Low Flow Relief

Options and Potential Outcomes for Building Trout Refuge Needed in Southwestern Colorado Mountain Streams

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Introduction

- Mountain streams in the upper Dolores River basin,
- Draining approximately 500 sq mi in southwestern Colorado,
- Are having problems from low flow conditions,
- Which are occurring more frequently and with greater intensity
- Due to climate change.
- The second lowest flow in 71 years was experienced in 2018.
- A few small streams temporarily dewatered to dryness in 2019.
- Recurring low and very low flows can jeopardize the health and survival of resident trout populations.

The leading question

- High volumes of water charge through these streams, however, during snowmelt.
- Can some of that water be held onto?
- And made available for trout to have refuge during low flows.
- And, ideally, made proximate to distributed trout populations.
- That is, can consequential trout refuge be built at streams?

Thinking about it

- Thinking might go like this.
- What about large-ish containment that could hold lots of trout?
- A pond, for example, for refuge.
- Created by a dam in the channel that also extends onto adjacent flood plain for holding lots of water.
- A seemingly ready solution.
- But a pond (or two) would be accessible mostly to trout nearby during low and very low flow conditions, due to limits on movement.
- And would increase stream water evaporation.

Thinking, cont.

- What about smaller containment, also using dams,
- That's easier to install at more places, that is, more distribution.
- That keeps water in the stream channel,
- The dam width being the channel width,
- So water surface area and evaporation are not increased,
- Creating backup pools.
- It's potentially a lot of dams to install.
- And to try keeping sealed to maintain intended refuge volume.
- But it is an option for building trout refuge.

Thinking, cont.

- So, what avoids dam challenges.
- And increases refuge distribution for trout access, too.
- Some natural examples are apparent at mountain streams,
- Where the downstream sides of some instream structures,
- Have deep-ish pools,
- Created by the scouring action of high flows on the streambed,
- From water plunging over the structures.
- They're sometimes called plunge pools, a third refuge option.

Noted

- For contemplating these three refuge options.
- Two distinctive flow conditions are noted:
  - High
  - And not-high.
- <u>High</u> flows can dislodge things and can scour.
- That is, they can <u>wash out</u> dams,
- And they can <u>scour out</u> plunge pools.

Noted, cont.

- Not-high flows are:
  - Medium,
  - Low,
  - And very low.
- Low and very low flows are the problems.
- Low flows limit trout habitat volume.
- Very low flows limit also trout movement.

Fitting

- Try fitting, conceptually
- These three options,
- A pond, backup pools, and plunge pools,
- Into a small, mountain stream setting.
- And see where logic leads,
- In reasonable expectations,
- About effectiveness, access for trout, maintenance, and resilience.

First, a setting

- The upper Dolores River basin, which has 42 trout-bearing streams,
- Half of which are small.
- They are 6 mi or less in length and 6 sq mi or less in drainage area.
- Small streams have the least water to lose,
- Before flow conditions become a problem for resident trout.
- The three options will be contemplated for small streams in the upper Dolores basin,
- Which may lead to consideration also for larger streams, that is, the other half of the basin's inventory.

Next

- Some brief observations at small streams
- Are shown in photographs next,
- Which may help anticipate results from applying options.
- Also shown are water temperature
- And water quality information
- And a tool to sort streams by features, such as, length, drainage area, mean flows, maximum elevations, etc.

Beaver pond

- Estimated refuge volume, 1575 cf.
- From an estimated pond size of 30 ft wide, 35 ft long, and 1.5 ft deep.
- It was May flow conditions at a small stream (Ryman).

Plunge pool

- Plunge pool volume, 96 cf.
- From wading in and measuring 6 ft wide, 8 ft long, and 2 ft deep.
- This was May flow at the small stream (Ryman).

Plunge pool

- Plunge pool volume, 200 cf.
- From wading in and measuring 5 ft wide, 10 ft long, and 4 ft deep.
- Plunge pools along this small stream were 5-7 ft wide, 5-10 ft long, and 1-4 ft deep.
- It was May flow at this stream (Ryman).

Plunge pool

- Developed below 2 fallen logs.
- Extending across a wider stream section.
- It was May flow at the small stream (Ryman).

Plunge pool

- Formed below fallen logs
- This was May flow at a small stream (Wildcat).

Plunge pool

- Formed below a fallen or placed log(s)
- At a large stream.
- Streambed material has filled behind the log structure.
- It was April flow at this large stream (Roaring Fork).

Plunge pool

- Another view, downstream,
- With the structure apparently well secured,
- Due to the streambed fill that is directly upstream
- Causing flow to go over the structure, pressing it down, instead of broadsiding and dislodging it.

Fill

- Streambed fill has accumulated behind the placed log dam.
- The dam likely was installed for both up- and downstream refuge.
- Little upstream refuge remains, however, predictably.
- It was September flow at this small stream (Ryman).

Scoured

- No backup pool or plunge pool developed here.
- It is because scouring
- Removed contact of the placed log with the streambed.
- This was September flow at a large stream (Coal).

Fill

- Accumulated silt on the right bank is evident,
- 2-3 ft deep,
- Which was left behind
- After washout of a beaver dam.
- This was September flow at a large stream (Taylor).

Reminder

- It is a small-scale reminder
- That an improvised structure,
- In this case, a check dam
- For managing water,
- Can disrupt channel flow
- And become so damaged itself
- That it <u>loses function</u>,
- As at this roadside ditch.

Beaver dam

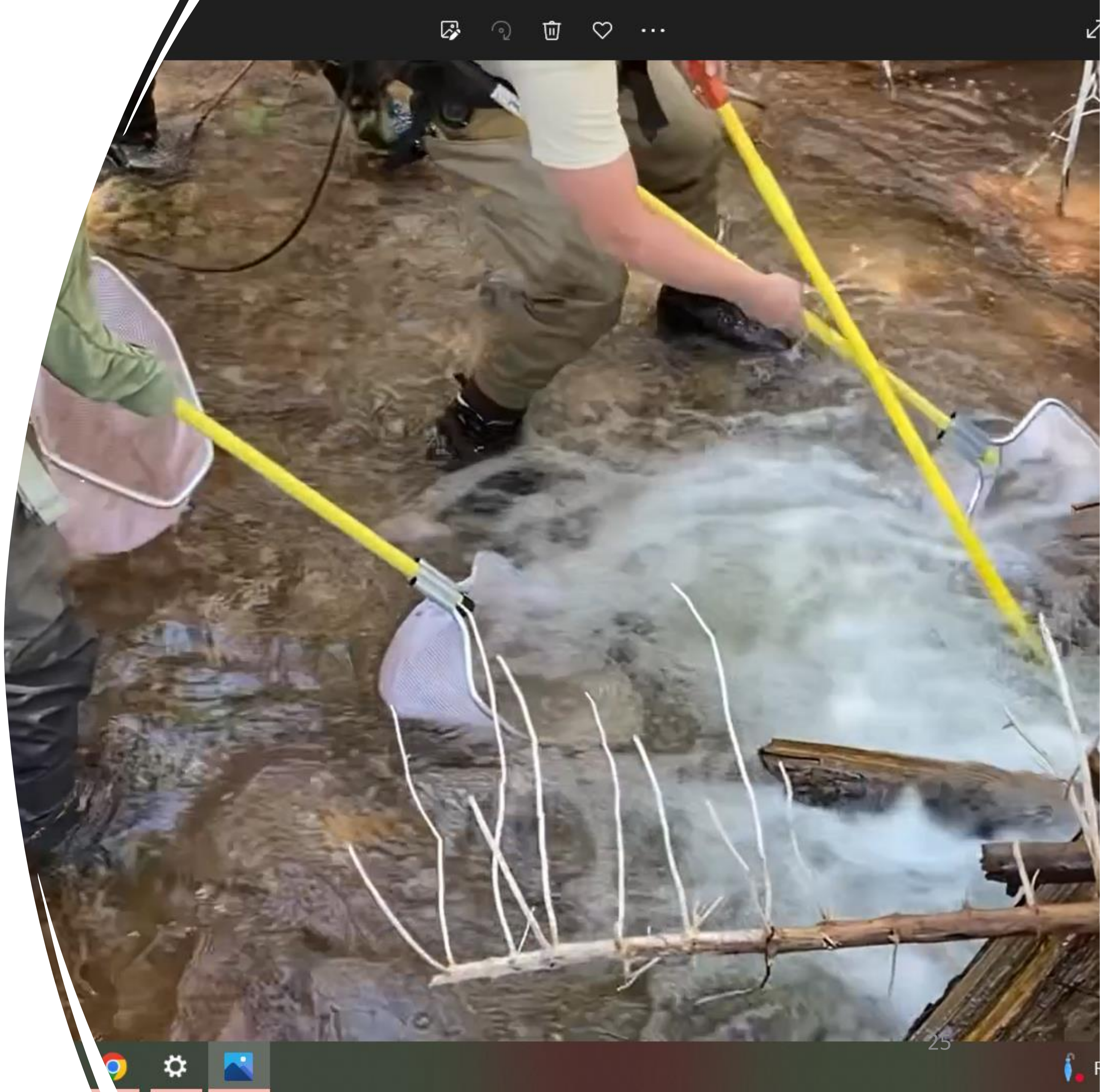
- Water level was below this dam top.
- Silt collected behind the dam.
- Estimated pond space to the top of the dam was 2025 cf.
- Water occupied perhaps a third of that pond space.
- It was September flow at the small stream (Ryman).

Leakage

- The beaver dam is at the bottom of this view.
- The dam leaks, which is normal,
- And flow continues downstream.
- But leakage limits the upstream refuge volume.
- This was September flow at the small stream (Ryman).

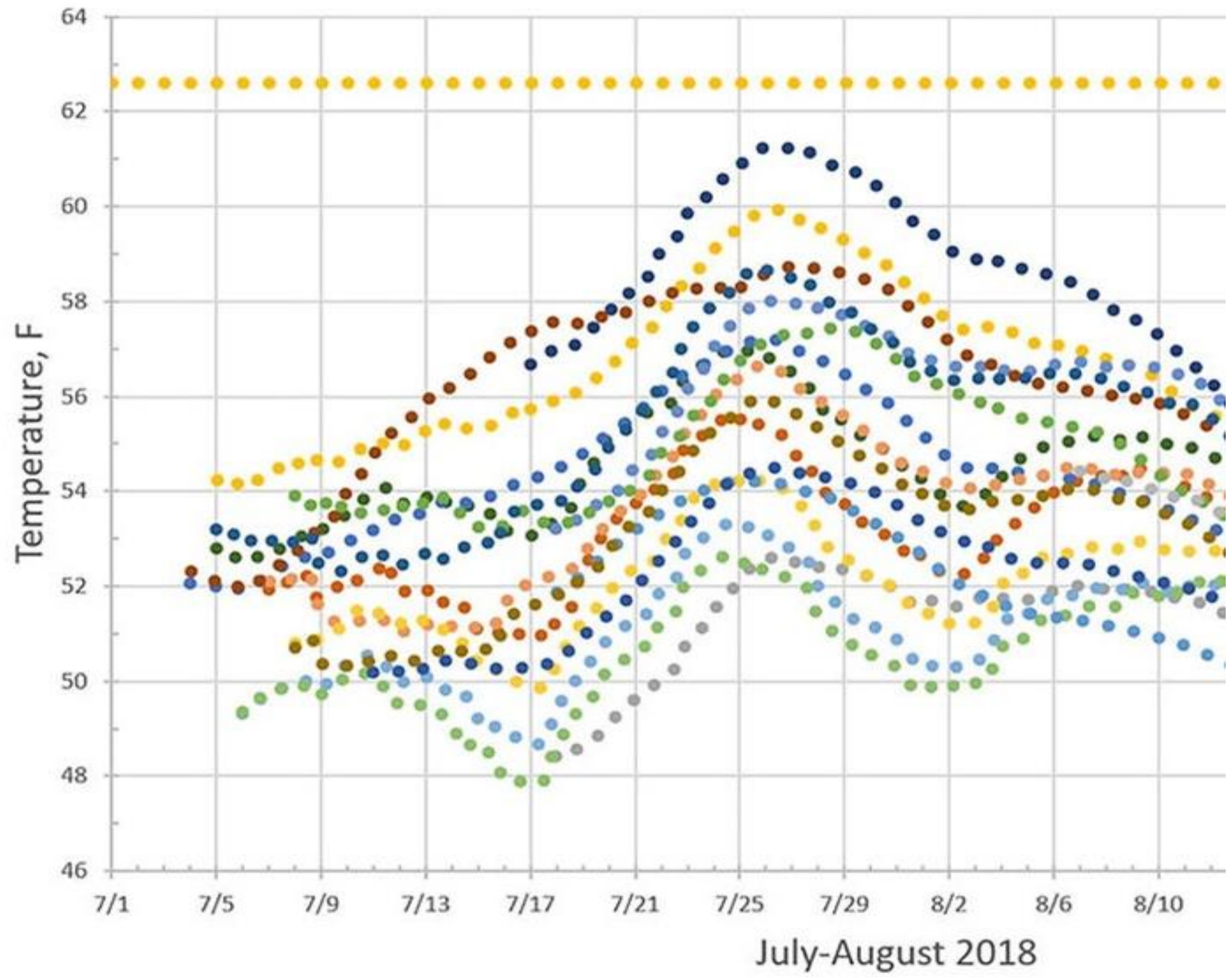
Assessment

- Electro-fishing technique was applied
- To determine trout presence
- In a plunge pool
- Directly below fallen logs
- At a small stream (Wildcat).



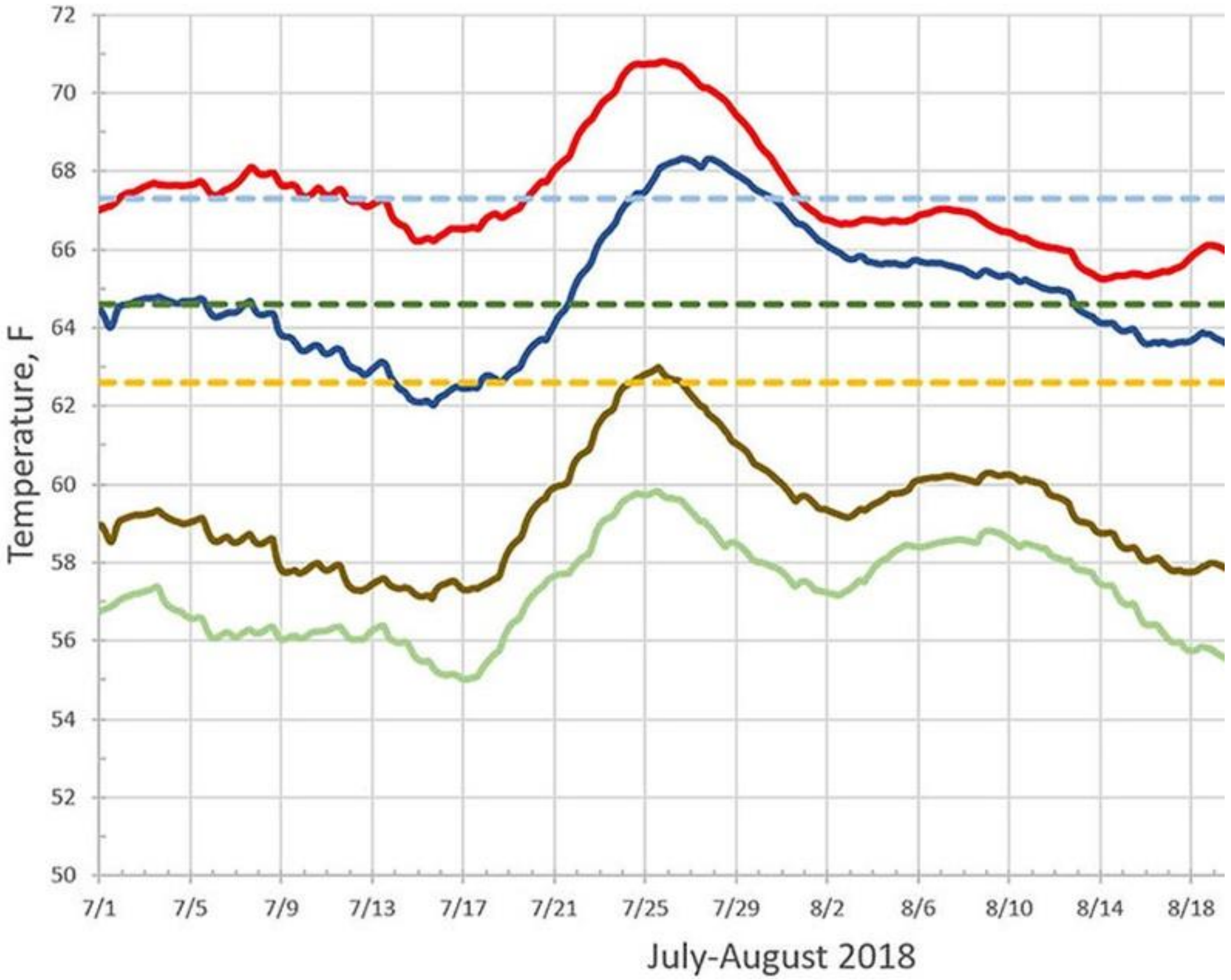
Cold enough

- Horizontal line is the CO chronic criterion.
- Irregular lines are stream temperatures.
- All streams were <u>cold enough</u>
- To be temperature-safe, warm-weather habitat.



Too warm

- Lower horizontal line is the CO chronic criterion.
- Irregular lines are water temperatures in the main stem
- At 7000, 7500, 8500, and 9000 ft, top to bottom.
- The main stem was <u>not cold enough</u> at 7000 and 7500 ft (the upper lines).



Good enough

- Water quality has been tested
- And found good enough
- Such that eight of the basin's streams
- Have been classified as CO Outstanding Waters.

Stream	Cadmium, ug/l, 85th pctl	Cadmium criterion, ug/l	Copper, ug/l, 85th pctl	Copper criterion, ug/l	Lead, ug/l. 85th pctl	Lead criterion, ug/l	Manganese, ug	Ma
Bear	0	0.75	0.70	9.4	0.10	2.7	3.7	1682
Coal	0	0.87	6.4	11	0.29	3.3	3.9	1793
East Fork	0	0.87	1.3	11	0.19	3.3	3.4	1798
Priest	0	0.60	1.0	13	0.10	4.2	6.0	1925
Slate	0	0.67	1.0	8.3	0.19	2.3	2.5	1604
Snow Spur	0	0.73	1.2	9.1	0.29	2.6	3.8	1661
Stoner, Lower	0	0.90	0.68	12	0.10	3.5	7.0	1822
West Fork, Burro	0	0.64	3.8	7.9	0.10	2.1	3.9	1570
Wildcat	0	0.97	0.60	13	0.04	3.9	6.6	1882

Sorting

- The upper Dolores basin streams
- Can be sorted for features,
- Such as, length, drainage area, maximum elevations,
- And <u>scored</u> for strength of combinations of features
- That might support stream and habitat resilience.

Tributary	Sort, in/out: 1/0	Outfall elevation, ft	Flow, Jul-Aug, cfs	Score	Flow, annual, cfs	Score	Drainage area, sq mi	Score	Max. elev, ft, x 1000	Score	Stream length, mi	Score	Total	Score
1 Bear	1	7895	**49.55**	100	**51.50**	100	**33.70**	100	13.2	93	**15.60**	100	**493**	100
2 East Fork	1	9603	35.70	72	36.10	70	17.00	50	13.7	96	7.03	45	334	68
3 Roaring Forks	1	8167	21.70	44	23.60	46	19.60	58	11.8	83	9.30	60	290	59
4 Scotch	1	8530	11.61	23	13.00	25	12.10	36	12.6	89	7.65	49	222	45
5 Barlow	1	9311	17.75	36	13.40	26	9.68	29	12.6	89	6.04	39	218	44
6 Coal	1	9190	10.73	22	11.40	22	6.41	19	13.8	97	6.42	41	201	41
7 Snow Spur	1	9603	8.26	17	13.40	26	9.68	29	13.2	93	6.04	39	203	41
8 Slate	1	9502	11.39	23	11.70	23	5.14	15	**14.2**	100	5.74	37	198	40
9 Priest	1	7974	7.93	16	9.05	18	9.61	29	11.5	81	7.81	50	193	39
10 Silver	1	9313	10.43	21	10.80	21	4.94	15	12.7	89	4.57	29	175	36
11 Kilpacker	1	9839	7.96	16	7.97	15	2.62	8	**14.2**	100	4.19	27	166	34
12 Fall (west)	1	8836	8.35	17	8.71	17	4.15	12	12.3	87	4.21	27	160	32
13 Meadow	1	9209	5.76	12	6.27	12	4.10	12	13.0	92	4.90	31	159	32
14 Wildcat	1	8341	4.83	10	5.51	11	5.27	16	11.9	84	5.34	34	154	31
15 Coke Oven	1	9310	5.04	10	5.46	11	3.34	10	11.9	84	4.06	26	141	29
16 Spring	1	8912	3.80	8	4.36	8	4.22	13	10.7	75	5.57	36	140	28

Pond option

- Refuge is built by
- Increasing the height of water in the channel
- And increasing also its width by expansion onto the adjacent flood plain,
- Establishing refuge upstream of a dam structure.

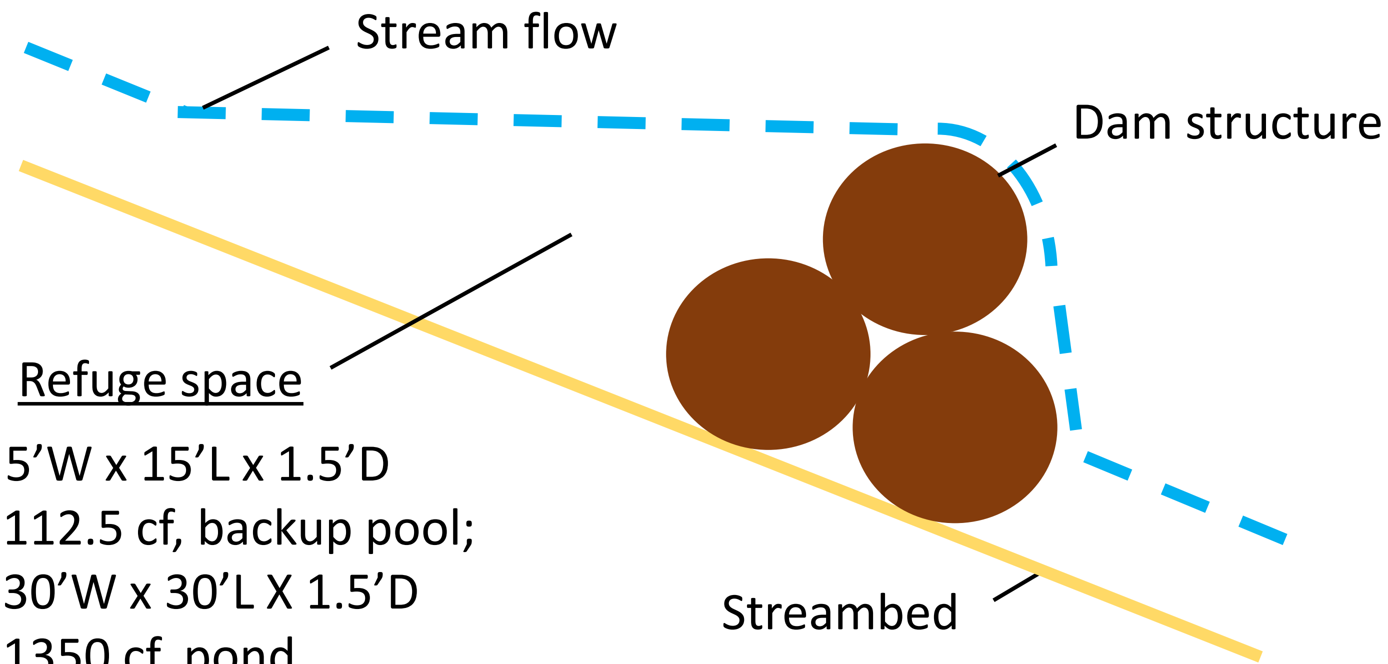
Backup pools option

- Refuge is created by
- Increasing water height within the channel,
- But not its width,
- To form in-channel refuge upstream of a dam structure.

Plunge pools option

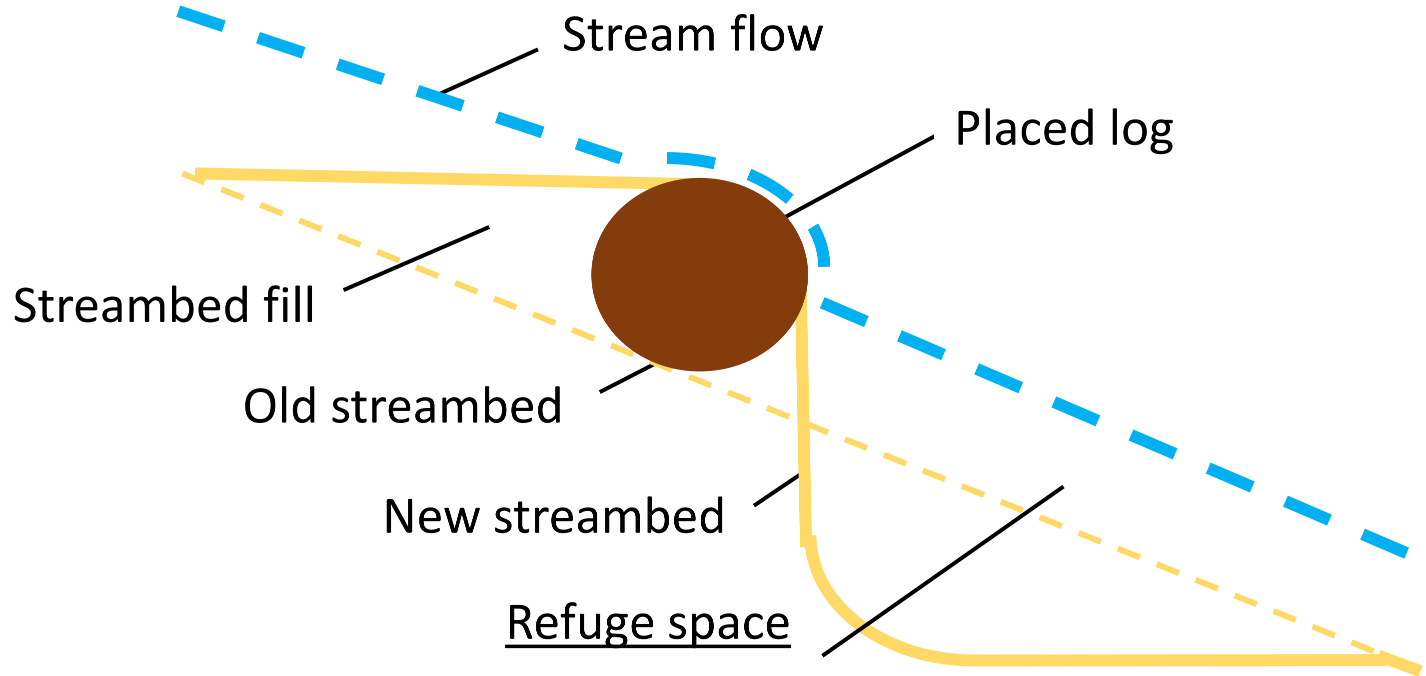
- Refuge results from
- Deepened water within the stream channel,
- Which occurs from scouring action during high flows happening directly downstream of a placed log.

Sketch: Backup pool or pond configuration



Examples: 5’W x 15’L x 1.5’D
112.5 cf, backup pool;
30’W x 30’L X 1.5’D
1350 cf, pond

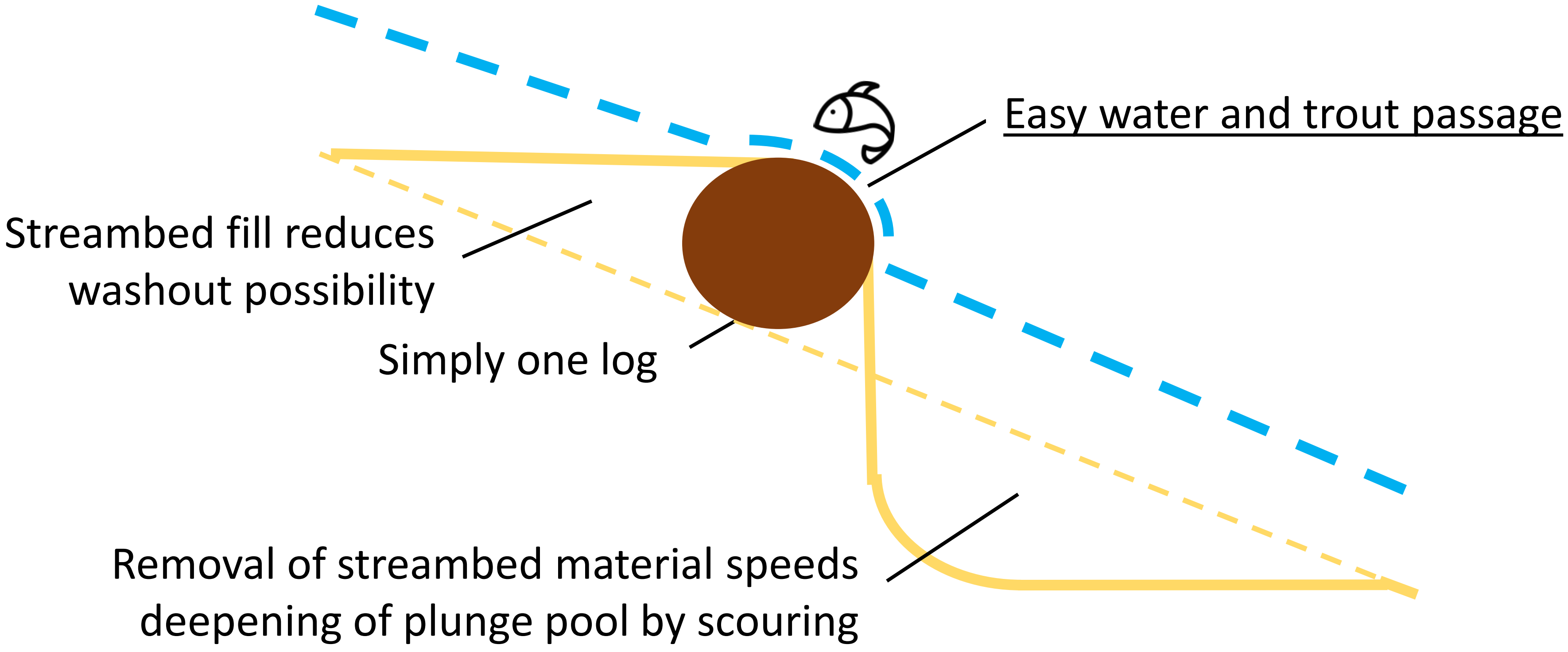
Sketch: Plunge pool configuration



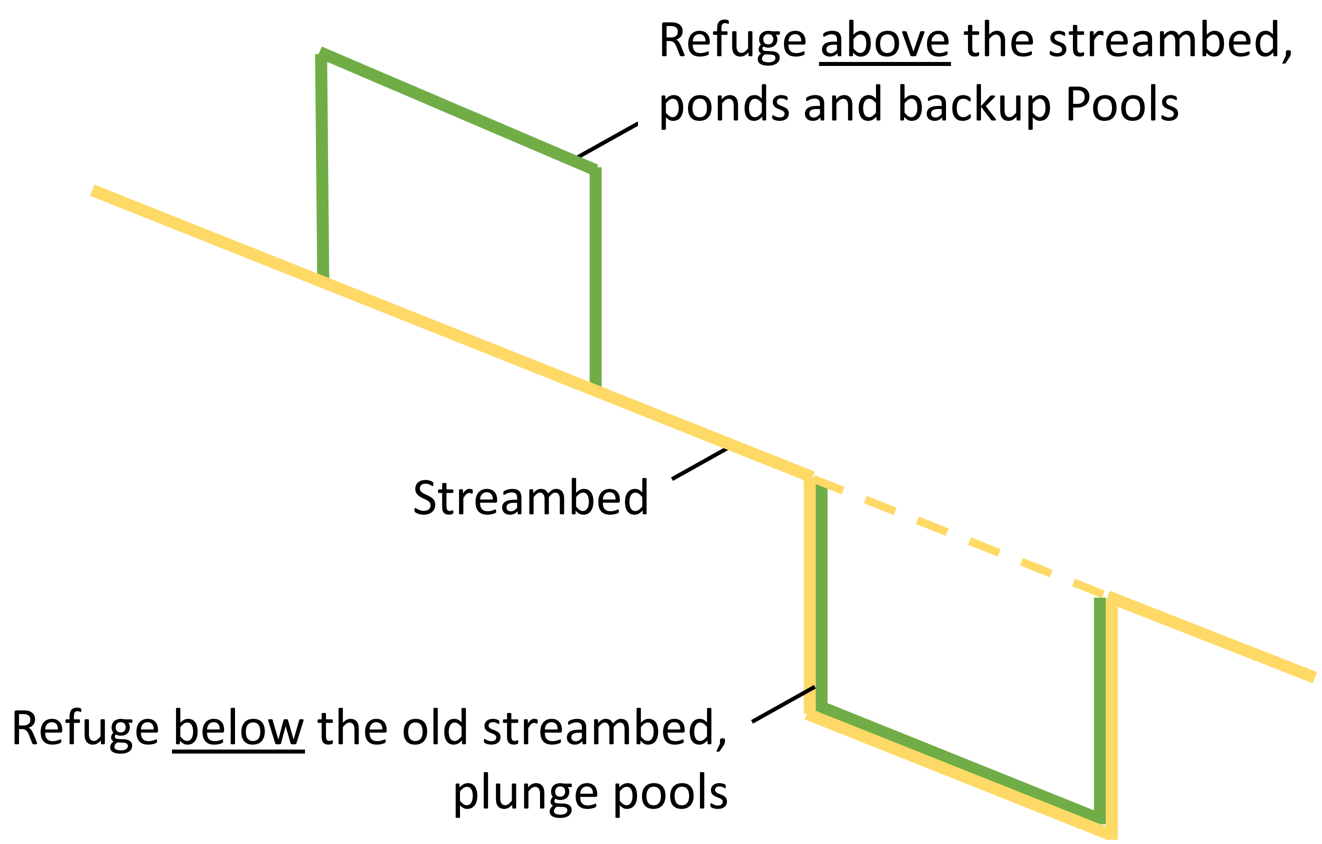
<u>Refuge space</u>

Example: 5'W x 6'L x 1.5'D
45 cf, plunge pool

Appeal of the plunge pool option



Key difference in refuge placement



Individual size

- Ponds observed in basin small streams were 25-35 ft wide, 30-50ft long, and 1-2 ft deep; these were beaver ponds.
- For this discussion, the representative pond size is 30 ft wide, 30 ft long, and 1.5 ft deep, a volume of 1350 cf.
- No backup pools were seen in the streams.
- The backup pool size conceptualized is 5 ft wide, 15 ft long, and 1.5 ft deep, a volume of 112.5 cf.
- Plunge pools observed in smalls streams were 5-7 ft wide, 5-10 ft long, and 1-4 ft deep.
- The representative plunge pool size used is 5 ft wide, 6 ft long, and 1.5 ft deep, a volume of 45 cf.

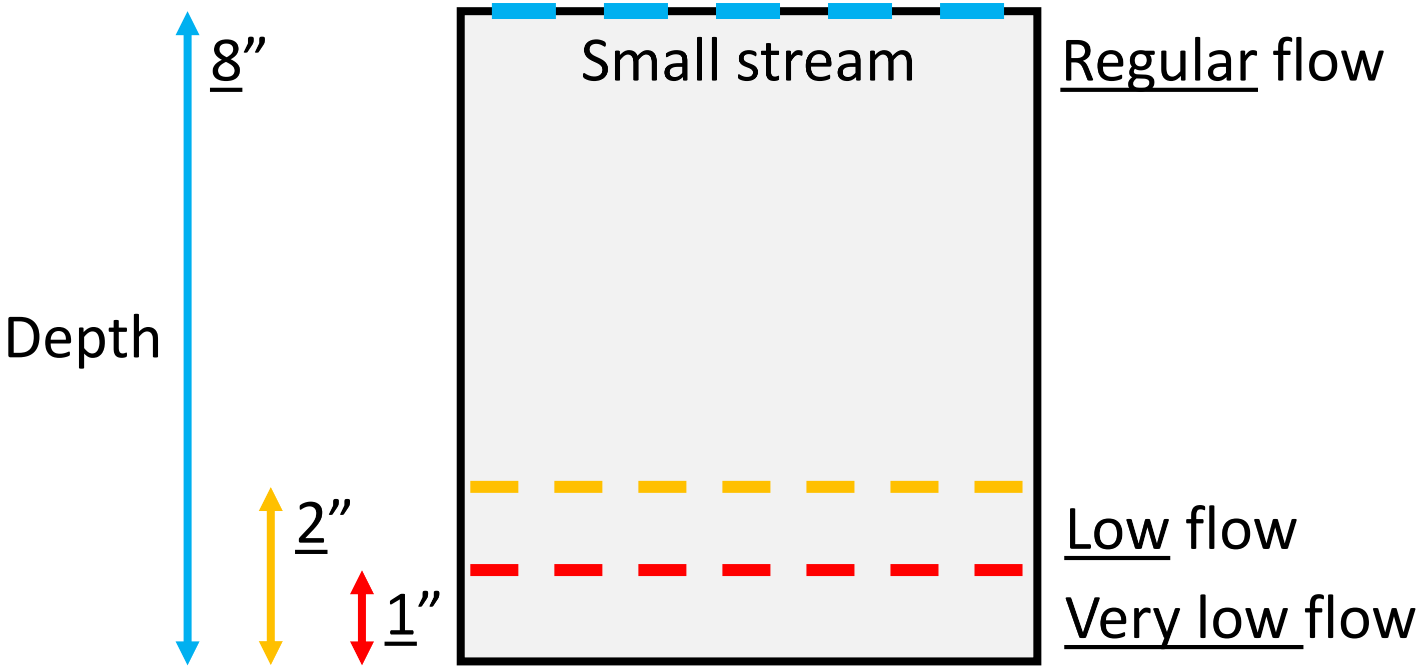
Total volume

- The pond's 1350 cf is the reference refuge volume for this discussion.
- 12 backup ponds, 112.5 cf each, equal 1350 cf.
- 30 plunge pools, 45 cf each, total 1350 cf.

Comparison

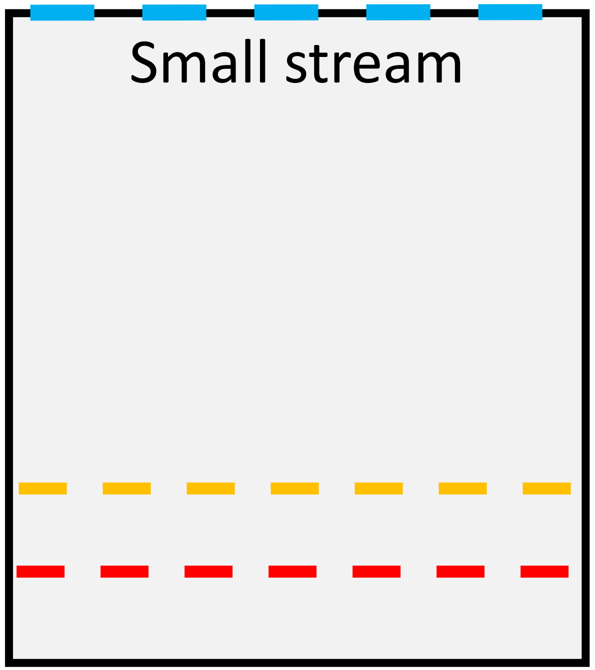
- How does the reference refuge volume
- Compare with small stream volumes
- At very low, low, and regular flow conditions?
- Stream volumes are based on
- Observed flow depths at small streams
- In the lower 2 mi of stream length.
- How much greater is stream volume
- From the installation of refuge volume?

Stream depths



Stream volumes

35,218 cf — Regular flow, 5’W x 2 mi L x 8”D



(15%) 5291 cf — Low flow, 3’W x 2 mi L x 2”D

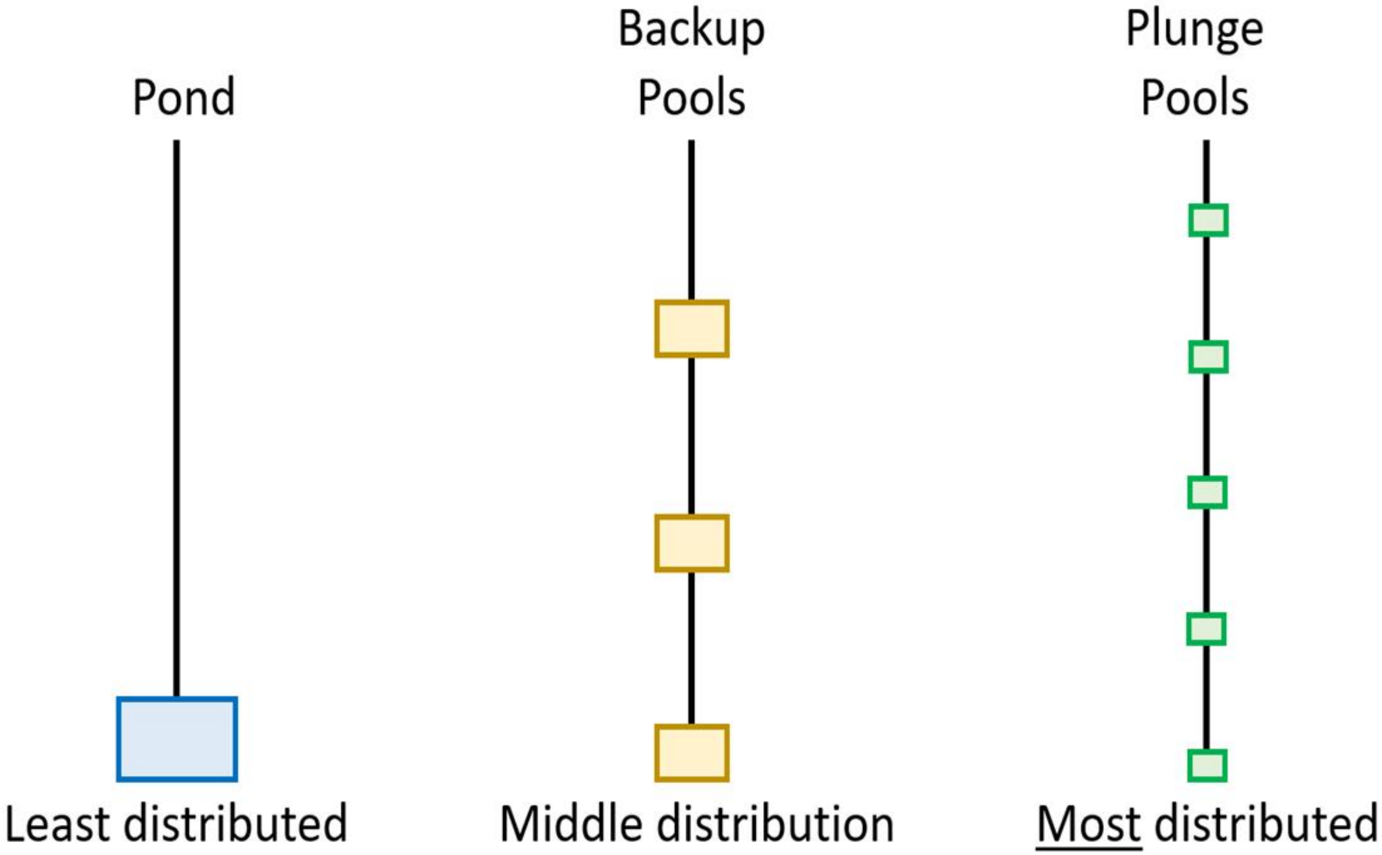
(5%) 1753 cf — Very low flow, 2’W x 2 mi L x 1”D

Combined volume

- Resulting from the addition of one refuge volume (1350 cf),
- Stream volume is greater
- By 77% during very low stream flow.
- By 26% during low flow.
- By 4% during regular flow.

Distribution

- Plunge pools can be the most distributed.
- Which makes them the most accessible to the most trout.
- 30 plunge pools require the same level of effort to install as 12 backup pools or 1 pond.



Pond option

- Advantages
  - Largest individual refuge volume.
  - May augment base flow.
- Disadvantages
  - Additional evaporation loss.
  - Least distributed.
  - Likely to leak; most maintenance.
  - Likely to accumulate silt, which reduces refuge volume.
  - Subject to washout.

Backup pools option

- Advantages
  - No additional evaporation loss.
  - May augment base flow.
- Disadvantages
  - Likely to leak; considerable maintenance.
  - Subject to washout.

Plunge pools option

- Advantages
  - Simplest to build; most distributed; lowest maintenance.
  - No additional evaporation loss; no dam; least likely to washout.
  - Readily enables water and trout passage.
- Disadvantages
  - Smallest individual volume.
  - Numerous installations.

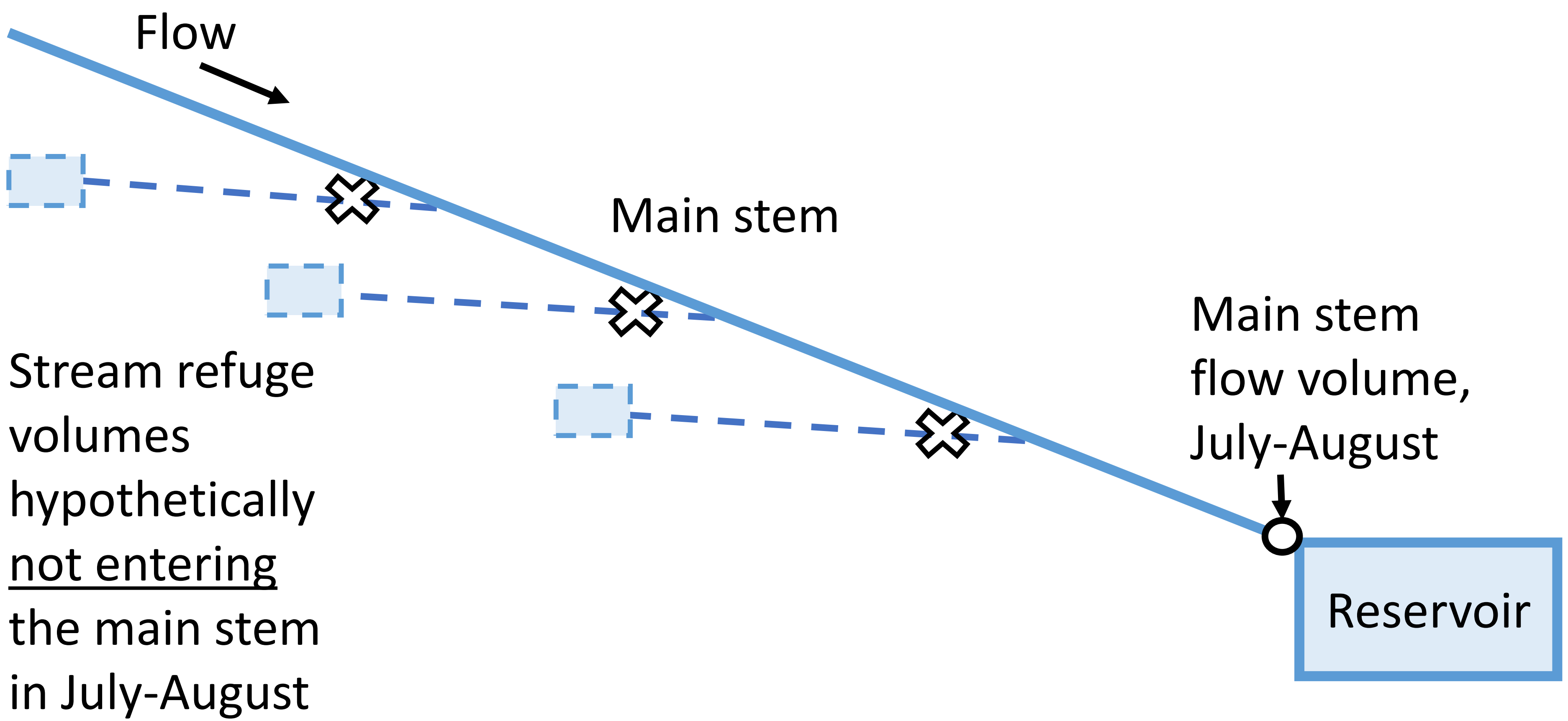
What about beaver dam analogs (BDAs)

- Possibilities
  - Picturesque concept: engagement with a beaver community.
  - Ideally, beavers will maintain the dam, even expand it.
  - Pond may augment baseflow and promote streamside vegetation.
- Potential problems
  - Beavers may not adopt or later may leave.
  - Pond adds to evaporation loss of stream water.
  - Dam is likely to leak and needs maintenance,
  - And is subject to washout.

Downstream

- Assume that none of the stream water retained for trout refuge
- Enters the main stem in July and August.
- This portrays a worst-case scenario.
- How many refuge volumes would it take
- To reduce main stem flow volume by 0.1%
- At the location where flow enters the reservoir?

Downstream flow consideration



Calculation results

- Number of refuge volumes (1350 cf) reducing main stem flow by 0.1%
- (Assuming none enters the main stem.)
- 68 at very low flow, 7D10Y, which is 7.2% of regular flow.
- 333 at low flow, which is 25% of regular flow.
- 1329 at regular flow.
- Conclusion: There would be no likely significant reduction in main stem flow volume in this worst-case scenario.

Calculation process

- Main stem flows were determined by applying the U.S. Geological Survey water resources program *Streamstats*.
- Regular is the average July-August flow.
- Low is 25% of regular flow.
- Very low is *StreamStats'* 7-day, 10-year (7D10Y) flow.
- The 62-day July-August period was used to calculate main stem volume.

Materials & tools

- Building trout refuge would use
- Materials available at streamside,
- That is, trees, logs, rocks, brush, and mud.
- And tools that are portable,
- Such as, saws, winches, pry bars, shovels, and ropes or chains.
- Certification is required for operating chainsaws on land managed by the U.S. Forest Service, the study basin.

Level of effort

- 5-10 (8-hr) workdays.
- Using a 4-person professional crew.
- For installation of any of the 3 options.
- That is, completion within 2 weeks.
- Volunteers may assist.

Monitoring & evaluation

- Anticipations
  - Woody debris may arrive behind dams.
  - It can be removed or left for shading and refuge.
  - Streambed material will fill behind dams.
- Periodic assessments
  - Document refuge volumes.
  - Note decreases in function.
  - Identify repairs or improvements.
  - Measure water temperatures.
  - Judge use by trout (simple, visual counting or assisted by electro-fishing).

Conclusions

- From among the options of a pond, backup pools, and plunge pools
- For building trout refuge against low and very low flow conditions
- In the small, mountain streams of the upper Dolores River basin,
- The possibly best option: plunge pools.
- None of the options will significantly reduce flow to the main stem.

Conclusions, cont.

- Plunge pools are likely the most effective because scouring will sustain the space.
- They will not accumulate streambed material or silt, that is, will not lose refuge volume.
- Provide the most access for distributed trout populations because they are distributed.
- Require the least maintenance since they use no dams that will need re-sealing or replacing.
- Are the most resilient since, due to streambed fill behind their log structure that redirects flow pressure, they are unlikely to wash out.