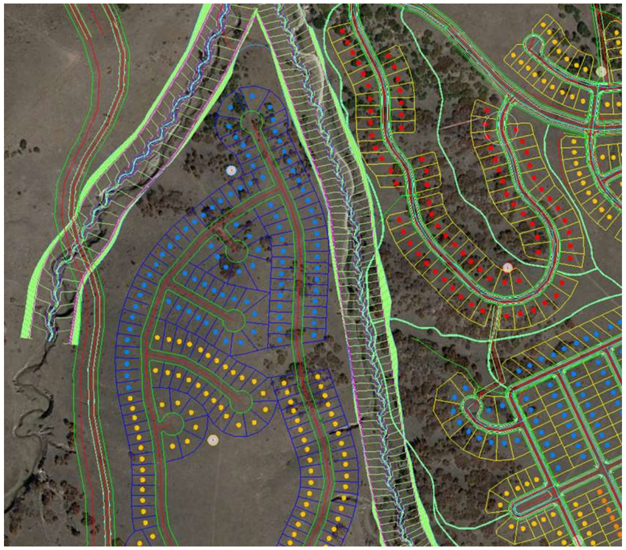
Naturalizing Performance Standards for Urban Channel "Restoration"



David Bidelspach,

Barbara Chongtoua

and Jim Wulliman

Stressful Concept Design
for Corridor Floodplain Layout
Denver Metro UDFCD

riverSHARED.org

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

S.H.A.R.E.D Philosophy

- **S**hare knowledge with humility.
- **H**ave patience and discernment for innovation.
- **A**dvocate excellence.
- **R**espect the risk and uncertainty in river systems.
- **E**mpower, challenge and question.
- **D**ocument and learn from unexpected results.

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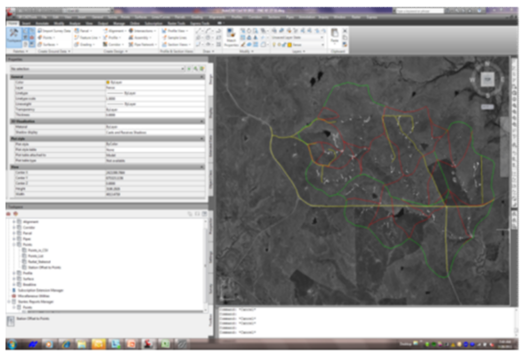
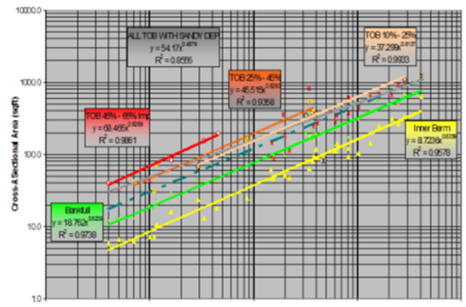
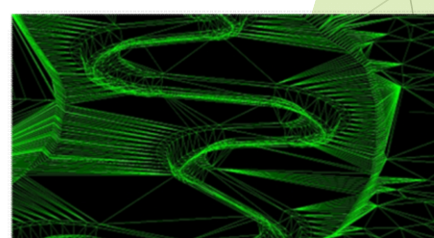
Share knowledge with humility

- Trade secrets are not good for maturing an industry, our understanding of river processes have come as a result of many other’s sharing their knowledge and not keeping trade secrets.







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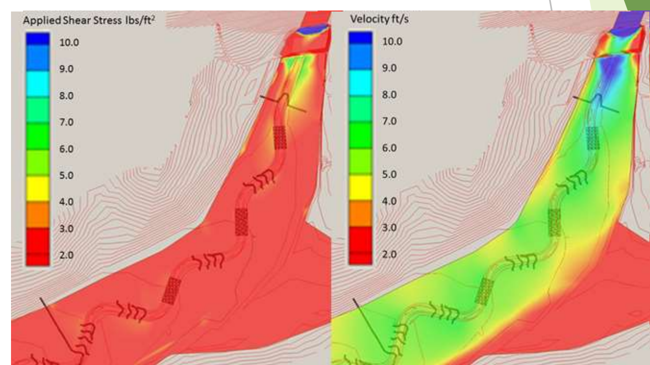
Have patience and discernment for innovation

- Innovation is great but, we must not rush innovation or lose sight of the established processes that have led to the innovation.



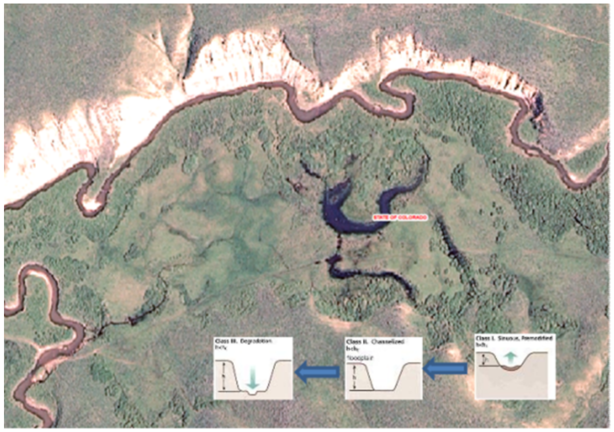
Advocate excellence

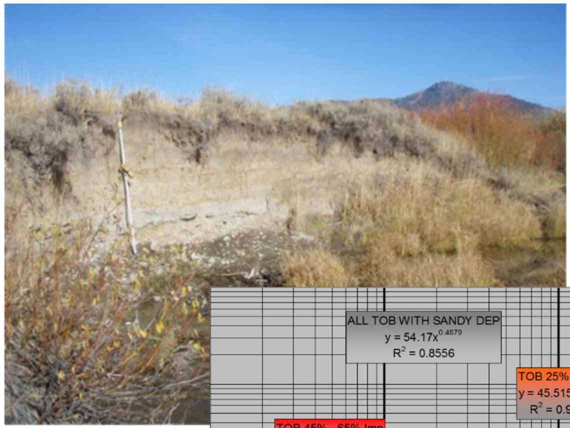
- Stay commitment to excellence and define excellence on all project. Strive to promote excellence throughout the profession

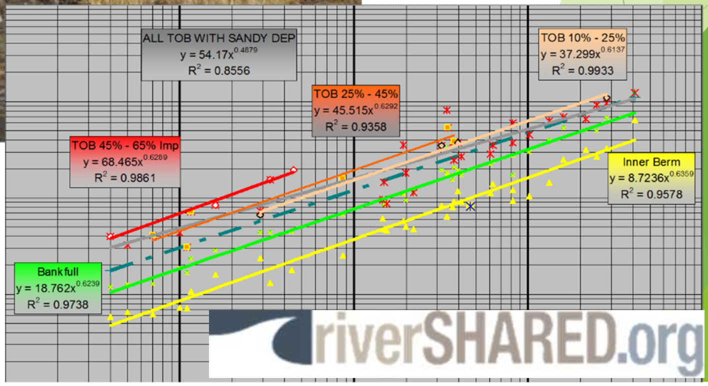
		Stream Stability GOAL			Water Quality GOAL				Buffer GOAL								
		Stop in-stream headcutting	Self-sustaining, natural, stable stream	Stream and floodplain manage shear stresses	Improve water quality and habitat of stream	Reduce sediment deposition and supply	Improve floodplain functions of water storage and habitat	SW control feature in watershed	Minimize impacts to wetland vegetation	Improve riparian buffer functions of stability, habitat, and aesthetics	*Linear Feet of Proposed Project*	*Required Fill (yd3)*	*Fill cost ($10/yd3)*	*Preliminary Cost Estimate of Proposed Project*	*UNIT COST*	MCDA Matrix Score	MCDA RANKING
	Concept Option Description	***2***	***1***	***2***	***1***	***1***	***1***	***1***	***1***	***1***							
Option #1	Tie into wetland floodplain as long as possible step down channel gradually; Higher slope at top, lower slope at bottom	1	1	3	1	1	1	0	1	1	1170	6000	$60,000	$ 1,330,000.00	$ 1,136.75	**12**	3
Option #2	Tie into wetland floodplain as long as possible step down channel gradually; More-or-less consistent slope	1	1	2	1	1	1	0	1	1	1170	7000	$70,000	$ 1,340,000.00	$ 1,145.30	**10**	1
Option #3	Stay very high and flat coming out of the wetland	1	1	2	1	1	1	0	1	1	1170	10000	$100,000	$ 1,320,000.00	$ 1,128.21	**10**	1
Option #4	Lower in Wetland and then inbetween 1 and 2	2	1	2	1	1	1	0	1	1	1170	6500	$65,000	$ 1,335,000.00	$ 1,141.03	**12**	3
Option #5	60% Design as drafted	2	3	4	1	1	1	0	2	1	1170	500	$5,000	$ 1,270,000.00	$ 1,085.47	**19**	6
Option #6	30% Design as drafted	2	2	3	1	1	2	0	2	1	1170	6000	$60,000	$ 1,330,000.00	$ 1,136.75	**16**	5

Respect the risk and uncertainty in river systems

- Rivers are complex, the more learned about riverine/riparian systems the more that is appreciated about the complexity of these systems. Innovation and modeling can be great tools, but the answers are still in the science and observation of the river.







Empower, challenge and question

- Empower others by encouraging them to question and challenge the design and geomorphic assumptions as well as conclusions. Others include, clients, design team, reviewers, regulators, grandmothers and others.

Document and learn from unexpected results

- Rivers are complex systems that have a high degree of uncertainty and sometimes our remedial alternatives produce unexpected results. Sometimes our results are very unexpected. Document uncertainty and learn from unexpected results so that we may have a better understanding of why the unexpected result has occurred.

New Suburban Development High Functioning Low Maintenance Stream Design

- UDFCD was established by the Legislature and 1969 after the Metro area was hit by the devastating 1965 flood. The Flood Control District was launched with a mil levy set at 1.0 by statute. Today, as then, the District partners with seven counties and 33 municipalities on a 50/50 basis to design and construct flood control and warning measures, open space and regional paths, and provide debris removal
- Protecting People, Property, and the Environment.
- Planning, design, construction, maintenance, and early flood warning – The work we do now increases your safety during a flood. Our philosophy of working in concert with nature produces open space and recreation for all to enjoy on the days when there is no flood.
- What is the Concept Design?
- How much space is needed for the Floodplain Corridor Width?
- Where can development occur that the channel resiliency will not be significantly compromised

LMS Project Phases

Concept Design — Establish goals and objectives

Preliminary Design — Consider how to achieve goals and objectives

Final Design — Demonstrate how project meets goals and objectives

Construction — Build project that meets goals and objectives

LMS Project Phases

Concept Design

Establish goals and objectives

1. Understand project context
2. Assess watershed
3. Assess stream
4. Understand hydrology
5. Concept layout
6. Deliverables

Concept Design Process (5/16/18 draft)

*Highlighting denotes areas where geomorphology input is particularly valuable

1. Understand Project Context

a Establish project goals and objectives.
 i. Define project limits and general elements.
 ii. What outcomes are important to the project owner and stakeholders?

b. Review local criteria and submittal requirements.
 i. Understand and comply with local submittal requirements, but within framework, focus on what is most important.
 ii. Simplify concept design and focus on the objective.

c. Know UDFCD criteria.
 i. Often referenced in local criteria.
 ii. Good source of information.

d. Review available stormwater master plans (OSP, MDP).
 i. Flow information (see Step 4 for additional tasks related to hydrology).
 ii. Recommended plan to be interpreted for broad principles in current context rather than reproducing specific measures drawn in plan.
 iii. Plan information provides general guidance, but doesn't replace comprehensive design process.

e. Regulatory floodplain information available from UDFCD (FHAD reports) and FEMA (FIS reports/maps), review:
 i. Floodplain delineations.
 ii. Water surface profiles.
 iii. Regulatory discharges.
 f. Topographic mapping.

g. Current and historic aerial photography.

h. NRCS soil survey information.

i. Land ownership/assessor's information.

j. Development plans.
 i. Planning areas.
 ii. Development type, lot size, densities, yield objectives.
 iii. Major arterial and collector streets.
 iv. Parks and open space.
 k. Utility information.

l. National Wetland Inventory map.

m. Threatened and endangered species information.

n. Cultural resource information.

2. Assess The Watershed

a. Use current and historic aerial photography and topographic mapping of the study area, evaluate:
 i. Size, shape, and general character of watershed.
 ii. Define how much of upstream watershed is controlled as part of the overall development project or stream project.
 iii. Extent of urbanization, locations and densities/imperviousness of existing developments.
 iv. Watershed vegetation.
 v. Sediment source, transport, and sink areas.
 vi. Changes over time.
 vii. High hazard and high response zones (existing or potential future).
 viii. Spatial relationships between watershed stressors and stream system.

b. It is recommended that watershed assessment include the off-site upstream and downstream area, since what goes on upstream affects study area and downstream area may be affected by conditions and choices made in the study area.

c. Using historic aerial photography of the study area and similar or nearby watersheds (similar watersheds can provide information on changes over time both from development and from natural evolution), evaluate:
 i. Nature of land use and development over time.
 ii. Character of vegetation.
 iii. Presence of fires in watershed over time.

d. Using any existing master plans or floodplain studies conducted for the watershed, examine the information on soils and projected imperviousness.

e. Using planning documents and development plans that show projected land use:
 i. Note the extents, representative densities, and anticipated timing of development projects in the watershed. The larger the development, higher the density, and quicker the anticipated build-out, the more the potential impact on downstream drainageways.

3. Assess The Stream

a. Using current and historic aerial photography and topographic mapping of study area and upstream and downstream reaches, evaluate:
 i. Layout of existing branched stream network, including any discernible first and second order streams, in addition to major drainageways, within study area.
 ii. General alignment and form of streams, including meander geometry and vegetation characteristics. Not changes over time.

b. Using any existing master plans conducted for the watershed, review recommended stream improvements and detention facilities.

c. Consider regulatory floodplain information reviewed in Step 1.

d. Document current longitudinal profile and compare against available historic stream invert elevations.

e. Undertake a field reconnaissance of the streams in the study area and upstream and downstream reference reaches. The geomorphology specialist and analysis framework should answer the following general questions for the supply and project reaches:
 i. What is the general layout of the stream planform, section, and profile? How does it differ and what controls the change between reaches?
 ii. Define geomorphic floodplain/migration zones
 iii. What are the lateral /floodplain constraints
 iv. What is controlling the stability (or lack of stability) of the bed? Consider Lane's balance- how will project tip the scale
 v. Characterize the reach grade controls (e.g., bedrock, riffles, steps, infrastructure).
 vi. Evidence of aggradation (e.g., embedded substrate, midchannel bars) or degradation (e.g., bed armoring, headcuts) in the bed? How do these areas relate spatially?
 vii. Determine whether project reach, upstream and downstream areas are source, transport or response reaches.
 viii. What is the grain size distribution of the bed and how does it vary between reaches?
 ix. What is controlling the stability (or lack thereof) of the banks?
 x. Is there evidence of mass wasting of banks (e.g., critical bank height approached or exceeded)?
 xi. Characterize the vegetation present at the site, including wetlands and other habitat features.
 xii. What constraints are present at the site?
 xiii. How do existing hydraulic structures (e.g., dams, ponds, detention facilities, storm sewer outfalls, or grade control structures) relate to observations of channel stability?

4. Understand Hydrology

a. Using available flood studies and master plans, review:
 i. Event-based peak flows for selected return periods for existing and future development conditions; assess magnitude of future flows relative to existing and pre-development flows (if modeled) and time frame for reaching projected development conditions.
 ii. Reduced peak flows based on regional detention if evaluated in master plans.

b. Flood frequency analyses using available stream gage data.
 i. May be proportioned based on area weighting for design flows at locations upstream or downstream of gage.
 ii. May be proportioned in an ungauged watershed based on area weighting from a gaged watershed with similar characteristics.

c. Flow-probability relationship using available stream gage data.

d. Determination of dominant discharge (e.g., effective, bankfull, half-yield, total effectiveness).

e. Regression relationships/representative unit discharges.
 i. Storage chapter regressions for pre-development conditions.
 ii. StreamStats or similar regression-based relationships.
 iii. Future development condition regressions.

f. Watershed modeling (limited in concept design).
 i. Local models.
  1. CUHP hydrographs/SWMM routing.
  2. SWMM hydrographs and routing.
 ii. Development conditions.
  1. Pre-development.
  2. Existing development.
  3. Projected future development.
 iii. Range of events.
  1. WQ event, 2-yr, 10-yr, 100-yr.

5. Concept Layout

a. Bring together what is learned in Steps 1- 4.

b. Define stream network.
 i. Identify the existing stream network evident in existing topo.
 ii. Identify reaches and riparian corridors that would be desirable to preserve.
 iii. Identify reaches that are in need of rehabilitation.

c. Lay out distributed detention (if applicable).
 i. In proximity to development areas
 ii. Between development areas and stream network.
  iii. Potential guideline: aim for 10 to 40 acre sub-catchment size.

d. Define opportunities to direct runoff to grass areas (receiving pervious area (RPA)).
 i. Within the stream network.
  1. First and second order grass swales, tributary systems.
  2. Floodplain benches along higher order streams.
 ii. Within parks and community areas.
 iii. Within site landscaping.

e. Determine adequate stream corridor widths by evaluating each of the following:
 i. Regulatory FP (plus buffer).
 ii. Geomorphic indicators/erosion hazards zone
  1. Meander belt
  2. Historic patterns of movement
  3. Laying back of steep banks.
 iii. Stable reaches, FP benches, healthy vegetation desirable to preserve.
 iv. Ecological considerations such as appropriate habitat types and vegetative communities along riparian corridors.
 v. Shear goals based on future development hydrology.
 vi. Distributed detention layout.
 vii. Parks, open space, and trail layout; create "meaningful" open spaces.

f. Lay out development areas.
 i. Base on desired stream network, detention, and corridor widths.
 ii. Consider creating corridors within neighborhoods to convey runoff in vegetated swales rather than storm sewers.
 iii. Lay out planning areas to achieve yield.
 iv. Lay out arterial and collector streets.
 v. If finer detail is beneficial to define development, layout local streets and individual lots.
 vi. Iterate to balance and optimize goals for development yield, stream network, and corridor widths.

6. Deliverables

a. Plan view concept drawing illustrating initial recommendations:
 i. Existing and proposed stream network.
  1. Existing stream reaches to be preserved.
  2. Existing stream reaches to be rehabilitated.
  3. Proposed stream reaches to be created.
 ii. Proposed distributed detention layout.
 iii. Proposed concepts for receiving pervious area (RPA).
 iv. Recommended stream corridor widths.
 v. Development areas, parks, OS.

b. Concept design report.
 i. Documentation of watershed and stream assessment.
 ii. Summary of hydrology/approximate design flows.
 iii. Formulation and initial evaluation of concept design recommendations.

Watershed Assessment

- Roundtop
  - Watershed Area (Stream Stats) = 0.1 sqmiles
  - 19.1” of Rainfall
  - Slope 2-3%
  - Proposed Q_{100} = ~200cfs (Master Planning Documents)

What are the project

Goals and Objectives?

Roundtop XS 2 Sta 4+49

Region ID: CO
Workspace ID: CO20171006214548842000
Clicked Point (Latitude, Longitude): 39.45408, -104.86103
Time: 2017-10-06 15:46:07 -0600

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	0.1	square miles
I6H100Y	6-hour precipitation that is expected to occur on average once in 100 years	3.56	inches
STATSCLAY	Percentage of clay soils from STATSGO	28.5	percent
OUTLETELEV	Elevation of the stream outlet in thousands of feet above NAVD88.	6344	feet

Peak-Flow Statistics Parameters [Foothills Region Peak Flow 2016 5099]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.1	square miles	0.6	2850

Project Goals and Objectives

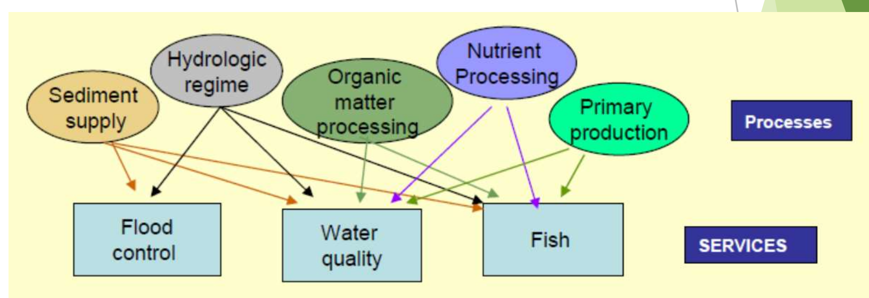
- Always define Goals and Objectives with stakeholders and allow for flexibility

Goals

1. Provide year-round fish passage at the Harmony Diversion site (except for when a call is placed on the river) for all species of fish that occupy the Nowood and Bighorn Rivers;
   a. Specifically shovelnose sturgeon and sauger;
2. Provide reliable supply of irrigation water for ditch user at all discharges;
3. Design and construct an improved instream diversion that can divert the entire river if needed during a call and minimizes instream maintenance;
   a. Designs can in no way compromise the integrity of the existing highway bridge that is upstream of the diversion site.
4. Improve transport of sediment and debris through diversion to avoid entry into headgate/screening structure;
5. Any design should be able to withstand significance ice flow events.

Objectives

1. Designs that leave the channel open and in a more natural state are preferred over designs that rely on a fish ladder to provide fish passage.
2. Designs must allow the landowner to take all flow (no more than 1-3 cfs can flow past the diversion) if the landowner has to put a call on the river.
3. If a fishway were to be considered: Fishway attraction flow of 2-4 ft/s within thalweg of channel and flow depths of 4 ft or more. Fishway passage velocity of 3-4 ft/s is preferred for shovelnose, but shovelnoses have negotiated velocities between 0.8 - 6.0 ft/s (White 2002).
4. New headgate structure and ISI cone shaped fish screens are designed for 40 cfs (20 cfs each screen). The irrigator holds senior water rights which can result in putting a call on the river, so Joyce can receive his water. The State Engineer requires him to divert all water from the river with only 1-3 cfs leaking through.
5. Somehow design an instream structure that will not be a complete dam or barrier. I feel that being in the fish passage program our goals are to remove dams, not to be constructing them. Maybe still look at using an Obermeyer weir. Construct a new structure that requires less maintenance and man hours for the landowner/irrigator.
6. Come up with a design that WYDOT will okay, since their bridge is about 55 ft upstream of the diversion site.



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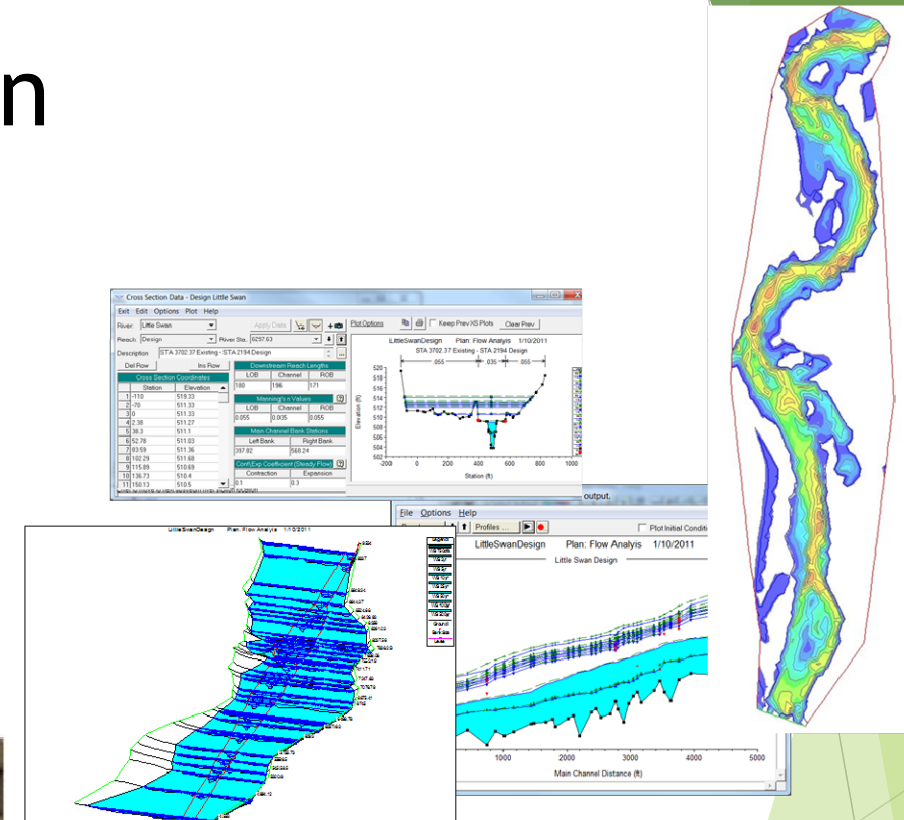
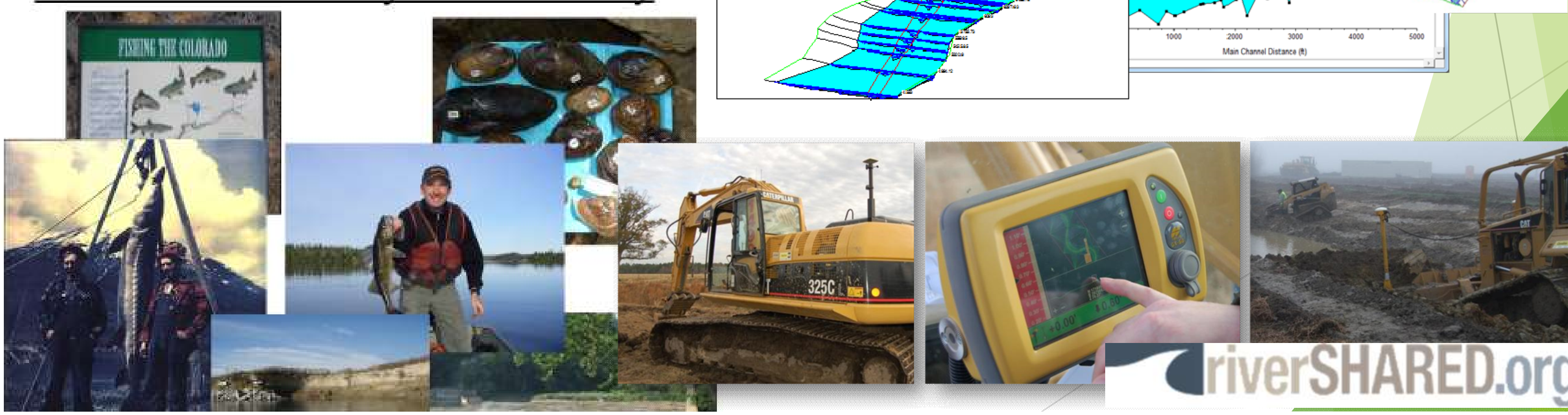
Design Optimization

Based on Goals and Objectives

- Hydraulic Component
- Construction Component
- Ecological Component
- Risk Component

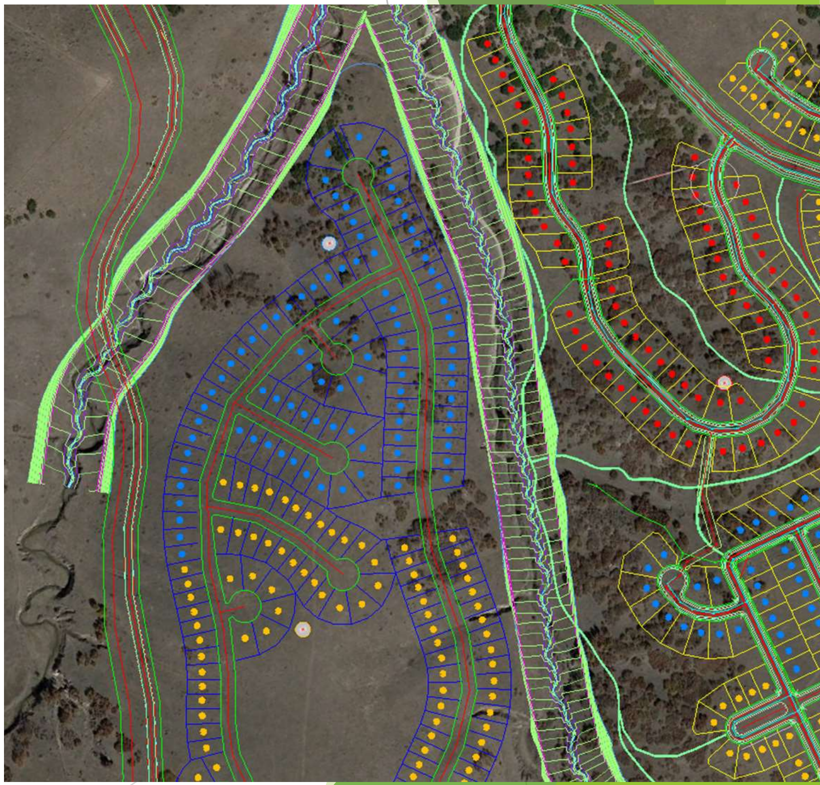
<u>Increased Variability and Diversity</u>





Corridor Width – Concept Design

- Hazzard Migration Zone – Big Rivers
- Existing Floodway – Mapped Drainages
- Existing Infrastructure
- Proposed Infrastructure
- Proposed Development
- Mitigation Potential
- Shear Stress Analysis – Vegetated Floodplains
  - $\tau = R * \gamma * S$




Saamis Coulee Medicine Hat , Alberta
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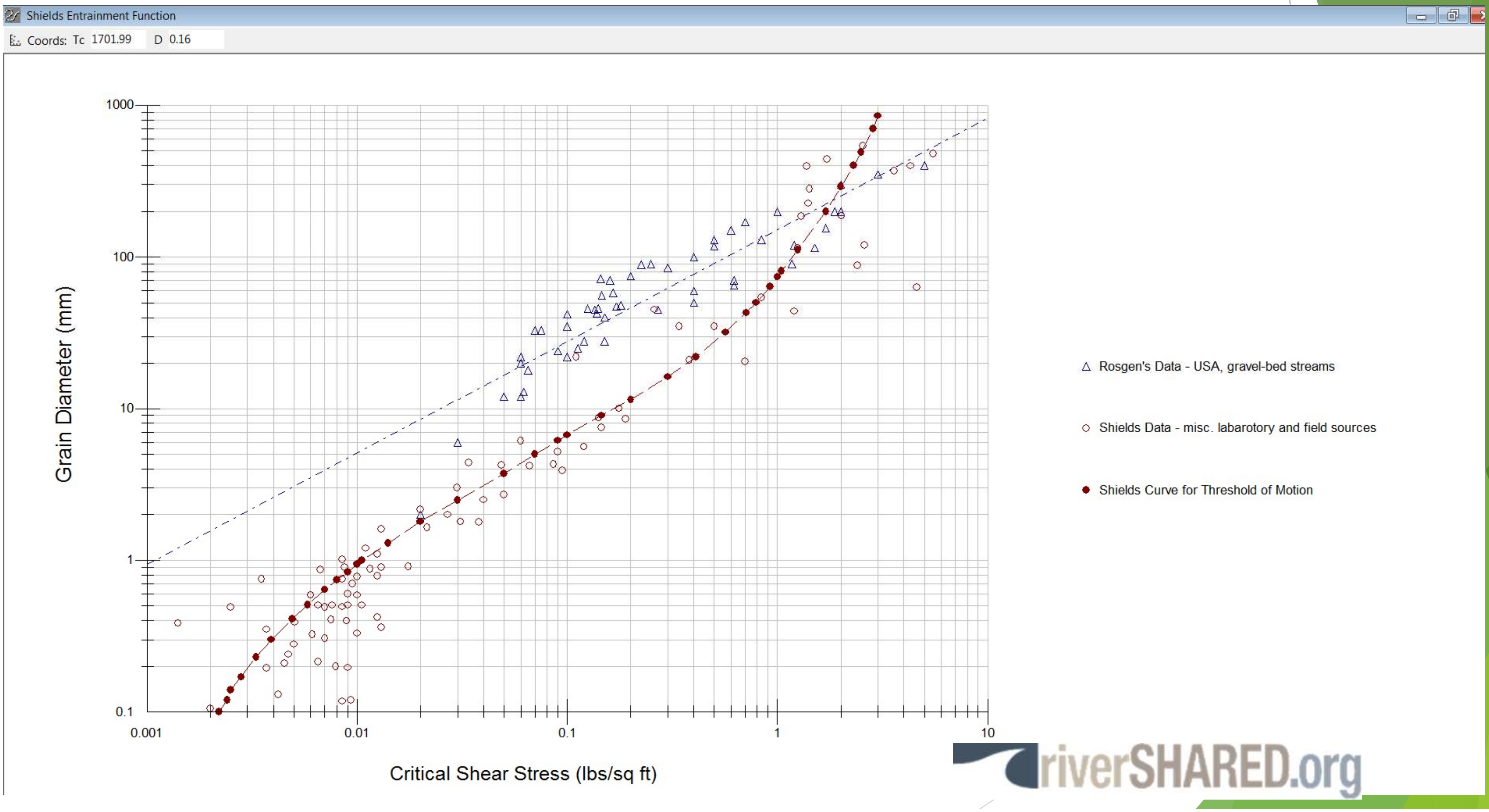
Shields Entrainment Function - Gravel



Reference Floodplain Shear Stress

- Resilient Floodplains that grow stronger with time
- Published values for critical applied shear stress are generally limited and not always appropriate
  - Identify the transition between a stable floodplain and signs of instability or floodplain scour
  - Survey scour or rack lines
  - Calculate applied critical Shear Stress = $R\gamma S$

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Field Based Reference Critical Shear Stress

- Field based reference, shear, stream power and graded slope


Saamis Coulee Medicine Hat , Alberta
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Saamis Coulee Medicine Hat , Alberta
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Floodplain Design for Shear Stresses

- **Given a Storm Event - 3750 cfs**

  Given Shear Stress ~2psf

- **Main Objective – Reduce Shear Stress on Floodplain and Erosion**

Q1: How can we Optimize Shear Stress?

Q2: Do I Need a 3D Surface and Model?

$\tau_{av} = \gamma R S$ = Average Shear Stress (lb/ft^2)

Q =VA

Mannings

Knowns: Shear Stress, Discharge, Unit Weight Water, Slope (based on existing valley)

Solve: Depth, Velocity (mannings), Area (mannings) Approximate Width of Floodplain needed

	Starting Valley Station	Ending Valley Station	PSF	GAMMA	Starting Floodplain Elevation	Ending Floodplain Elevation	DROP	LENGTH	SLOPE	HR	VELOCITY	Q	SQFT	WIDTH	sqft fill area	average fill depth	fill needed
Upstream	0	300	2.0	62.4	88	82	6	325	0.01846	1.73611	8.355478	1630	195.082	112.367	11000	3.5	1425.93
Middle	300	450	3.0	62.4	82	76	6	150	0.04	1.20192	9.624975	1630	169.351	140.9	16000	8	4740.74
Downstream	450	600	5.0	62.4	76	67	9	150	0.06	1.33547	12.64592	1630	128.895	96.5168	29000	6	6444.44
																	12611.1

100 yr Floodplain Design – Roundtop Reach 1 @ 1psf

- 200 cfs = 100-yr Discharge Upstream
- Basis of Design Applied Shear Stress from 100-yr discharge below **1 psf** based on average boundary Shear Stress
- A Threshold of **1 psf** will be able to reuse all existing sod without the costly import of materials for stabilization of floodplains.
- $\tau = R * \gamma * S$
- Slope = 0.0288 (2.88%)
- γ = 62.4 lbs/ft^3
- R ~ Floodplain Depth = τ / (Slope * γ) ~0.55’
- 100-YR Min Floodplain Width @ 2.8 fps (manning’s n =~0.06)
- Min Width = Q / (v * D) = 127’

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100 yr Floodplain Design – Roundtop Reach 1 @ 1.5 psf

- 200 cfs = 100-yr Discharge Upstream
- Basis of Design Applied Shear Stress from 100-yr discharge below **1.5 psf** based on average boundary Shear Stress
- A Threshold of **1.5 psf** will be able to reuse all existing sod without the costly import of materials for stabilization of floodplains.
- $\tau = R * \gamma * S$
- Slope = 0.0288 (2.88%)
- γ = 62.4 lbs/ft^3
- R ~ Floodplain Depth = τ / (Slope * γ) ~0.83'
- 100-YR Min Floodplain Width @ 3.7 fps (manning's n =~0.06)
- Min Width = Q / (v * D) = 64'

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Roundtop Gulch

τ_c = 1.0psf


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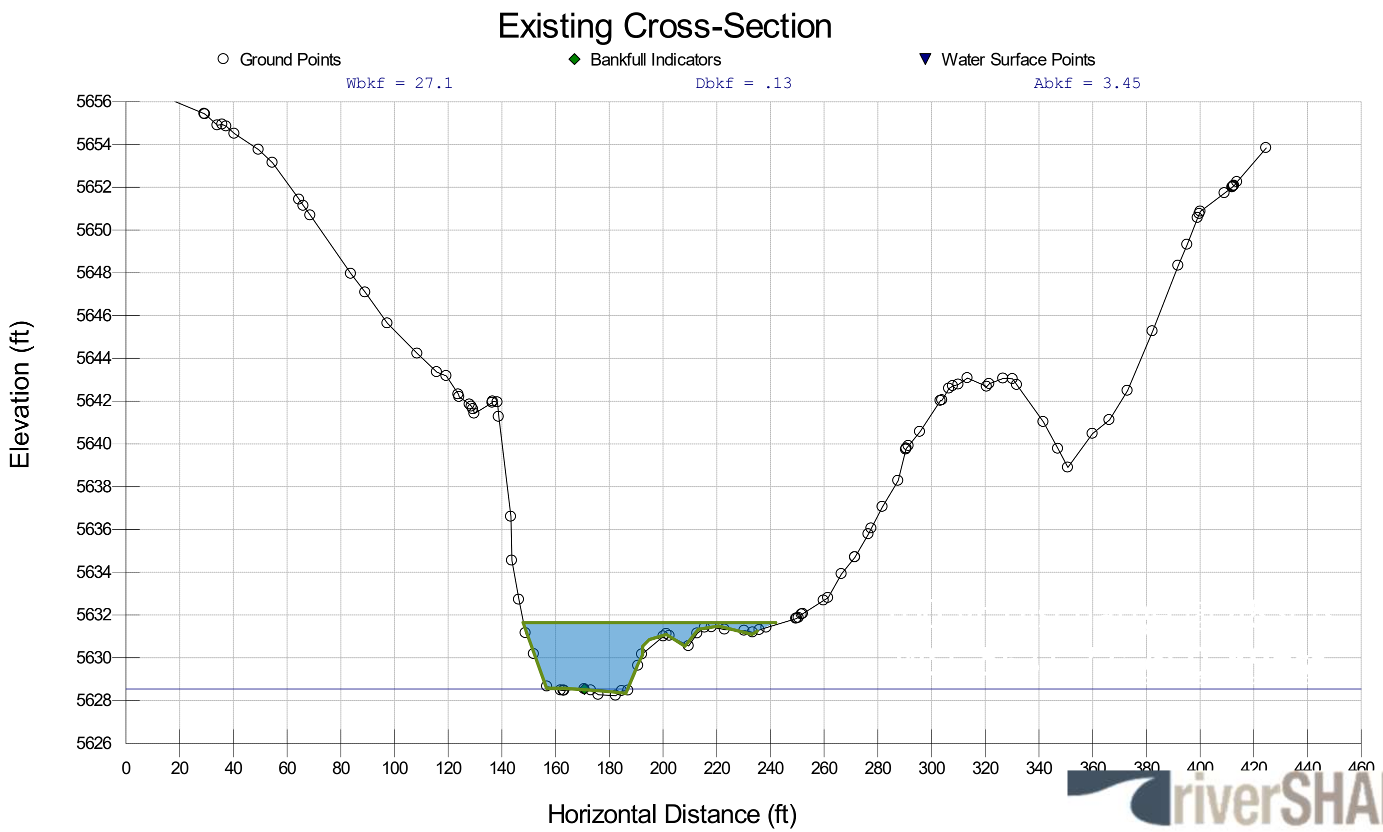
Cros ch

Existing 100-yr Discharge 483cfs



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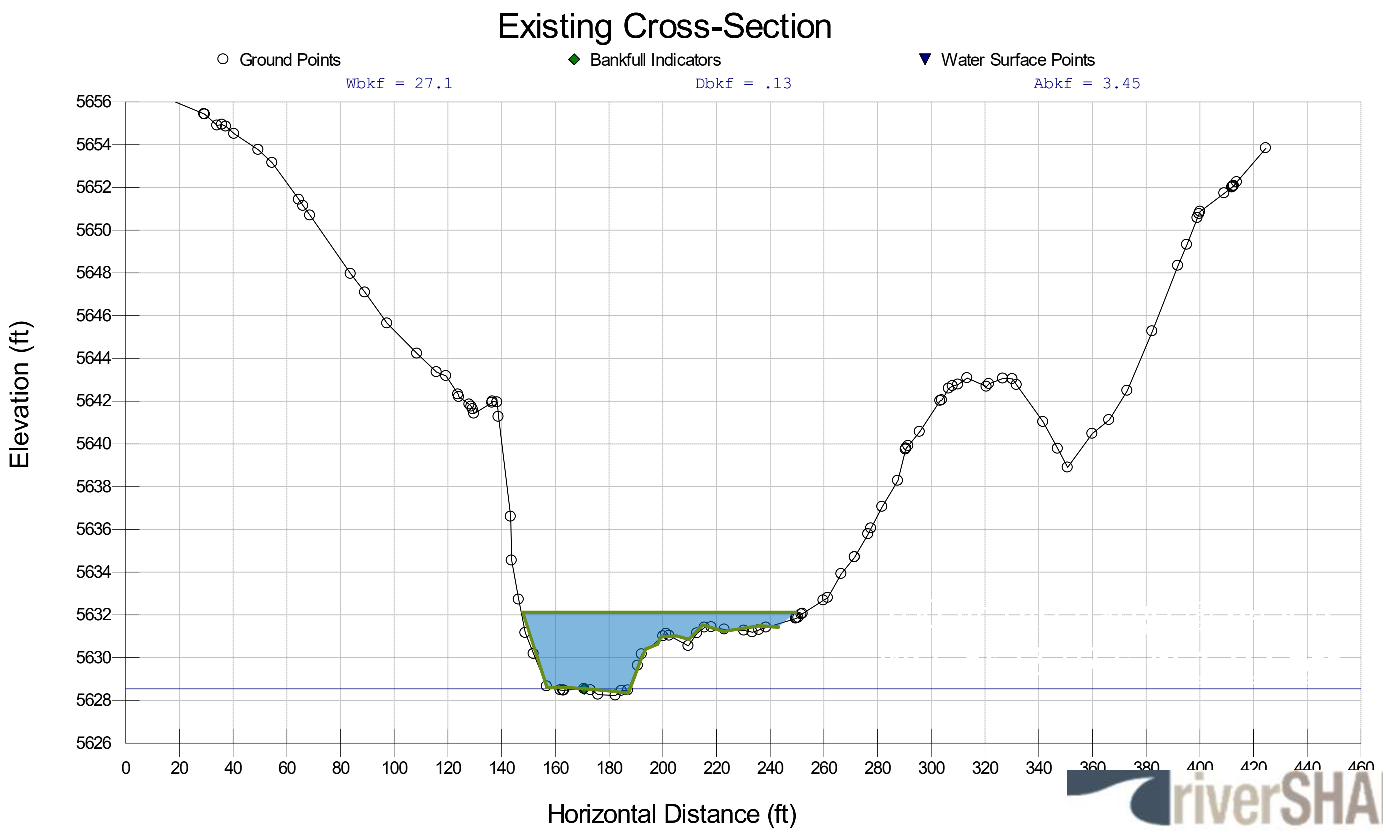
Existing 200-yr Discharge 645cfs



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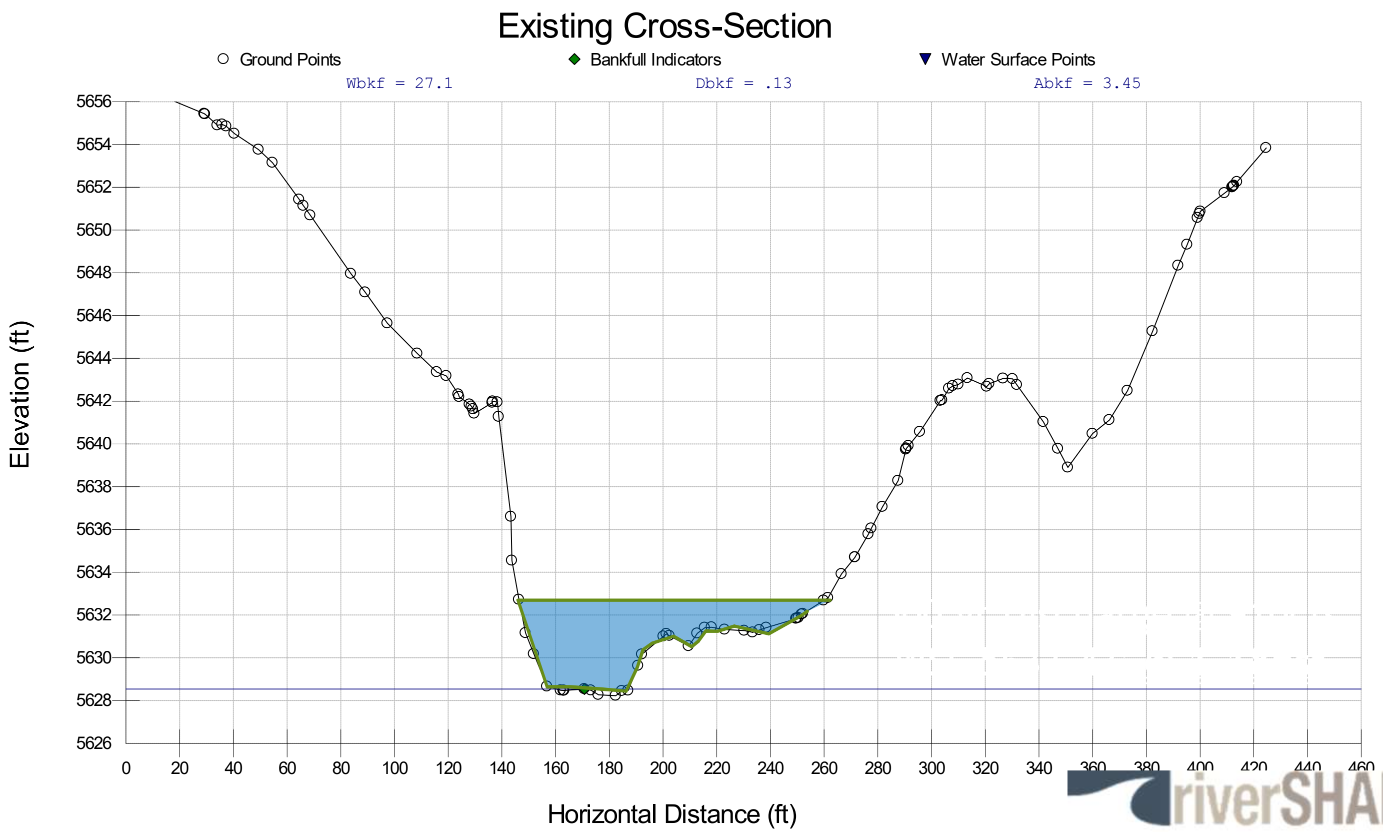
Existing 500-yr Discharge 910cfs



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West Branch Sterling Gulch
τ_c = 1.3psf
Notice High Terrace Erosion

Rooney Gulch
τ_c = 1.8psf

Roundtop Gulch

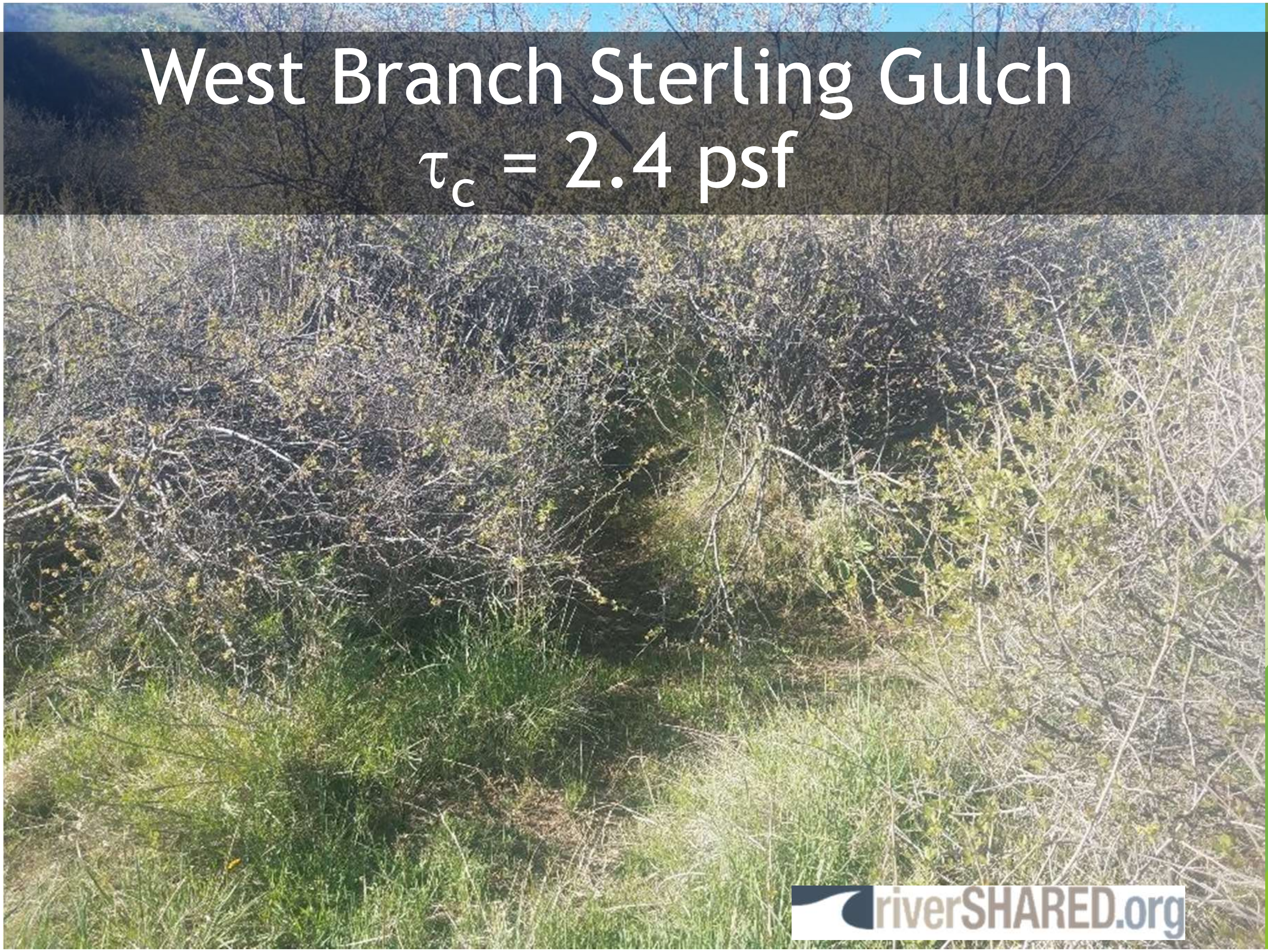
$\tau_{Applied} > 1.2$psf

West Branch Sterling Gulch

τ_c = 2.2psf

West Branch Sterling Gulch
τ_c = 2.4 psf

West Branch Sterling Gulch
τ_c = 2.4 psf



100 yr Floodplain Design – Roundtop Reach 1 @ 1.5 psf

- 200 cfs = 100-yr Discharge Upstream
- Basis of Design Applied Shear Stress from 100-yr discharge below **1.5 psf** based on average boundary Shear Stress
- A Threshold of **1.5 psf** will be able to reuse all existing sod without the costly import of materials for stabilization of floodplains.
- $\tau = R * \gamma * S$
- Slope = 0.0288 (2.88%)
- γ = 62.4 lbs/ft^3
- R ~ Floodplain Depth = τ / (Slope * γ) ~0.83'
- 100-YR Min Floodplain Width @ 3.7 fps (manning's n =~0.06)
- Min Width = Q / (v * D) = 64'
- Can the RISK be mitigated if there is not enough room for the Floodplain Corridor?

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Mitigation for Excess Shear
Floodplain Shear Stress Treatments

- 0-1.0 psf - Treatment Seed and Straw with Riparian Plantings
- 1.1 -1.6 psf – Treatment Floodplain Coir Matting / Seed and Straw with Riparian Plantings
- 1.7 – 2.0 psf - Treatment Floodplain Boulder/ Log Sills, Floodplain Coir Matting / Seed and Straw with Riparian Plantings
- 2.0 – 4.0 psf - Treatment Floodplain Vegetated Rip-Rap, Floodplain Coir Matting / Seed and Straw with Riparian Plantings NOT DESIRED BY UDFCD

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Floodplain Shear Stress Treatments

- 1.1 -1.6 psf – Treatment Floodplain Coir Matting / Seed and Straw with Riparian Plantings

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Floodplain Shear Stress Treatments

- 1.7 – 2.0 psf - Treatment Floodplain Boulder/ Log Sills, Floodplain Coir Matting / Seed and Straw with Riparian Plantings

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CAT
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324E
1426
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Floodplain Shear Stress Treatments

- 2.0 – 4.0 psf - Treatment Floodplain Vegetated Rip-Rap, Floodplain Coir Matting / Seed and Straw with Riparian Plantings NOT DESIRED BY UDFCD

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NOT DESIRED BY UDFCD
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Mitigation for Excess Shear
Floodplain Shear Stress Treatments

- 0-1.0 psf - Treatment Seed and Straw with Riparian Plantings
- 1.1 -1.6 psf – Treatment Floodplain Coir Matting / Seed and Straw with Riparian Plantings
- 1.7 – 2.0 psf - Treatment Floodplain Boulder/ Log Sills, Floodplain Coir Matting / Seed and Straw with Riparian Plantings
- 2.0 – 4.0 psf - Treatment Floodplain Vegetated Rip-Rap, Floodplain Coir Matting / Seed and Straw with Riparian Plantings NOT DESIRED BY UDFCD

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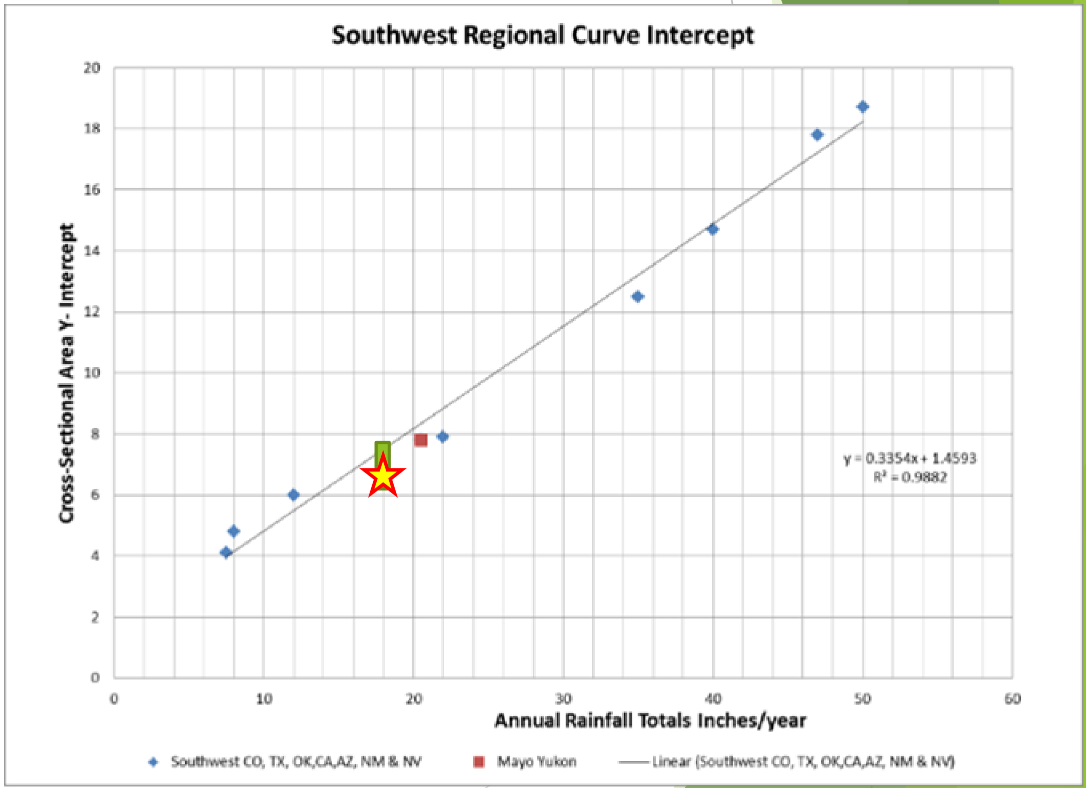
Watershed Area and Bankfull XS Area

- Drainage Area
  - 0.59 sq mi
- Bankfull XS Area
  - 4.35 sq ft – 5.50 sq ft
- Watershed Response Factor
  - 6.2-7.8 (Design 6.5)
- Design Bankfull WDR from Reference 14-20
- Annual Precipitation ~ 18.1 in/yr



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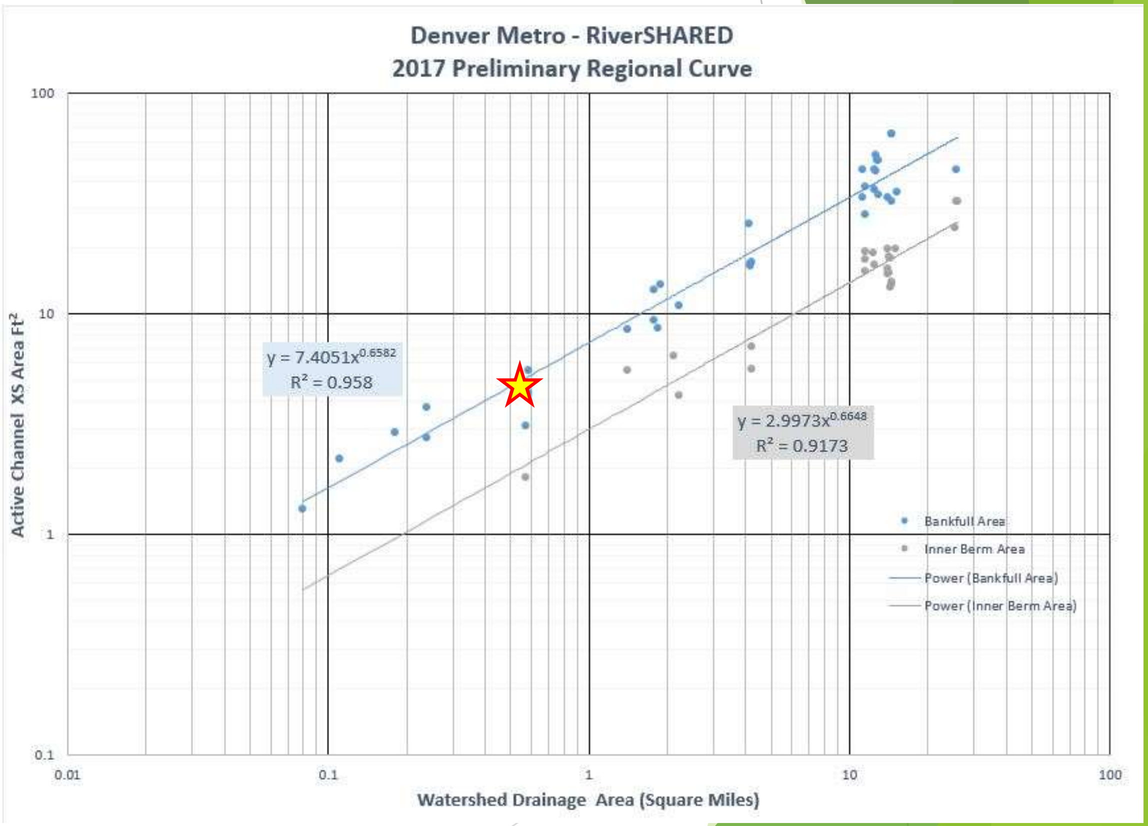
Concept Design and Floodplain Corridor vs. Preliminary Design and Bankfull Channel Layout

- Drainage Area
  - 0.56 sqmiles
- Bankfull XS Area
  - 4.40 sq ft – 5.04 sq ft
  - Watershed Response Factor (Design 6.5)
- Design Bankfull WDR from Reference Slope 14-20



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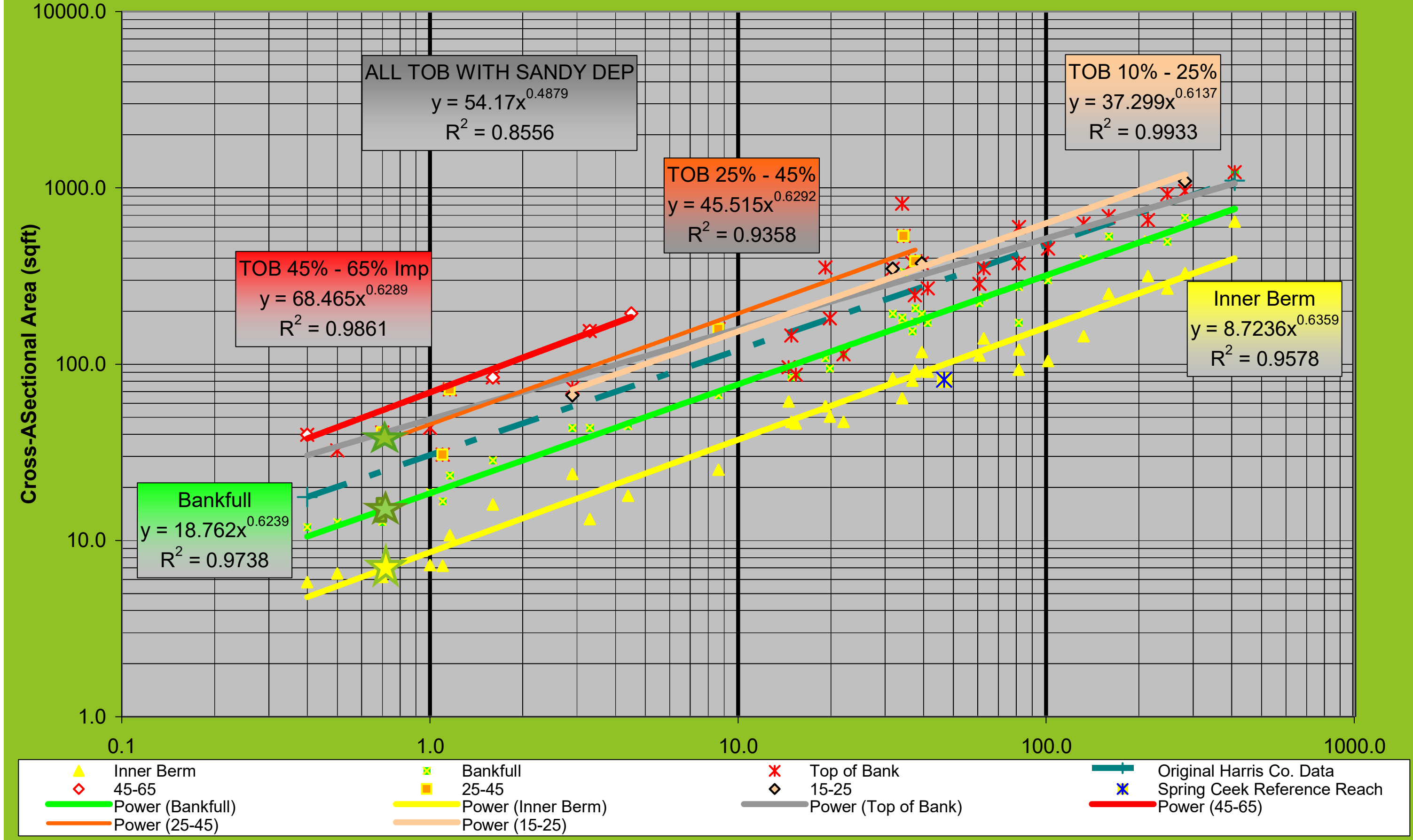
Phase II: Regional and Local Relations
Multiple Depositional Surfaces



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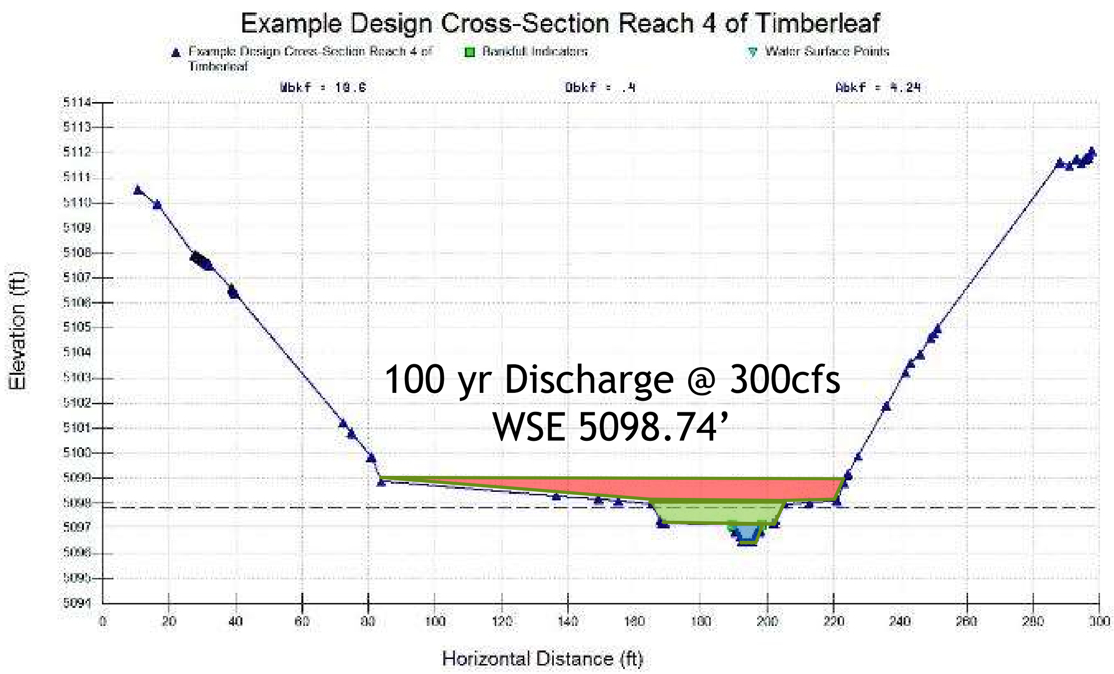
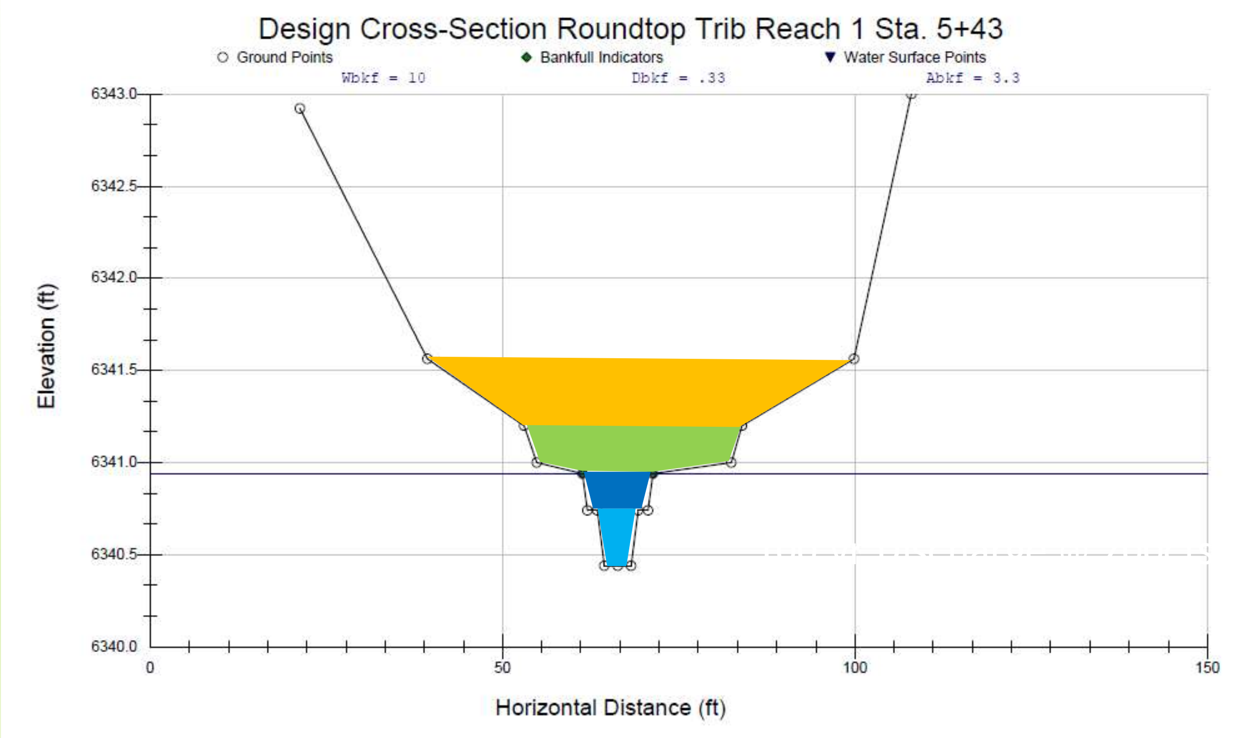
Example – 4 Stage Step-Pool Channel Design



- 100-yr Discharge = 300cfs
- 100-yr Design Applied Shear Stress < 1psf
- Applied Shear Stress greater than 2psf will significantly increase the risk of failure
- Discharge of 1,170cfs will reach an applied shear stress of 2psf
- 230 TNS of 4-8" Rock for Riffles

Discharge Profile	ELEV (ft)	DEPTH (ft)	AREA (sq ft)	WET PER (ft)	WIDTH (ft)	HYD RAD (ft)	MEAN D (ft)	SLOPE (ft/ft)	ROUGH [n] (ft^(1/6))	R/D84	VELOCITY (fps)	U/U*	U^2/2g (ft)	DISCHARGE (cfs)	SHEAR (psf)	POWER/W (lb/ft/s)	FROUDE
InnerBerm	5096.84	0.4	1.82	7.63	7.49	0.24	0.24	0.0188	0.06	0	1.31	3.44	0.03	2.39	0.28	0.37	0.47
Bankfull	5097.13	0.69	4.19	9.47	9.2	0.44	0.46	0.0188	0.06	0	1.97	3.81	0.06	8.23	0.52	1.05	0.51
Flood Terrace	5097.94	1.5	32.93	40.32	39.88	0.82	0.83	0.0188	0.06	0	2.98	4.22	0.14	98	0.96	2.88	0.58
100-yr toe	5098.64	2.2	91.03	118.15	117.61	0.77	0.77	0.0188	0.06	0	2.85	4.18	0.13	259.78	0.9	2.59	0.57
100-yr Discharge	5098.74	2.3	103.27	127.62	127.06	0.81	0.81	0.0188	0.06	0	2.95	4.22	0.14	304.83	0.95	2.81	0.58
Discharge Below 2psf	5099.74	3.3	244.43	146.33	145.5	1.67	1.68	0.0188	0.06	0	4.78	4.76	0.35	1168.76	1.96	9.42	0.65

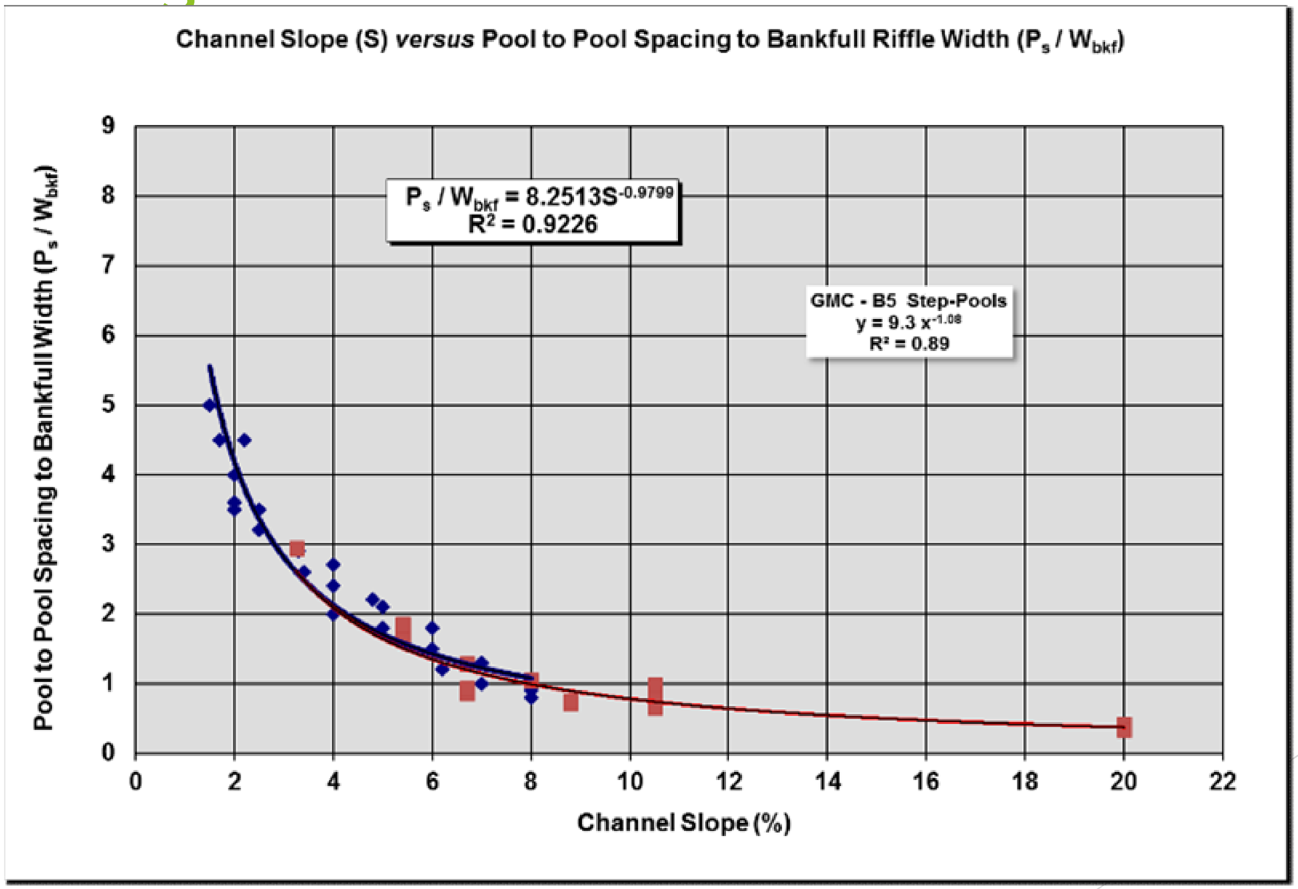
Roundtop Tributary Reach 1



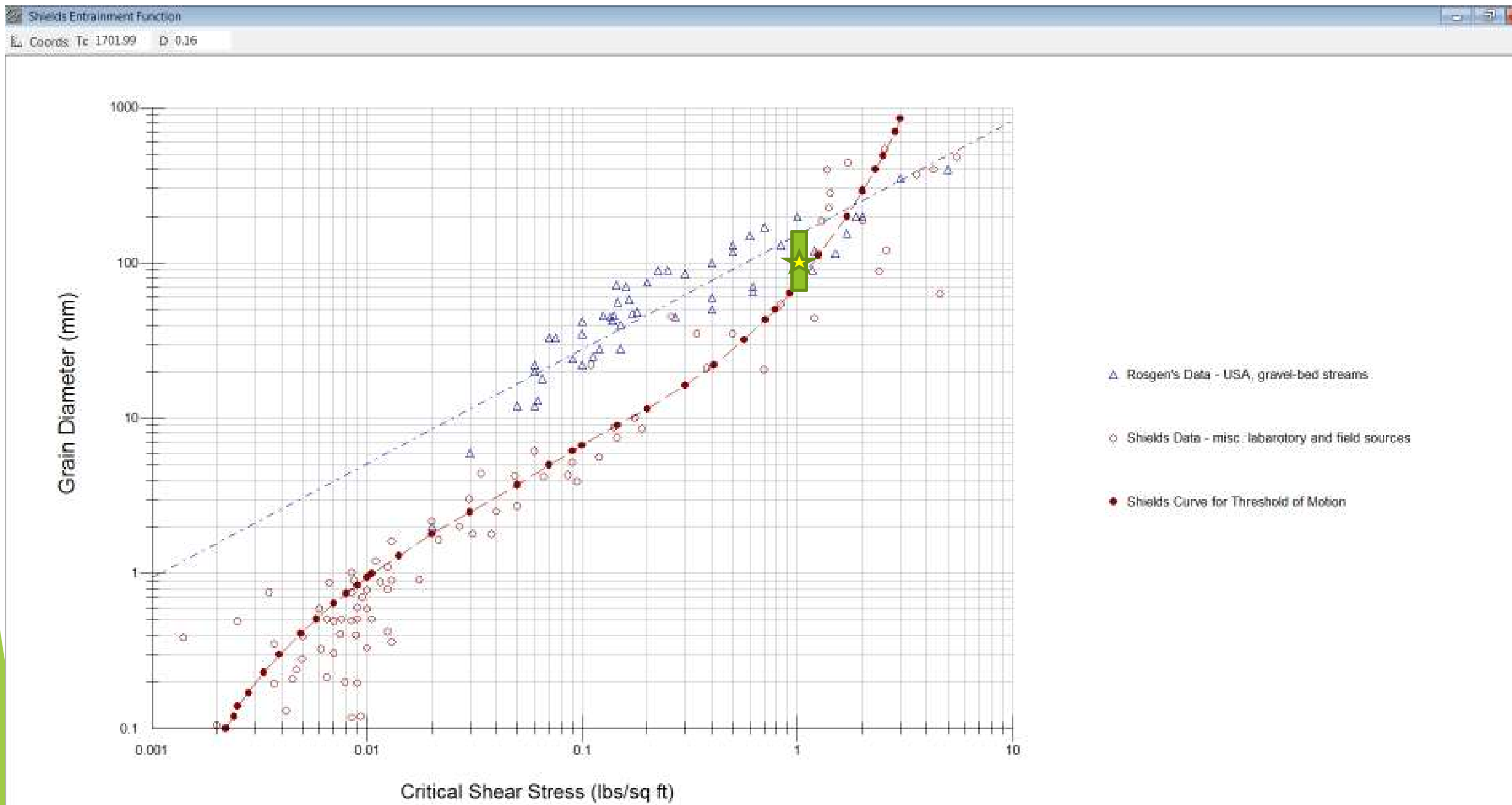
- 100-yr Discharge = 200cfs
- 100-yr Design Applied Shear Stress < 1.1psf
- Applied Shear Stress greater than 2psf will significantly increase the risk of failure
- Discharge of 870cfs will reach an applied shear stress of 2psf

Discharge Profile	ELEV	DEPTH	AREA	WET PER	WIDTH	HYD RAD	MEAN D	SLOPE	ROUGH	R/D84	VELOCITY	U/U*	U^2/2g	DISCHARGE	SHEAR	POWER	POWER/W	FROUDE	TRANSPORT
	(ft)	(ft)	(sq ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	[n] (ft^(1/6))		(fps)		(ft)	(cfs)	(psf)	(lb/s)	(lb/ft/s)		(lb/s)
Inner Berm	6340.74	0.3	1.44	5.89	5.8	0.24	0.25	0.029	0.03489	2.93	2.8	5.92	0.12	4.04	0.43	7.3	1.26	0.99	0
Bankfull	6340.94	0.5	3.3	10.14	10	0.33	0.33	0.029	0.03249	4.02	3.72	6.7	0.21	12.28	0.6	22.22	2.22	1.14	6.43
Flood Terrace	6341.24	0.8	11.58	34.33	34.16	0.34	0.34	0.029	0.0323	4.15	3.82	6.78	0.23	44.21	0.62	80	2.34	1.15	25.05
100-yr Toe	6341.54	1.1	25.5	58.82	58.64	0.43	0.43	0.029	0.03095	5.24	4.66	7.35	0.34	118.81	0.78	214.99	3.67	1.25	106.95
100-yr Discharge	6341.74	1.3	37.88	64.08	63.88	0.59	0.59	0.029	0.02951	7.19	6.03	8.13	0.57	228.58	1.07	413.65	6.48	1.38	311.39
Discharge Below 2 psf	6342.44	2	87.24	77.45	77.16	1.13	1.13	0.029	0.02749	13.78	9.99	9.73	1.55	871.66	2.04	1577.36	20.44	1.66	1778.42

Step-Pool Channel Design Pool-Pool Spacing



Shields Entrainment Function

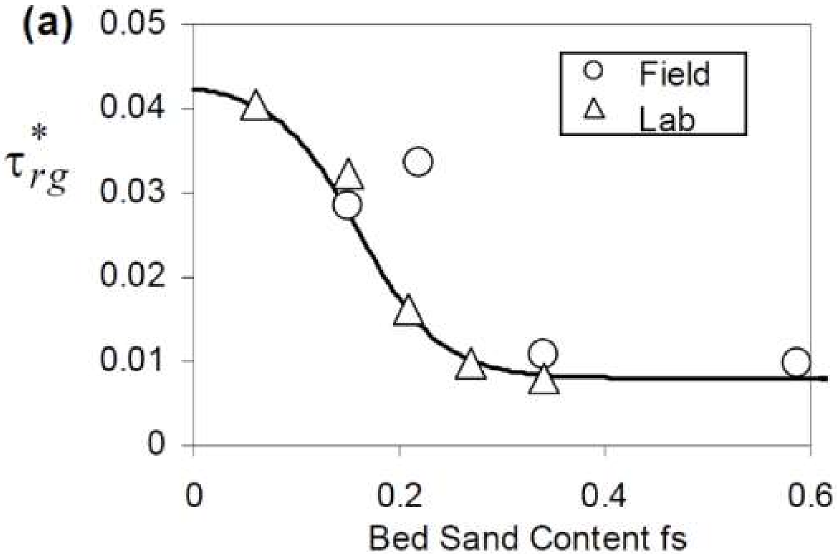


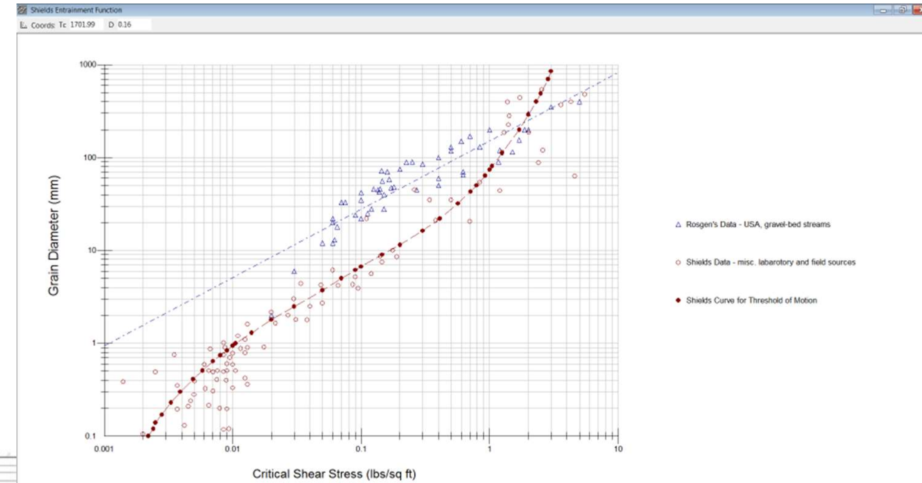
- 1psf
- 78mm diameter
- 150mm diameter
- 3” – 6” Gravel Rock
- * Design 4” – 8”

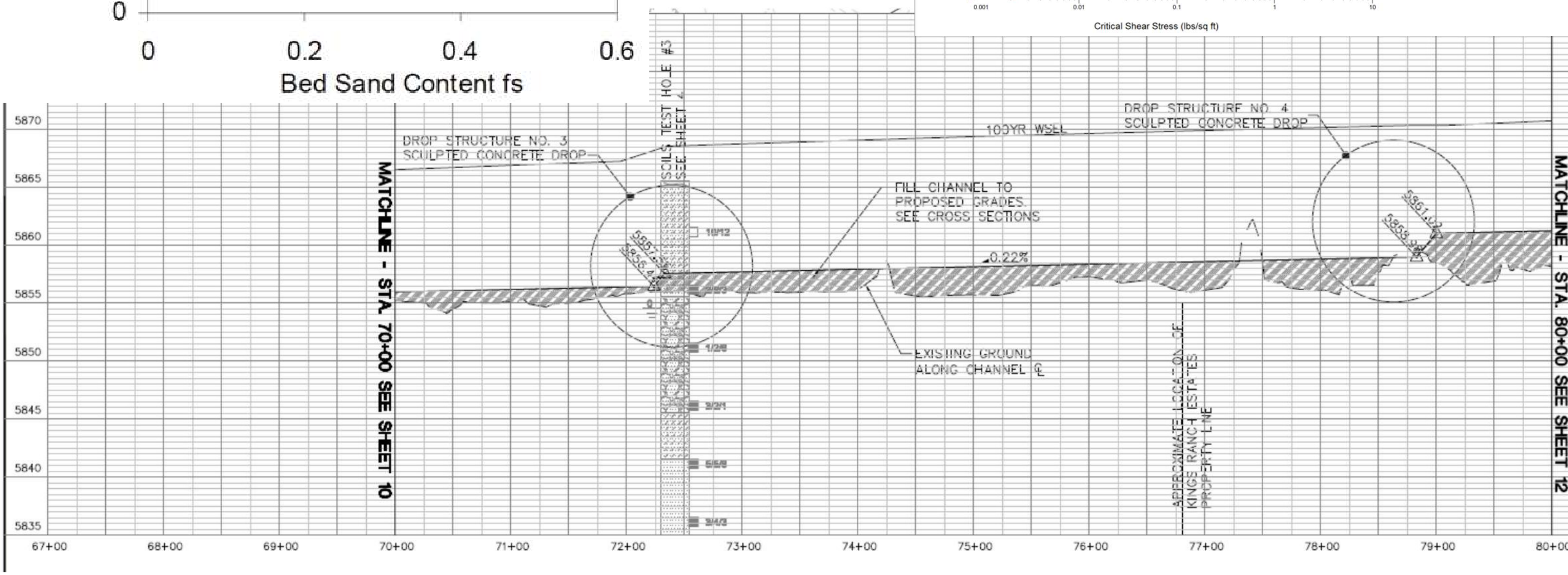
Upstream and Downstream Comparison on a Sandy Reach

Design Concerns for Sandy Reaches

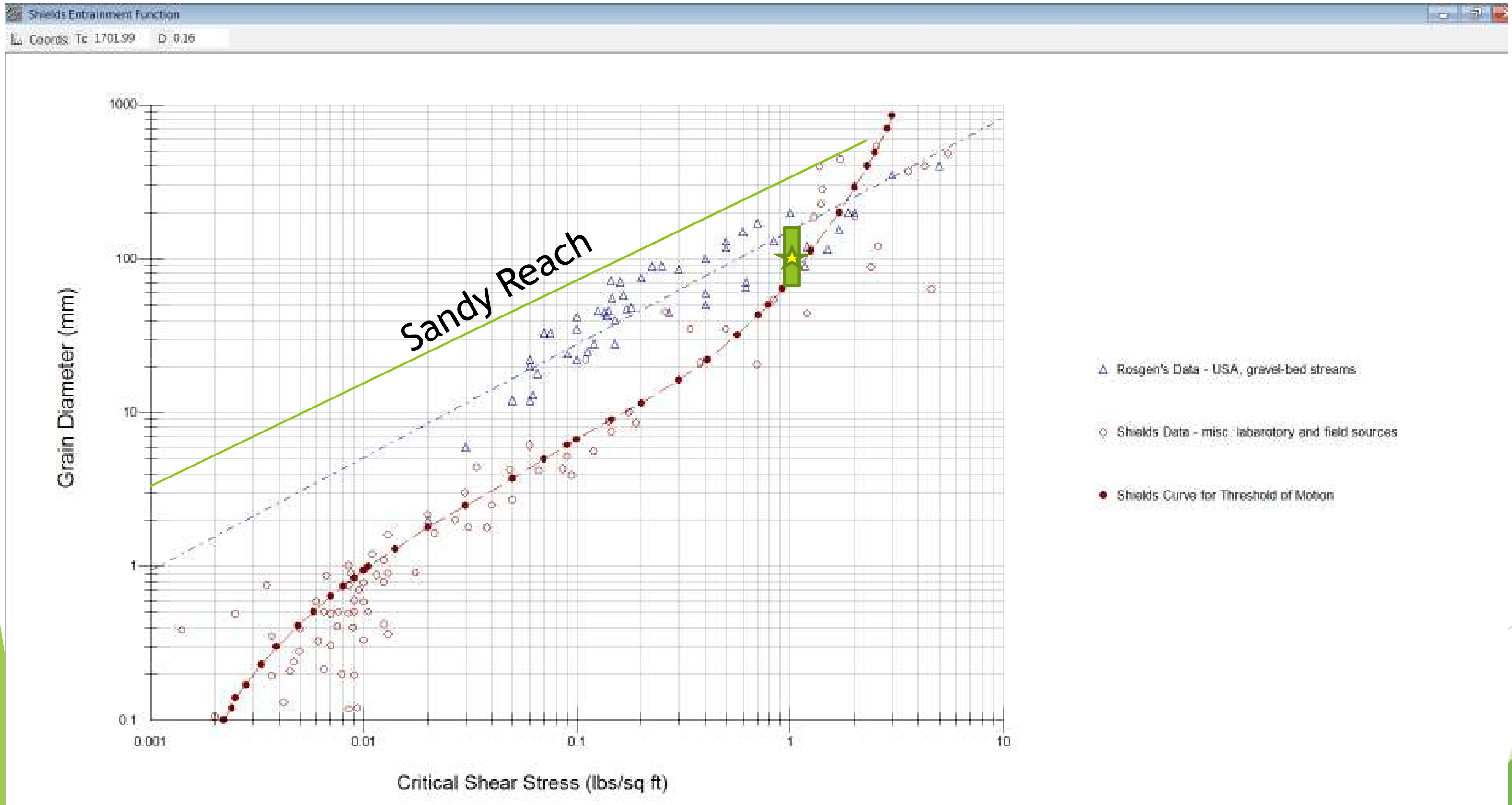
- Sediment regime may have to change to achieve resiliency, high function and low maintenance
- The primary sediment source in the reach is from localized bank erosion within the reach, upstream there is significantly less sediment supply and there is available storage for excess sediment
- The design of a channel constructed in fill is higher risk of failure because the fill material is not sorted and the fine material in the fill serves as a lubricant in sediment transport and reduces the critical shear stress required to move large gravels by as much as 3 fold.
  - We never recommend using fill for grade control without having a good understanding of design channel gradation of both the armor and sub-armor layers


(a)
Field
Lab
τ^*_{rg}
0.05
0.04
0.03
0.02
0.01
0
0
0.2
0.4
0.6
Bed Sand Content fs


Shields Entrainment Function
Grain Diameter (mm)
Critical Shear Stress (lbs/sq ft)
Rosgen's Data - USA, gravel-bed streams
Shields Data - misc. labarotory and field sources
Shields Curve for Threshold of Motion


DROP STRUCTURE NO. 3
SCULPTED CONCRETE DROP
DROP STRUCTURE NO. 4
SCULPTED CONCRETE DROP
100YR WSEL
SOILS TEST HOLE #3
SEE SHEET 4
FILL CHANNEL TO
PROPOSED GRADES.
SEE CROSS SECTIONS
0.22%
EXISTING GROUND
ALONG CHANNEL ℄
APPROXIMATE LOCATION OF
KINGS RANCH ESTATES
PROPERTY LINE
MATCHLINE - STA. 70+00 SEE SHEET 10
MATCHLINE - STA. 80+00 SEE SHEET 12
5870
5865
5860
5855
5850
5845
5840
5835
67+00
68+00
69+00
70+00
71+00
72+00
73+00
74+00
75+00
76+00
77+00
78+00
79+00
80+00

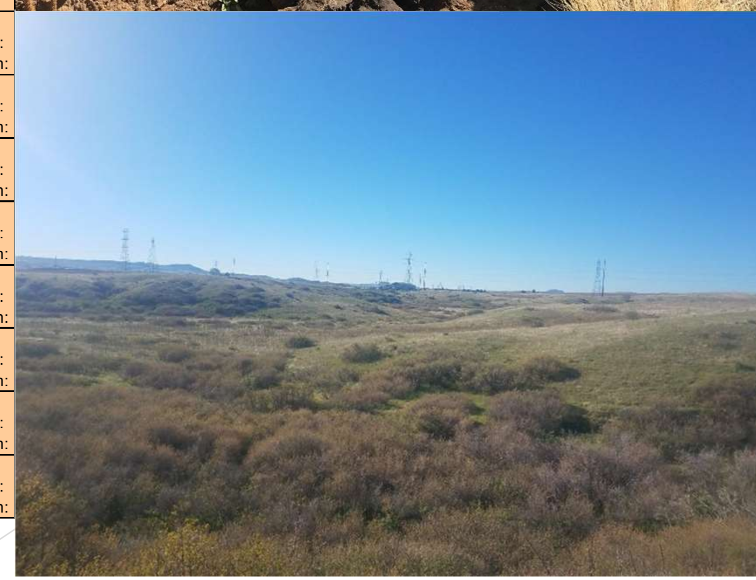
Sandy Shields Entrainment Function

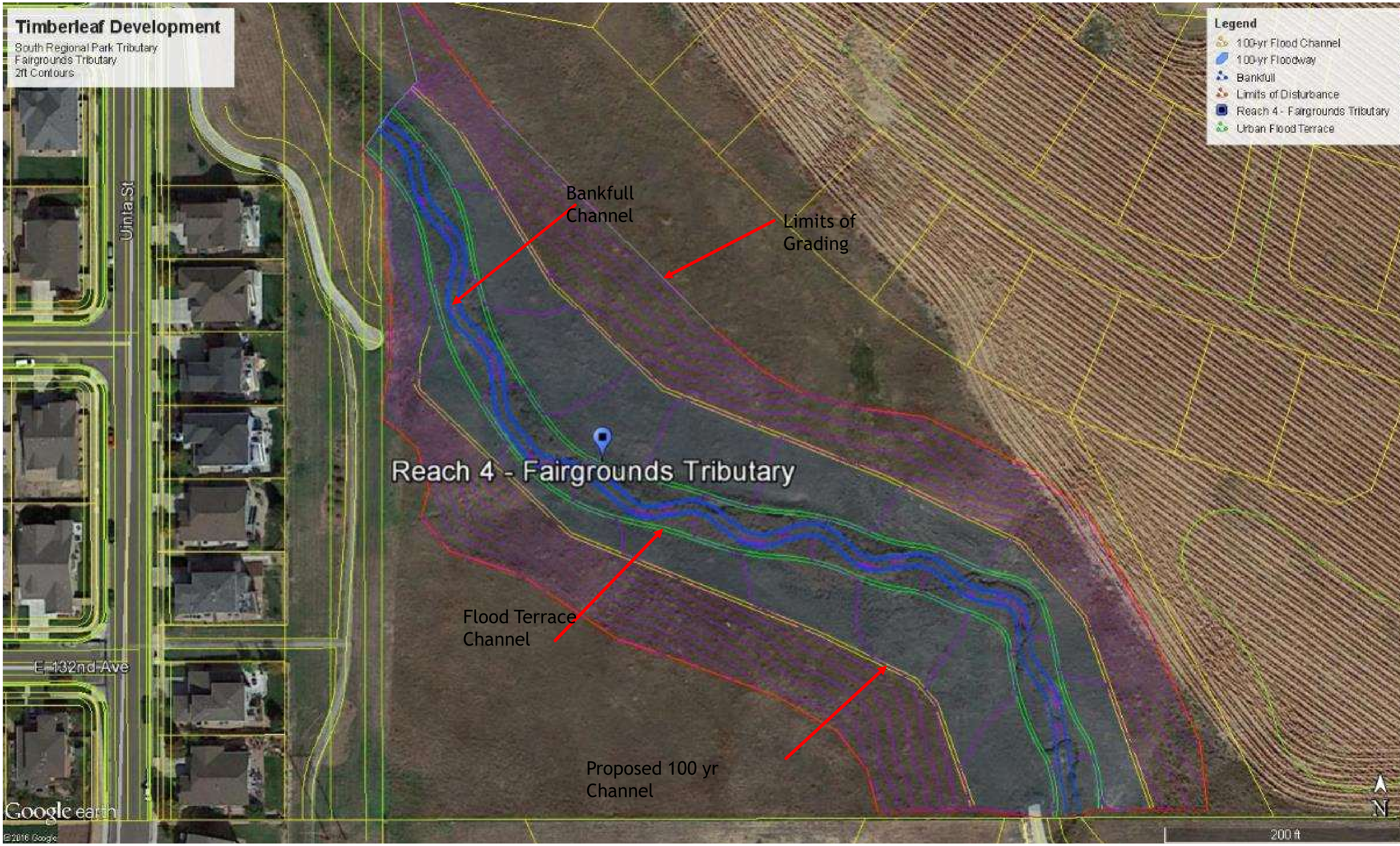


- 1psf
- 350 mm diameter
- 12"-16" Rock
- NOT -3" – 6" Gravel

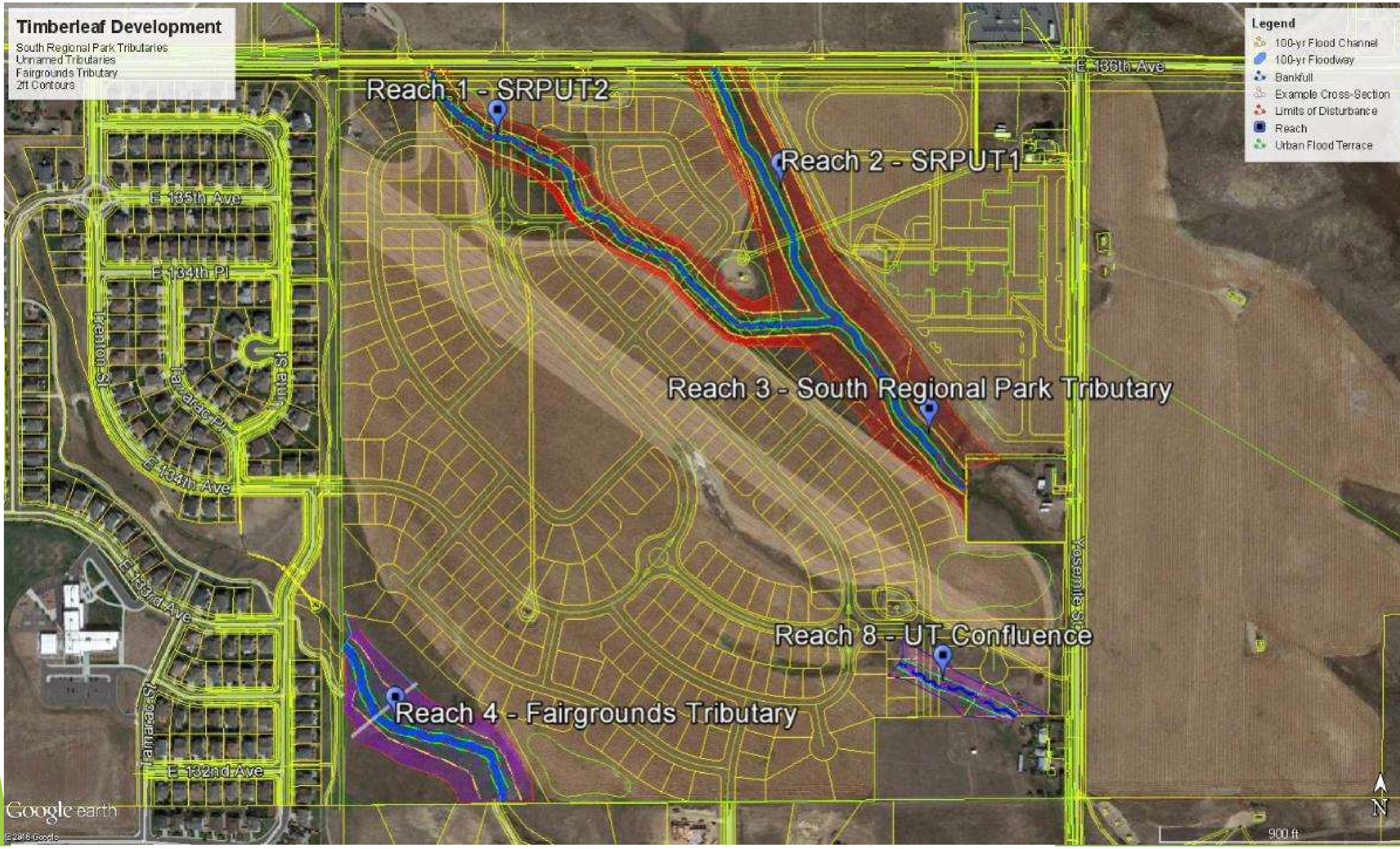
Reference Reach Approach

MORPHOLOGICAL CHARACTERISTICS OF THE EXISTING AND PROPOSED CHANNEL WITH GAGE STATION AND REFERENCE REACH DATA (Adapted from Rosgen, 1996)						
Restoration Site:	**Newlin Gulch - Canyons**					
USGS Gage Station:	**N/A**					
Reference Reach:	**West Branch of Sterling Gulch, Newlin Gulch ~2,000ft Upstream of East Main Street**					
Surveyors:	**5SSR- River SHARED**					
Date:	**10/5/2017**					
Weather:	**Clear and Sunny**					
Variables			**Reference Reach**		**Reference Reach**	
			Newlin Gulch @ East Main		**West Branch Sterling Gulch**	
1. Stream Type			C4/5		B5/4	
2. Drainage Area (sq. mi)			11.5		0.59	
3. Bankfull Width (Wbkf) ft	Mean:	Mean:	24.0	Mean:	10.5	Mean:
	Minimum:	Minimum:	23.0	Minimum:	9.0	Minimum:
	Maximum:	Maximum:	26.0	Maximum:	11.0	Maximum:
4. Bankfull Mean Depth (dbkf) ft	Mean:	Mean:	1.25	Mean:	0.43	Mean:
	Minimum:	Minimum:	1.50	Minimum:	0.40	Minimum:
	Maximum:	Maximum:	1.65	Maximum:	0.50	Maximum:
5. Width/Depth Ratio (Wbkf/dbkf)	Mean:	Mean:	19.2	Mean:	10.5	Mean:
	Minimum:	Minimum:	18.0	Minimum:	9.5	Minimum:
	Maximum:	Maximum:	20.0	Maximum:	12.5	Maximum:
6. Bankfull Cross-Sectional Area (Abkf) sq ft	Mean:	Mean:	30.0	Mean:	4.5	Mean:
	Minimum:	Minimum:	24.0	Minimum:	4.0	Minimum:
	Maximum:	Maximum:	35.0	Maximum:	5.6	Maximum:
7. Bankfull Mean Velocity (Vbkf) fps	Mean:	Mean:	3.0	Mean:	4.3	Mean:
	Minimum:	Minimum:	2.8	Minimum:	4.0	Minimum:
	Maximum:	Maximum:	3.3	Maximum:	4.5	Maximum:
8. Bankfull Discharge (Qbkf) cfs	Mean:	Mean:	90	Mean:	19	Mean:
	Minimum:	Minimum:	80	Minimum:	15	Minimum:
	Maximum:	Maximum:	100	Maximum:	25	Maximum:
9. Maximum Bankfull Depth (dmax) ft	Mean:	Mean:	2.0	Mean:	0.7	Mean:
	Minimum:	Minimum:	1.9	Minimum:	0.65	Minimum:
	Maximum:	Maximum:	2.1	Maximum:	0.75	Maximum:
10. Ratio of Low Bank Height to Maximum Bankfull Depth (lbh/dmax)	Mean:	Mean:	1.000	Mean:	1.00	Mean:
	Minimum:	Minimum:		Minimum:		Minimum:
	Maximum:	Maximum:		Maximum:		Maximum:





Timberleaf Development
South Regional Park Tributary
Fairgrounds Tributary
2ft Contours
Legend
100-yr Flood Channel
100-yr Floodway
Bankfull
Limits of Disturbance
Reach 4 - Fairgrounds Tributary
Urban Flood Terrace
Uinta St
E 132nd Ave
Bankfull Channel
Limits of Grading
Reach 4 - Fairgrounds Tributary
Flood Terrace Channel
Proposed 100 yr Channel
N
200 ft
Google earth
©2016 Google



Timberleaf Development
South Regional Park Tributaries
Unnamed Tributaries
Fairgrounds Tributary
2ft Contours
Legend
100-yr Flood Channel
100-yr Floodway
Bankfull
Example Cross-Section
Limits of Disturbance
Reach
Urban Flood Terrace
Reach 1 - SRPUT2
Reach 2 - SRPUT1
Reach 3 - South Regional Park Tributary
Reach 4 - Fairgrounds Tributary
Reach 8 - UT Confluence
E 136th Ave
E 135th Ave
E 134th Pl
E 134th Ave
E 133rd Ave
E 132nd Ave
Trenton St
Tamarac Pl
Uinta St
Tamarac St
Yosemite St
900 ft
N
Google earth

Augmented Constructed Riffle Grade Control
~20ft Wide BKF Channel

Rock Constructed Riffle Grade Control ~44ft Wide BKF Channel

Wood Toe

Log J-Hook


riverSHARED.org
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