d).</td>
<td>6</td>
<td>6.5 to 7.5</td>
<td>non-specific</td>
<td>Cobbles and gravelly sandy or clay loam Alluvial soils.</td>
</tr>
<tr>
<td><em>Soli</em> glauca L.</td>
<td>container</td>
<td>mid- to late-spring as cotton is appearing on female catkins (mid-April through mid-June)</td>
<td>annually</td>
<td>10,000,000 cleaned seeds/lb</td>
<td>recalcitrant (little to no shelf-life)</td>
<td>Seed: Seed must be fresh-collected and direct sowed, as it has minimal shelf life. 75°F distilled H2O(2h); 80°F greenhouse (8-10 d emergence). Seed should be lightly covered with germination mix. Cutting - semi-hardwood: no pre-soak; gel rooting mix 70°F greenhouse (30 d). Cutting - hardwood: (dormant stems ½ to 1¾” width, 12-24” length, bottom diagonally cut); soak 5-10 d; gel rooting mix 35-60°F (30 d).</td>
<td>8</td>
<td>5.5 to 7.5</td>
<td>non-specific</td>
<td>Cobbles and gravelly sandy or clay loam Alluvial soils.</td>
</tr>
<tr>
<td>Scientific Name</td>
<td>Project Implementation Plant Materials Type</td>
<td>Seed Collection Time</td>
<td>Seed Periodicity</td>
<td>Average Cleaned Seed Weight</td>
<td>Seed Viability in Proper Storage (approx. 40°F and under 10% humidity)</td>
<td>Germination/ Vegetative Protocol</td>
<td>C-Value</td>
<td>pH preference</td>
<td>Aspect Preference</td>
<td>Soil Texture</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------------------------</td>
<td>---------------------</td>
<td>-----------------</td>
<td>------------------------------</td>
<td>---------------------------------------------------------------------</td>
<td>-------------------------------</td>
<td>---------</td>
<td>---------------</td>
<td>--------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Carex nebrascensis Dewey</td>
<td>container</td>
<td>August to early-October</td>
<td>annually</td>
<td>450,000 seeds/lb with perigynia intact; 800,000 to 912,000 seeds/lb with perigynia removed</td>
<td>2 to 3 years</td>
<td>Seed: 75°F distilled H2O(24h); 40°F cold stratification (85d or until radical emergence); 90°F greenhouse (emergence 8-12d). Seed should be covered with germination mix (1/16&quot; depth). Division: Divide in a manner that maintains the maximum amount of root material without compromising the integrity of root culm through over-division. Materials should be divided while young, such as that culms are small and easily transplantable. Once divided, materials should be maintained at 65-70°F within the greenhouse for 12 to 15 weeks until no soil sloughs from the plug upon removal from the container.</td>
<td>5</td>
<td>5.7 to 8.5</td>
<td>non-specific</td>
<td>Medium coarse to moderately fine soils.</td>
</tr>
<tr>
<td>Carex pellita Muhl. ex Willd.</td>
<td>container</td>
<td>mid-August through early October</td>
<td>every 2 years</td>
<td>236,000 to 312,075 seeds/lb</td>
<td>2 to 3 years</td>
<td>Seed: 75°F distilled H2O(24h); 40°F cold stratification (100d or until radical emergence); 90°F greenhouse</td>
<td>6</td>
<td>6.0 to 8.5</td>
<td>non-specific</td>
<td>Medium coarse fine soil.</td>
</tr>
<tr>
<td>Scientific Name</td>
<td>Project Implementation Plant Materials Type</td>
<td>Seed Collection Time</td>
<td>Seed Periodicity</td>
<td>Average Cleaned Seed Weight</td>
<td>Seed Viability in Proper Storage (approx. 40°F and under 10% humidity)</td>
<td>Germination/Vegetative Protocol</td>
<td>C-Value (AA)</td>
<td>pH Preference (AB)</td>
<td>Aspect Preference (AC)</td>
<td>Soil Texture (AD)</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------------------------------------</td>
<td>----------------------</td>
<td>------------------</td>
<td>-----------------------------</td>
<td>---------------------------------------------------------------------</td>
<td>-------------------------------</td>
<td>--------------</td>
<td>-------------------</td>
<td>----------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td><em>Delphinium x occidentale</em> (S. Wats.) S. Wats. (pro sp.) [barbeyl x glocom]</td>
<td>container</td>
<td>August through September</td>
<td>annually</td>
<td>500,000 seeds/lb</td>
<td>1 to 2 years</td>
<td>Seed: Most successful protocol to date is to seed directly to 10 c plugs in November that are filled with 3:1:1 peat:vermiculite:perlite blend and treated with rootguard. Once seed is sewn top with light cover of pea gravel and store outside. Germination begins in March. Containers are watered only during dry periods. Plants are moved to the lath house in June and allowed to grow until the following season. Plants should be lightly insulated with reemay over second winter season, then are ready for planting by the beginning of the second growing season.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Dodecatheon pulchellum</em> (Raf.) Merr.</td>
<td>container</td>
<td>July through mid-August</td>
<td>2 to 3 years</td>
<td>4,303,920 seeds/lb</td>
<td>2 to 3 years</td>
<td>Seed: 75°F distilled H2O(1h); 40°F cold stratification (60 to 120d or until radical emergence); 80°F greenhouse (emergence 30d). Seed should be covered with germination mix (1/16” depth).</td>
<td>8</td>
<td>6.5 to 8.5</td>
<td>non-specific</td>
<td>Sandy to medium fine loam</td>
</tr>
</tbody>
</table>
The Colorado Revegetation Matrix

Application:

- NRCS/CWCB Emergency Watershed Protection
- 2013 Flood Impacted Areas
- 68 / 117 Projects Implemented by 2018
- Revegetation Guides / Planting Plans
### Broadview Estimated Planting Requirements

#### Revegetation Area Poles and Stakes

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Percent of Mix</th>
<th>Material Type</th>
<th>Container Size</th>
<th>Plant Spacing</th>
<th>Number of Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Populus angustifolia</em></td>
<td>narrowleaf cottonwood</td>
<td>15</td>
<td>Cutting</td>
<td>60-inch cutting</td>
<td>6-foot spacing</td>
<td>10</td>
</tr>
<tr>
<td><em>Salix exigua</em></td>
<td>narrowleaf willow</td>
<td>25</td>
<td>Cutting</td>
<td>48-inch cutting</td>
<td>6-foot spacing</td>
<td>16</td>
</tr>
<tr>
<td><em>Salix pacifica</em></td>
<td>Geyer’s willow</td>
<td>20</td>
<td>Cutting</td>
<td>48-inch cutting</td>
<td>6-foot spacing</td>
<td>18</td>
</tr>
<tr>
<td><em>Salix lasiolepis</em></td>
<td>Foothill mountain willow</td>
<td>20</td>
<td>Cutting</td>
<td>48-inch cutting</td>
<td>6-foot spacing</td>
<td>18</td>
</tr>
<tr>
<td><em>Salix lasiolepis</em></td>
<td>steppe willow</td>
<td>10</td>
<td>Cutting</td>
<td>48-inch cutting</td>
<td>6-foot spacing</td>
<td>7</td>
</tr>
<tr>
<td><em>Salix lasiolepis</em></td>
<td>whipple willow</td>
<td>10</td>
<td>Cutting</td>
<td>48-inch cutting</td>
<td>6-foot spacing</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>103</td>
<td>56</td>
</tr>
</tbody>
</table>

#### Broadview Seed

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Percent of mix</th>
<th>Seed Number using 150 seeds/sq ft</th>
<th>Pure Live Seed (PLS) Weight</th>
<th>PLS lbs Required per</th>
<th>PLS lbs Required Per</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceratostigma willmottianum</td>
<td>Mexican germander</td>
<td>2</td>
<td>3</td>
<td>4,000,000</td>
<td>0.10</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
<td>150</td>
</tr>
</tbody>
</table>
REVITALIZATION AND BIOSTABILIZATION RECOMMENDATIONS FOR UPPER BIG THOMPSON RIVER RESTORATION AT ROCK AND ROLL

TECHNICAL MEMORANDUM

BACKGROUND

The 2013 floods resulted in ongoing streambank erosion and sedimentation that are impacting residences, bridges, businesses, and bridges on this reach of the Upper Big Thompson River. The project proposes to remove and treat variable sediment to reduce flood hazards and improve habitat. Additionally, the project proposes to remove flood damage that has been left in the channel. It will provide and enhance riparian greenbelts and existing floodplain protection to stabilize streambanks. A low-flow channel and rock structures will be added to increase channel capacity and enhance fish habitat. Disturbed areas will be revegetated to enhance streambank stabilization.

PROJECT AREA DESCRIPTION

The Upper Big Thompson River Restoration at Rock and Roll is located in Larimer County, in the Estes Valley Watershed, just south of Highway 36 and directly abutting a business and residence. It is approximately 130 feet of the Upper Big Thompson living site. The project reach spans approximately 180 feet.

SEEDING, PLANTING, AND MULCHING

All seed and woody plant material recommendations were based on site elevation, county occurrence, hydrologic preference, topography, aspect preference, successional stage, habitat preference, soil texture, native tolerance, and growth form, as well as attributes including cost, aspect, structure, and dimension (Ackerfeld 2015, Monder 2014). To maximize ecological success, all plant materials will be as ecotypic as possible. Ecotypic vegetation is beneficial in restoration efforts as it has co-evolved to live in local climates, soil types, and with local environmental pressures.

All seed should be from ecotypic sources. If possible, and should represent the species and quantities presented in TABLE 1. Any deviation from the recommended species and quantities should be cleared through the project restoration ecologist (R. Monder and/or S. Capo Franco, Great Ecology). The contractor should apply the mix to all areas disturbed by restoration activities through broadcast seeding at a rate of 24 lbs Pure Live Seed (PLS) per acre, hand seeded to your 4-inch depth to minimize seed loss, then surface-seeded through a water-flooded peat-moss to facilitate good seed-soil contact. All seed must be labeled as ‘certified’ and should not include the presence of nuisance or invasive species prohibited under the Colorado Seed Act (as indicated on the tag by the Colorado Seed Group Association approval labeling). All seed should be inspected by the restoration ecologist and/or watershed coordinator prior to installation and all tags must be maintained for documentation by the watershed coordinator, or their designee. Prior to delivery, seed should be processed by the seed provider on a ‘gravity table’ to remove non-target seed types, such as yellow sweetclover (Melilotus officinalis), alfalfa (Medicago sativa), and serrated tuft daisies (Leucanthemum). All seed recommendations are based on the 18.3 PLS per square foot, as determined on a percentage basis by species to facilitate ecological functionality, to minimize interspecific competition, and to promote proper revegetation. Once the seed has been properly applied to the site, the contractor should apply 3048 square feet of biodegradable erosion control blanket in 24 hours of seed application as necessary. Biodegradable erosion control blankets will be placed on graded portions of all zones. The remainder of the site will be applied with a 75% cover (5,000 lbs/acre) of woodchips. In addition to the seed mix, the contractor should install woody plant materials within the designated ‘Revegetation Area’ (0.04 acre) located on the site. Woody plant materials will be planted in cohesive plant material based on the condition and submitted plans by the contractor. Recommended species and percentages are presented in TABLE 2. The exact location of live plant material will be based on final grading, as determined by Emergency Watershed Protection vegetation experts who will be onsite.
Ecotypic Plant Materials Are Key

- **Ecotype**: a genetically distinct geographic variety, population, or race within a species which is adapted to specific environmental conditions.

- **Native**: a species that occurs naturally in a particular site as determined by living (biotic) and non-living (abiotic) factors and was not introduced by human activities.
Ecotypic plant materials are important because these plants:

- Have improved site adaptability;
- Improve water conservation;
- Are less likely to become invasive;
- Co-evolved with local site conditions such as hydrology and biophysiology, therefore tend to have greater resiliency to stress;
- Tend to be more aesthetically aligned (display sense of place);
- May be required by law, policy, or covenant; and
- Tend to impart long-term improved economics through reduced maintenance and irrigation costs.
Species were grouped by hydrologic and elevational preference. For the purposes of restoration design, a total of five distinct ecological zones were recognized:

- **Zone 1**: Wetland (0 - 1 ft above low-flow water surface, 70 – 100% wet annually);
- **Zone 2**: Riparian (1 - 3 ft above low-flow water surface, bankful, 40 – 70% wet annually);
- **Zone 3**: Transitional (2 – 4 ft above low-flow water surface; 100 yr flood elevational 40% wet annually to bankful height);
- **Zone 4**: Upland (4+ ft above low-flow water surface);
- **Zone 5**: Overbank or swale.
Plant Material Increase and Storage

Photos courtesy of R. Mandel
The greatest challenges to date have been:

- Timing and budget (always too tight and never enough);
- Irrigation (plants like water);
- Noxious and/or invasive species (limited budgets for control; water nexus);
- Availability for some key species and need for cultural studies to improve production capabilities;
- Availability of trained installation crews with consistent attention to planting detail; and
- Long-term monitoring and its funding.
2013 Flood Restoration: The Before
The Implementation
The Implementation
2013 Flood Restoration: The After
NNBF Riverine & Fluvial Application Summary

- Nature-Based Design
- Watershed Context
- Proactive Groundwater Measurement
- Hydrology-Based Grading
- Ecotypic Plant Materials
- Planting Techniques
  - By Hydrologic Zone
  - Bioengineering
  - Staking
  - Planting
  - Seeding
- Irrigation (Transitional/Upland)
- Iterative Management
The Important Role of Community & Stakeholder Engagement
Great Ecology: Great Ecology specializes in the design, restoration, and enhancement of ecosystems throughout the United States and abroad. We bring higher ecological thought to leading organizations, corporations, and governments throughout the world. With offices in San Diego, Denver, Manhattan, and Soda Springs, we integrate ecological project design with biological and financial assessment, project implementation, and iterative management.
Questions?

Randy Mandel  
Vice President, Technical Services  
Great Ecology  
rmandel@greatecology.com  
970.379.3169