COLDWATER CANYON WASH
TRANSITIONING FROM A FAN AND BEYOND

Riverside County Flood Control and Water Conservation District

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OUTLINE

- Project Purpose
- Geomorphic Overview
- Future Erosion Assessment
- Equilibrium Assessment
- Mitigation Alternatives
Project Purpose

- 70+ years CCW experienced significant alteration of it’s geomorphic floodplain.
  - Realignment and Channelization
  - Floodplain Encroachment
  - Sediment Capture
- Resulted in:
  - Unpredictable behavior
  - Lateral Erosion
  - Sedimentation
  - Channel scour

RCFCWCD wanted a system-wide, holistic understanding of CCW to determine the most appropriate course of action to mitigate future adverse impacts.
Geomorphologic Overview

- Dynamic system
- Variable channel pattern
- Multiple landforms
Geomorphic Overview

- Channelization
- Channel diversion
- Reduced channel length

2016
Geomorphic Overview

- Signs of Instability
  - Change in slope
  - Scour
  - Sedimentation
Has CCW reached a new equilibrium?

Can additional channel adjustments be expected?
- Later Migration? Where?
- Channel degradation (scour)? Where? How often?
- Have reaches reached armoring threshold? What magnitude?

What can be done to mitigate???
Future Erosion Assessment

- Geomorphic Trend Assessment
- Hydrology
- Sediment Characterization
- Hydraulic and Sediment Transport Modeling
- Stable Bank Slope
- Erosion Resistance Assessment
- Sediment Volume Comparison
- Sediment Continuity
Geomorphologic Trends

- Channel pattern relationships
- Channel geometry characteristics
  - Regime equations
    - Width (bank erosion, deposition)
    - Depth (scour, deposition)
    - Slope (scour, deposition)
    - Velocity (scour, deposition)
  - Computed vs. Observed
### Geomorphic Trends (historical)

<table>
<thead>
<tr>
<th>Cross-Sections</th>
<th>Channel Bank</th>
<th>Average Migration Distance (feet) (1948-2014)</th>
<th>Reach Average Annual (1948-2014) Lateral Migration Rate (feet/year)</th>
<th>Reach Dominant Migration Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL</td>
<td>Left</td>
<td>44</td>
<td>0.7</td>
<td>Westward</td>
</tr>
<tr>
<td>ALL</td>
<td>Right</td>
<td>53</td>
<td>0.8</td>
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<td>8500-12500</td>
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<tr>
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<td>0.3</td>
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<tr>
<td>500-3000</td>
<td>Left</td>
<td>87</td>
<td>1.3</td>
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<tr>
<td>500-3000</td>
<td>Right</td>
<td>118</td>
<td>1.8</td>
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</table>
Geomorphologic Trends
Geomorphic Trends (historical)

<table>
<thead>
<tr>
<th>River Station</th>
<th>Bed Elevation Change 1951-2015 (feet)</th>
<th>Average Annual Degradation Rate (feet/year)</th>
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</thead>
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<tr>
<td>8500</td>
<td>0.4</td>
<td>0.01</td>
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<tr>
<td>8000</td>
<td>2</td>
<td>0.03</td>
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<tr>
<td>7500</td>
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<tr>
<td>7000</td>
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<tr>
<td>6500</td>
<td>15</td>
<td>0.24</td>
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<tr>
<td>6000</td>
<td>19</td>
<td>0.29</td>
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<tr>
<td>5500</td>
<td>12</td>
<td>0.18</td>
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<tr>
<td>5000</td>
<td>17</td>
<td>0.27</td>
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<tr>
<td>4500</td>
<td>27</td>
<td>0.42</td>
</tr>
<tr>
<td>4000</td>
<td>33</td>
<td>0.52</td>
</tr>
<tr>
<td>3500</td>
<td>12</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Average Rate Entire Reach (feet/year) 0.22
<table>
<thead>
<tr>
<th>Equation</th>
<th>Observed and Expected Channel Characteristics for Coldwater Canyon Wash</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100Yr</td>
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<tr>
<td>Bray - Equation #1</td>
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<tr>
<td>Bray - Equation #2</td>
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<tr>
<td>Hydiosity</td>
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<tr>
<td>Ackers &amp; Charlton/Lacey</td>
<td>108</td>
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<tr>
<td>Parker</td>
<td>163</td>
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<tr>
<td>Change</td>
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<td>Kellerhals</td>
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<td>AMJHPCA</td>
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<td>BUREC</td>
<td>55</td>
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<tr>
<td>Average</td>
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<tr>
<td>HEC-RAS Data</td>
<td>106</td>
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</tbody>
</table>

Hydrology

- 6-Hour Controlling Storm
- Two Inflow Locations

<table>
<thead>
<tr>
<th>Recurrence Interval (year)</th>
<th>Outlet of Coldwater Canyon</th>
<th>Confluence with Trilogy Development Outfall</th>
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<tbody>
<tr>
<td>2</td>
<td>1,052</td>
<td>1,595</td>
</tr>
<tr>
<td>5</td>
<td>1,509</td>
<td>2,344</td>
</tr>
<tr>
<td>10</td>
<td>1,917</td>
<td>2,957</td>
</tr>
<tr>
<td>25</td>
<td>2,490</td>
<td>3,822</td>
</tr>
<tr>
<td>50</td>
<td>2,963</td>
<td>4,526</td>
</tr>
<tr>
<td>100</td>
<td>3,455</td>
<td>5,247</td>
</tr>
</tbody>
</table>

$Q_p = 477\text{ cfs}$

Hydrograph represents flow at upstream end of model

Model Time (hour)
Sediment Characterization

- Zones of notable armoring
- Sediment sampling
  - Sieve analysis
  - Pebble counts
- Reconstruction of ‘Historic’ gradation

Distinct armor layer
Hydraulic Modeling

- 1D using HEC-RAS (Steady hydraulic / sediment transport)
- 338 cross-sections (40 ft avg. spacing)
- Modeling goals
  - Identify areas of flooding inundation
  - Quantify hydraulic nature for empirical equations (e.g., V, S, D, etc.)
  - Simulate CCW response to flood events
Hydraulic Modeling

- Conclusions
  - Significant flooding hazards primarily in two areas
  - Undersized culverts

<table>
<thead>
<tr>
<th>Type</th>
<th>2-Year</th>
<th>2-Year %</th>
<th>5-Year</th>
<th>5-Year %</th>
<th>10-Year</th>
<th>10-Year %</th>
<th>25-Year</th>
<th>25-Year %</th>
<th>50-Year</th>
<th>50-Year %</th>
<th>100-Year</th>
<th>100-Year %</th>
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<tbody>
<tr>
<td>Glen Ivy Road RCP</td>
<td>120</td>
<td>11%</td>
<td>125</td>
<td>8%</td>
<td>128</td>
<td>7%</td>
<td>131</td>
<td>5%</td>
<td>134</td>
<td>5%</td>
<td>136</td>
<td>4%</td>
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<tr>
<td>Squaw Mountain Road Bridge/Pier</td>
<td>1,052</td>
<td>100%</td>
<td>1,509</td>
<td>100%</td>
<td>1,917</td>
<td>100%</td>
<td>2,490</td>
<td>100%</td>
<td>2,963</td>
<td>100%</td>
<td>3,455</td>
<td>100%</td>
</tr>
<tr>
<td>I-15 Southbound Bridge/Pier</td>
<td>1,595</td>
<td>100%</td>
<td>2,344</td>
<td>100%</td>
<td>2,957</td>
<td>100%</td>
<td>3,822</td>
<td>100%</td>
<td>4,526</td>
<td>100%</td>
<td>5,247</td>
<td>100%</td>
</tr>
<tr>
<td>I-15 Northbound Bridge/Pier</td>
<td>1,595</td>
<td>100%</td>
<td>2,344</td>
<td>100%</td>
<td>2,957</td>
<td>100%</td>
<td>3,822</td>
<td>100%</td>
<td>4,526</td>
<td>100%</td>
<td>5,247</td>
<td>100%</td>
</tr>
<tr>
<td>Rinker plant entrance CMP</td>
<td>715</td>
<td>45%</td>
<td>708</td>
<td>30%</td>
<td>733</td>
<td>25%</td>
<td>755</td>
<td>20%</td>
<td>768</td>
<td>17%</td>
<td>771</td>
<td>15%</td>
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<tr>
<td>Dawson Canyon Road RCBC</td>
<td>1,595</td>
<td>100%</td>
<td>2,023</td>
<td>86%</td>
<td>2,032</td>
<td>69%</td>
<td>1,990</td>
<td>52%</td>
<td>1,902</td>
<td>42%</td>
<td>1,828</td>
<td>35%</td>
</tr>
</tbody>
</table>
Model Validation

- No gage data available
- 2010 event captured by photographs and video
Stable Bank Slope

- Analysis assumes toe of bank is fixed moving forward
- Stable bank slopes for coarse, non-cohesive material bounded between slopes of 1.73:1 and 3.08:1 (Wolman and Brush, 1961).
- Both left and right banks are over-steepened in select locations
- Will likely laterally erode over time
- Surficial lateral erosion distances between 20 and 60 feet
Erosion Resistance

- **Vertical Erosion**
  - Depth to armor, Bureau of Reclamation, (Pemberton and Lara, 1984)
  - Required $D_{50}$ for armoring computed using Yang Equation
  - 2-year event selected as ‘dominant discharge’

- **Lateral Erosion**
  - Bank Erosion Hazard Index (BEHI) (Rosgen, 2001)
  - Provides index based on metrics
    - Ratio of root depth to bank height, root density, bank angle, surface protection
Required armoring for 2010 event

System is adequately armored in select areas for this event

Depth to armor (ft) for larger events
Erosion Resistance

- **Vertical**
  - Not properly armored for 2-year event
  - Degradational trend will continue

- **Lateral**
  - Very high potential for further erosion
  - Primary driver is lack of vegetation along channel banks
Sediment Volume Comparisons

- Topographic comparison between 2009 and 2015
  - Only none significant flow event was observed
- End area method
- Mixed Results
  - Loose correlation
  - Topographic uncertainty
  - Anthropogenic
Sediment Continuity

- Sediment-lean condition imposed by channelization around gravel pit
- Largely degradational downstream of gravel pit
Equilibrium Assessment

- Dominant Discharge
- Equilibrium Slope
- Sediment Continuity
Dominant Discharge

- Defines the flow rate at which most channel-forming work in a watercourse is performed

- Approach
  - Geomorphic indicators not appropriate
  - Analytical approach using HEC-RAS
  - Compute sediment throughput
    - 2-year, 5-year, 10-year
  - Weight based on probability
Equilibrium Slope

- $Q_{s,in} = Q_{s,out}$
- Inflow computed using HEC-RAS results
- Sediment-lean conditions coupled with encroachment
- Results indicate CCW is subject to long-term scour

<table>
<thead>
<tr>
<th>Equilibrium Slope</th>
<th>Start Station</th>
<th>End Station</th>
<th>Existing Slope</th>
<th>Equilibrium Slope</th>
<th>Long-Term Bed Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subreach</td>
<td></td>
<td></td>
<td>[ft/ft]</td>
<td>[ft/ft]</td>
<td>[ft]</td>
</tr>
<tr>
<td>1</td>
<td>Temescal Wash</td>
<td>Dawson Canyon Road</td>
<td>0.0135</td>
<td>0.0061</td>
<td>-3.8</td>
</tr>
<tr>
<td>2</td>
<td>Dawson Canyon Road</td>
<td>Rinker entrance</td>
<td>0.0213</td>
<td>0.0064</td>
<td>-5.7</td>
</tr>
<tr>
<td>3</td>
<td>Rinker entrance</td>
<td>I-15</td>
<td>0.0194</td>
<td>0.0069</td>
<td>-41.1</td>
</tr>
<tr>
<td>4</td>
<td>I-15</td>
<td>Trilogy Confluence</td>
<td>0.0183</td>
<td>0.0062</td>
<td>-17.0</td>
</tr>
<tr>
<td>5</td>
<td>Trilogy Confluence</td>
<td>Temescal Canyon Road</td>
<td>0.0238</td>
<td>0.0104</td>
<td>-27.0</td>
</tr>
</tbody>
</table>

Yang Methodology (1974)

\[
\log C_t = 5.435 - 0.286 \log \frac{\omega d_m}{\nu} - 0.457 \log \frac{u_*}{\omega} + \left(1.799 - 0.409 \log \frac{\omega d_m}{\nu}\right)\log \left(\frac{V_S}{\omega} - \frac{V_C}{\omega}\right)
\]

\[
\log C_t = 6.681 - 0.633 \log \frac{\omega d_m}{\nu} - 4.816 \log \frac{u_*}{\omega} + \left(2.874 - 0.305 \log \frac{\omega d_m}{\nu}\right)\log \left(\frac{V_S}{\omega} - \frac{V_C}{\omega}\right)
\]
Dominant discharge applied indefinitely
Results indicate a degradational system
Close agreement between equilibrium slope and HEC-RAS
Conclusion

- Flood inundation during high recurrence interval (< 2-year) events
- The past (historical), future (geomorph and analytical trends), and equilibrium analyses yielded consistent results
- Development of channel bed armoring coupled with little bank erosion resistance and over-steepened banks will promote bank erosion during routine flow events
  - Small scale storm (< 2 –year) in January 2017 yielded 12 feet of horizontal movement.
Alternative Assessment Plan

- On-going task involving JE Fuller and RCFCWCD
- Develop alternatives for each issue of the reach
- Evaluate and rank based on weighted criteria matrix
- Select one or multiple options as the preferred route
  - Preliminary design
  - With-project hydraulic and sediment transport modeling
  - Concept level 100-scale stabilization plan
  - Planning-level cost estimate
Questions