A framework for linking land use and restoration to resource transport and processing in stream corridors with expansive hyporheic zones

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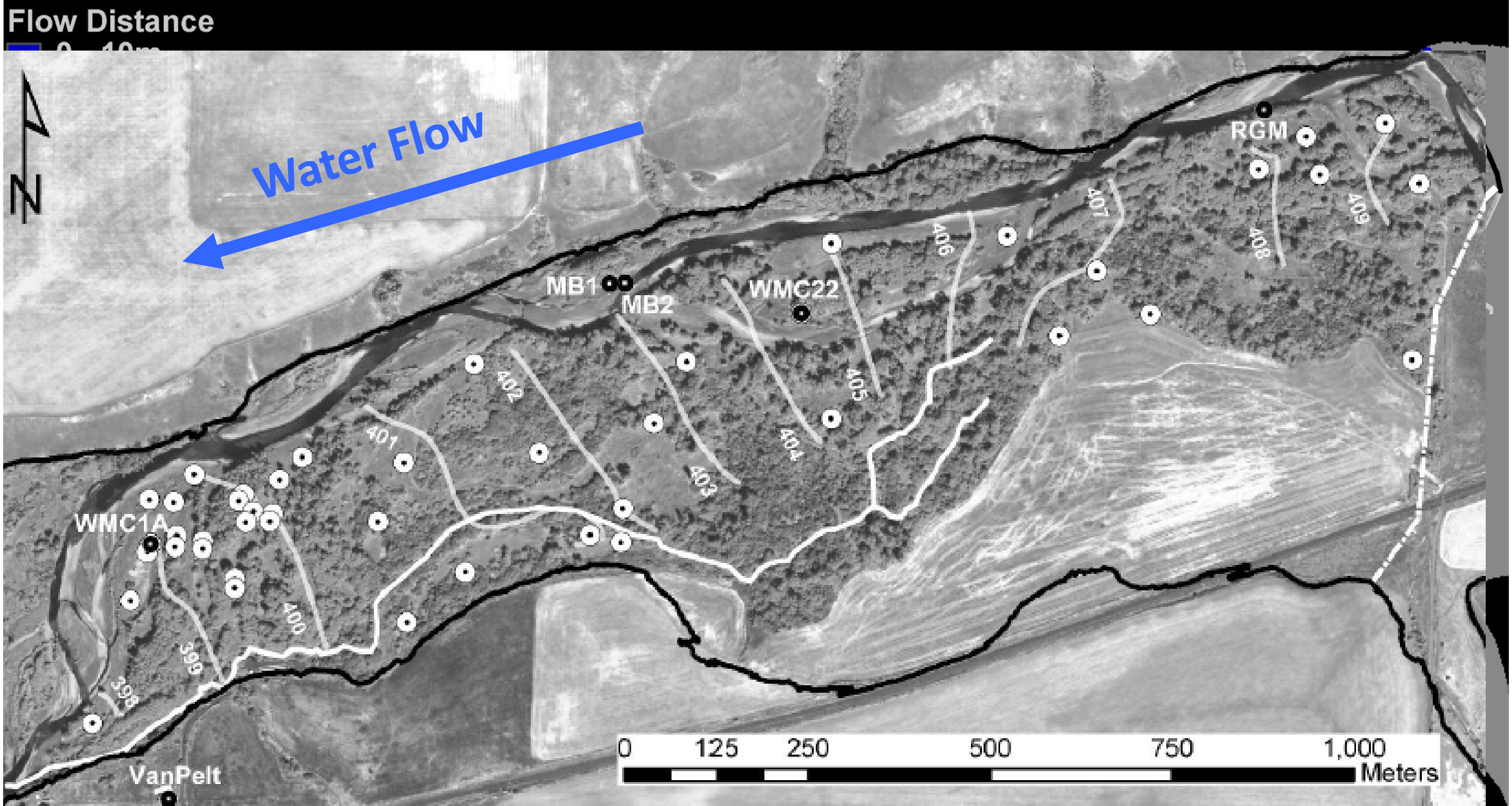
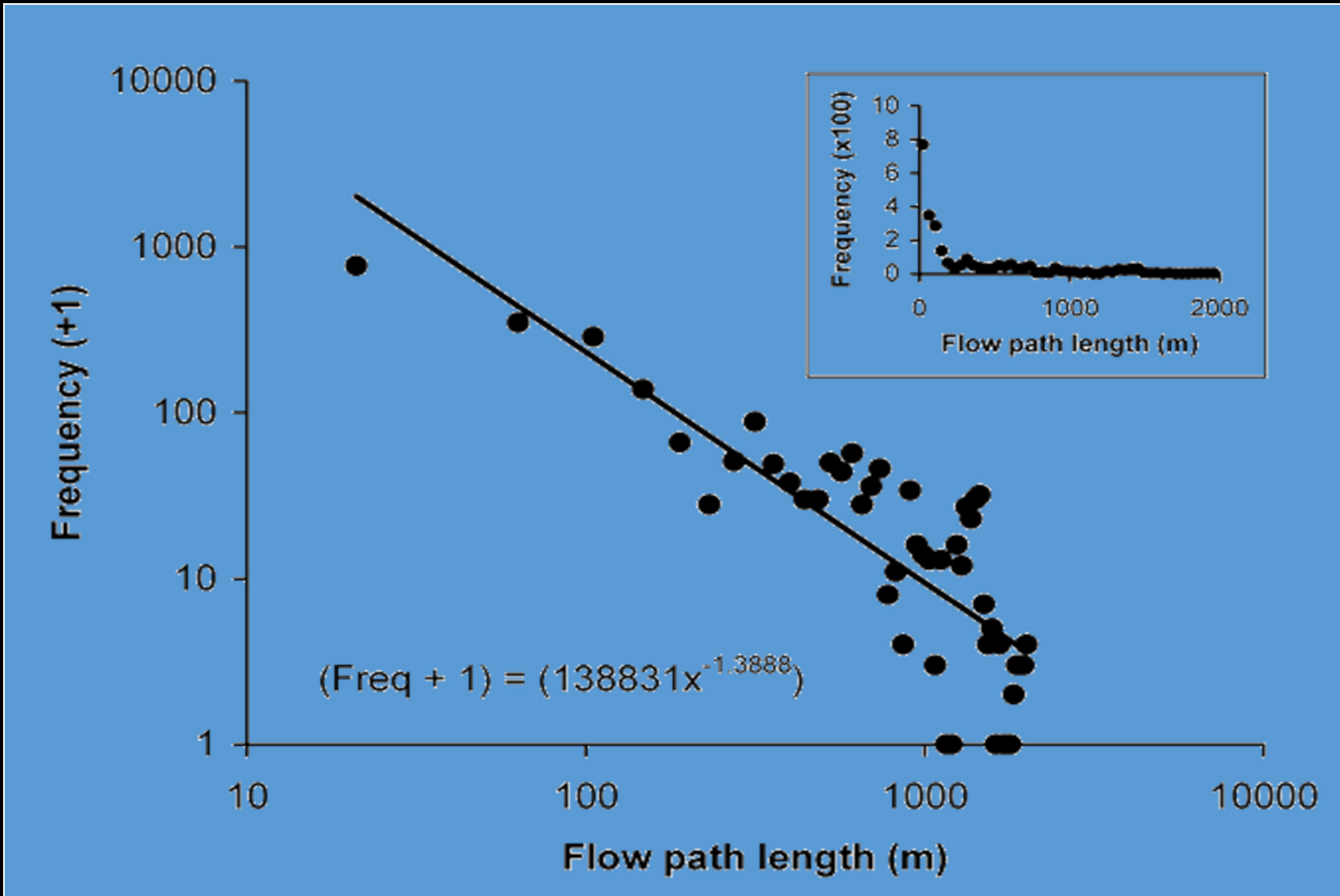
Confederated Umatilla Tribes

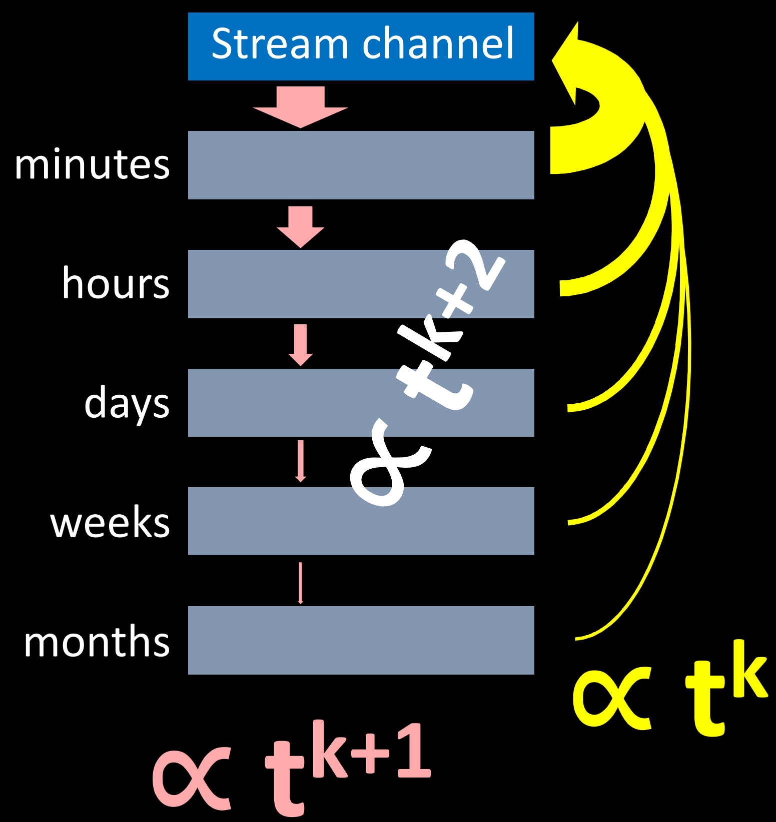

Meacham Creek, Oregon, USA
5 years post-restoration
Immediate post-restoration
Pre-restoration



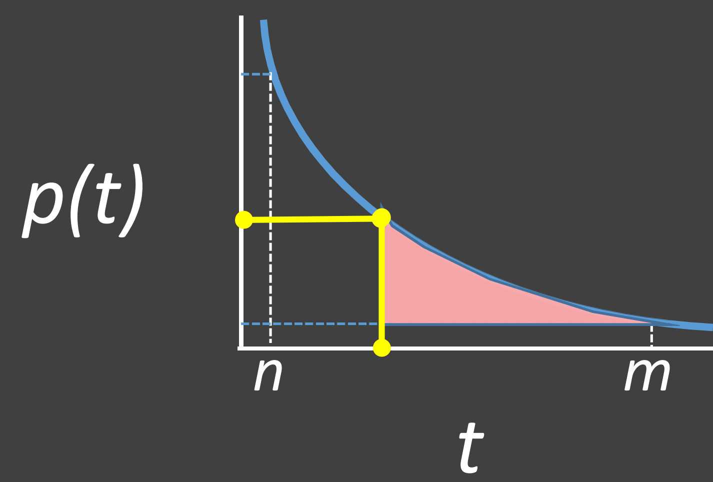
Umatilla River, OR



Poole et al. 2008. *River Research and Applications.*



$$PDF(t) = \frac{t^k - m^k}{\int_n^m t^k - m^k}$$

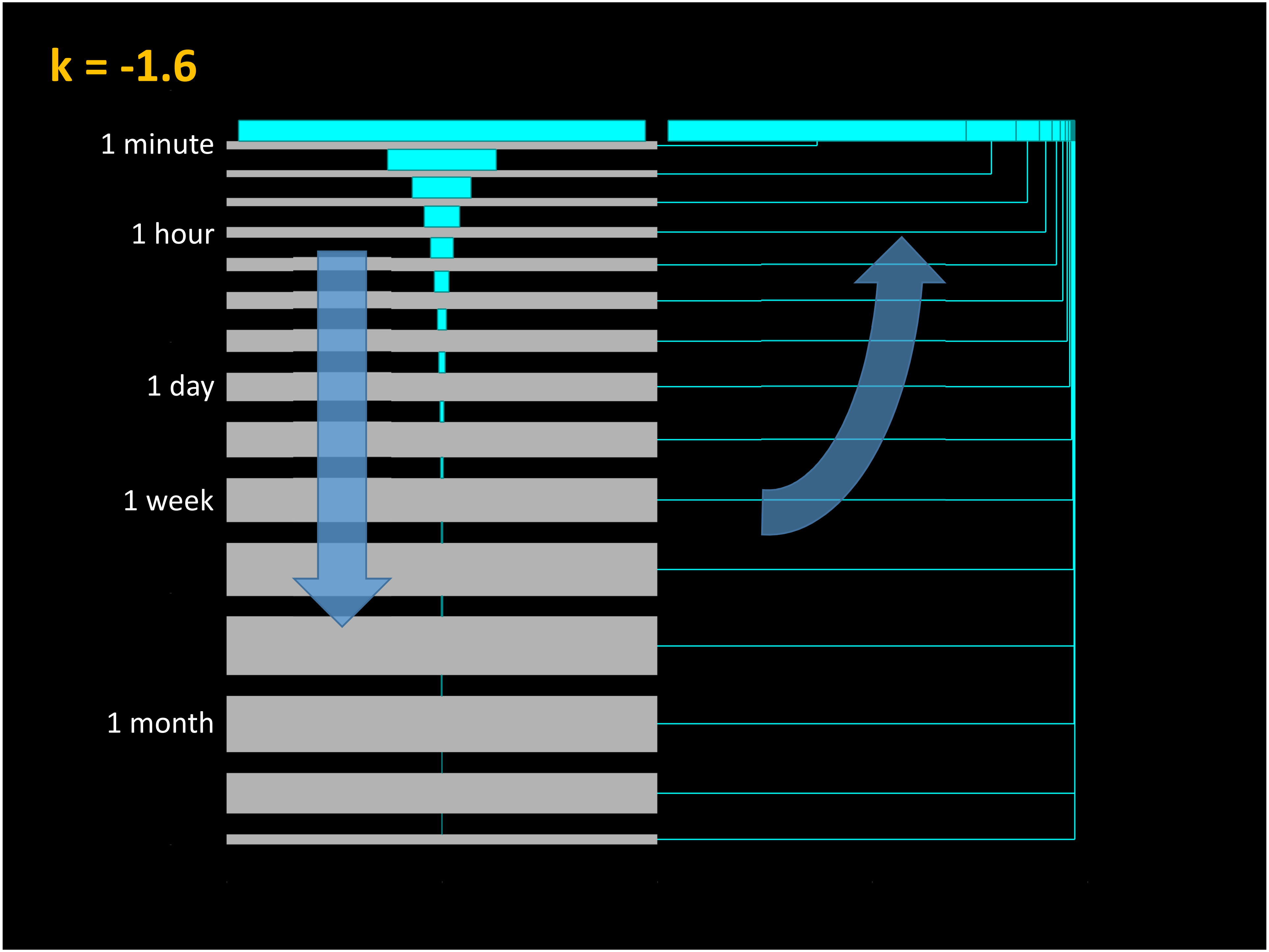


storage = flow x t

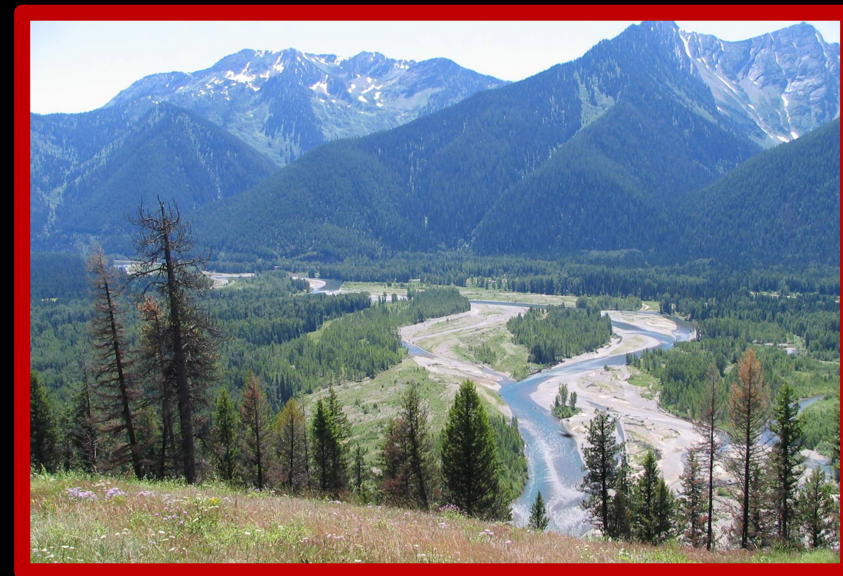
$\propto t^{k+1} \times t$

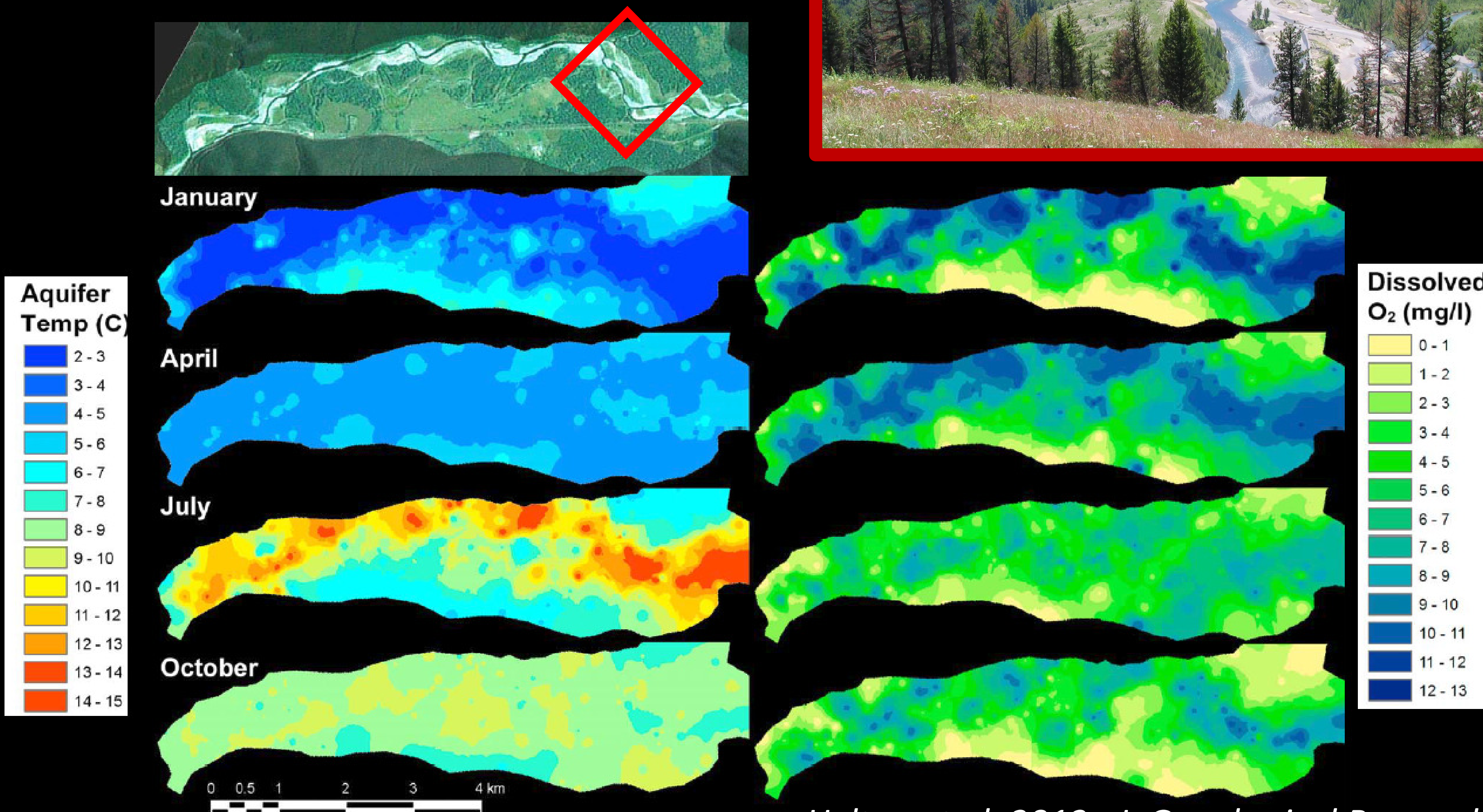
$\propto t^{k+2}$

Poole et al. In Preparation.

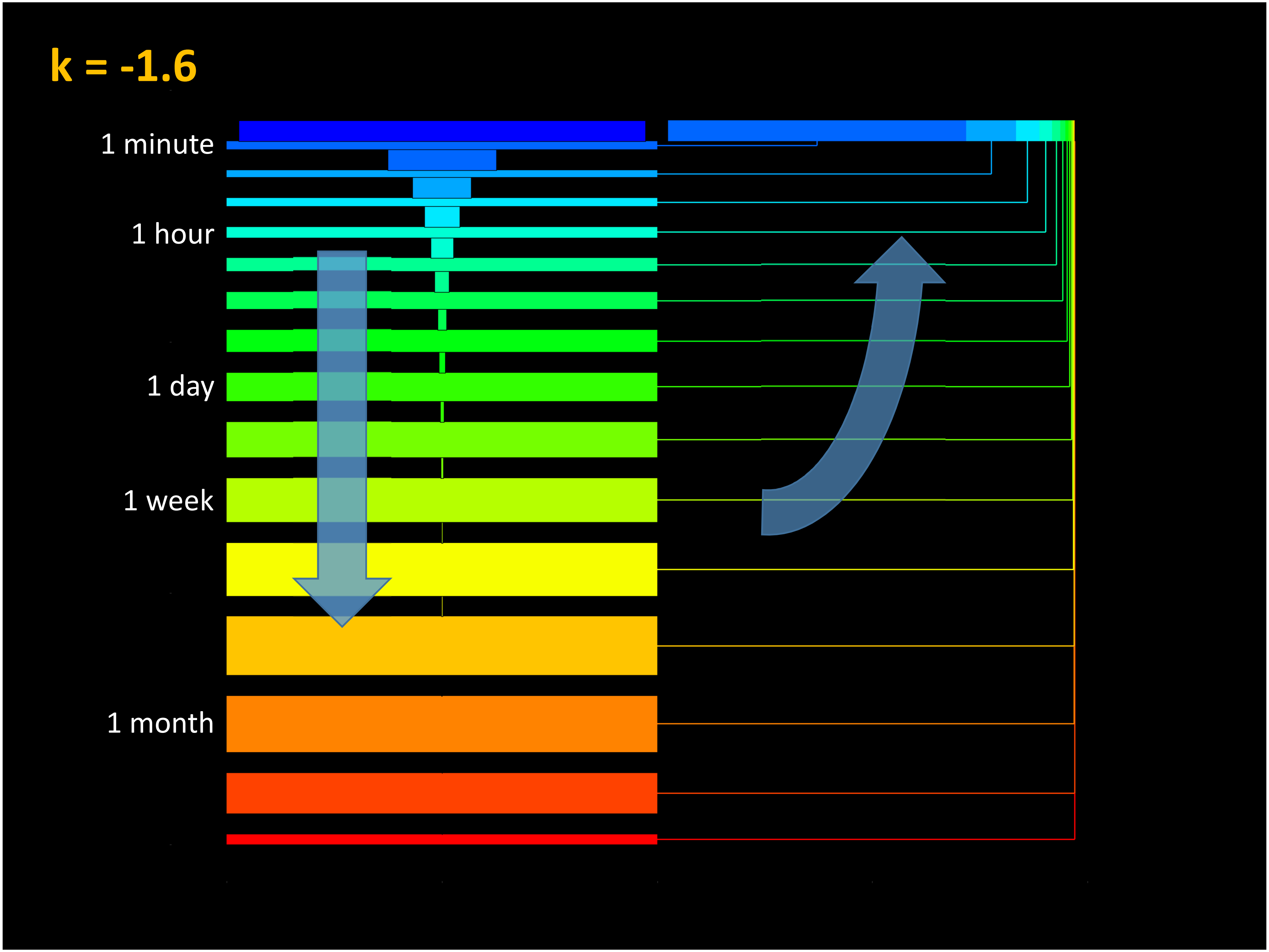

k = -1.6
1 minute
1 hour
1 day
1 week
1 month

Nyack Floodplain
Middle Fork Flathead River, MT

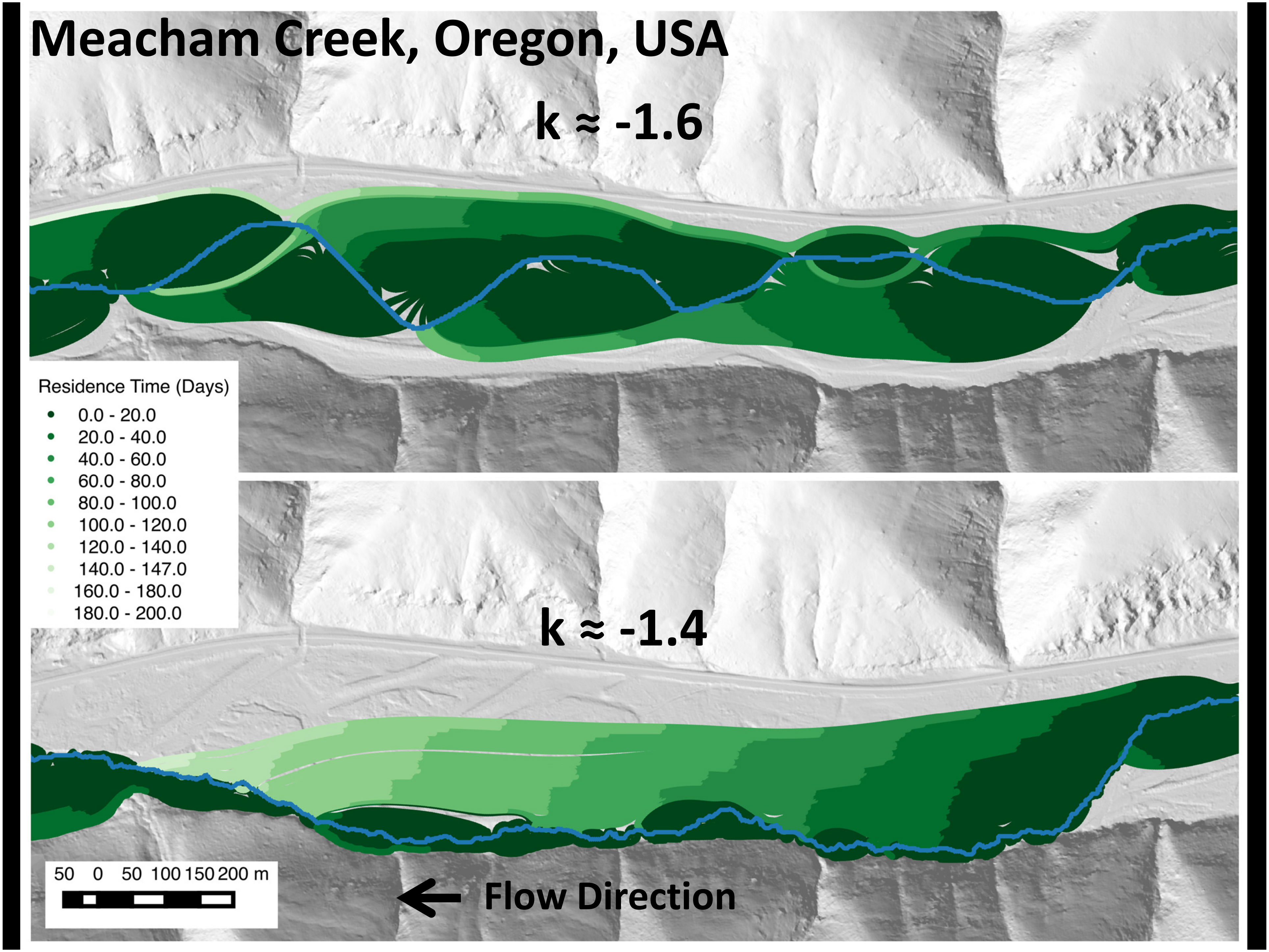


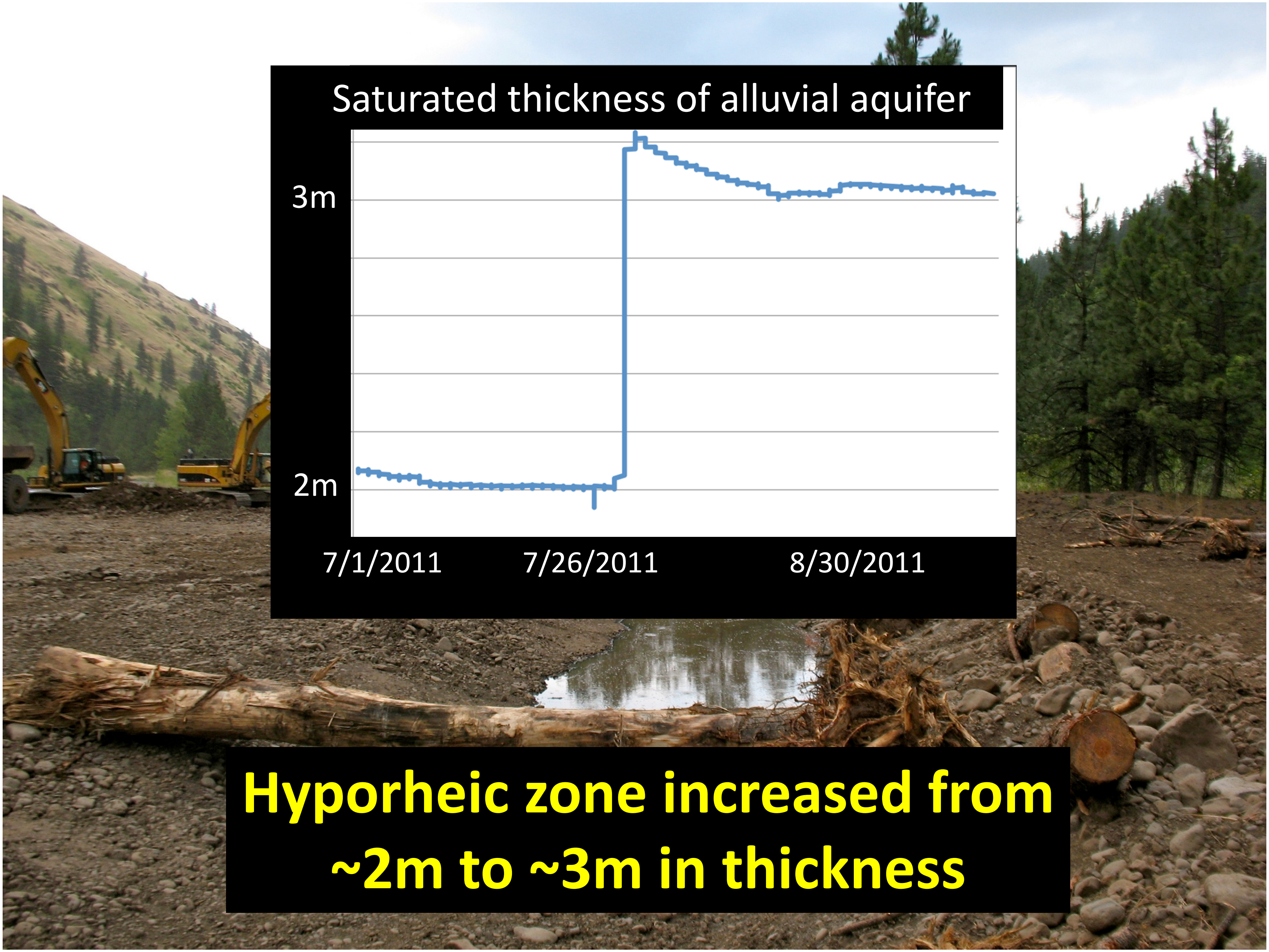


Helton et al. 2012. J. Geophysical Research.

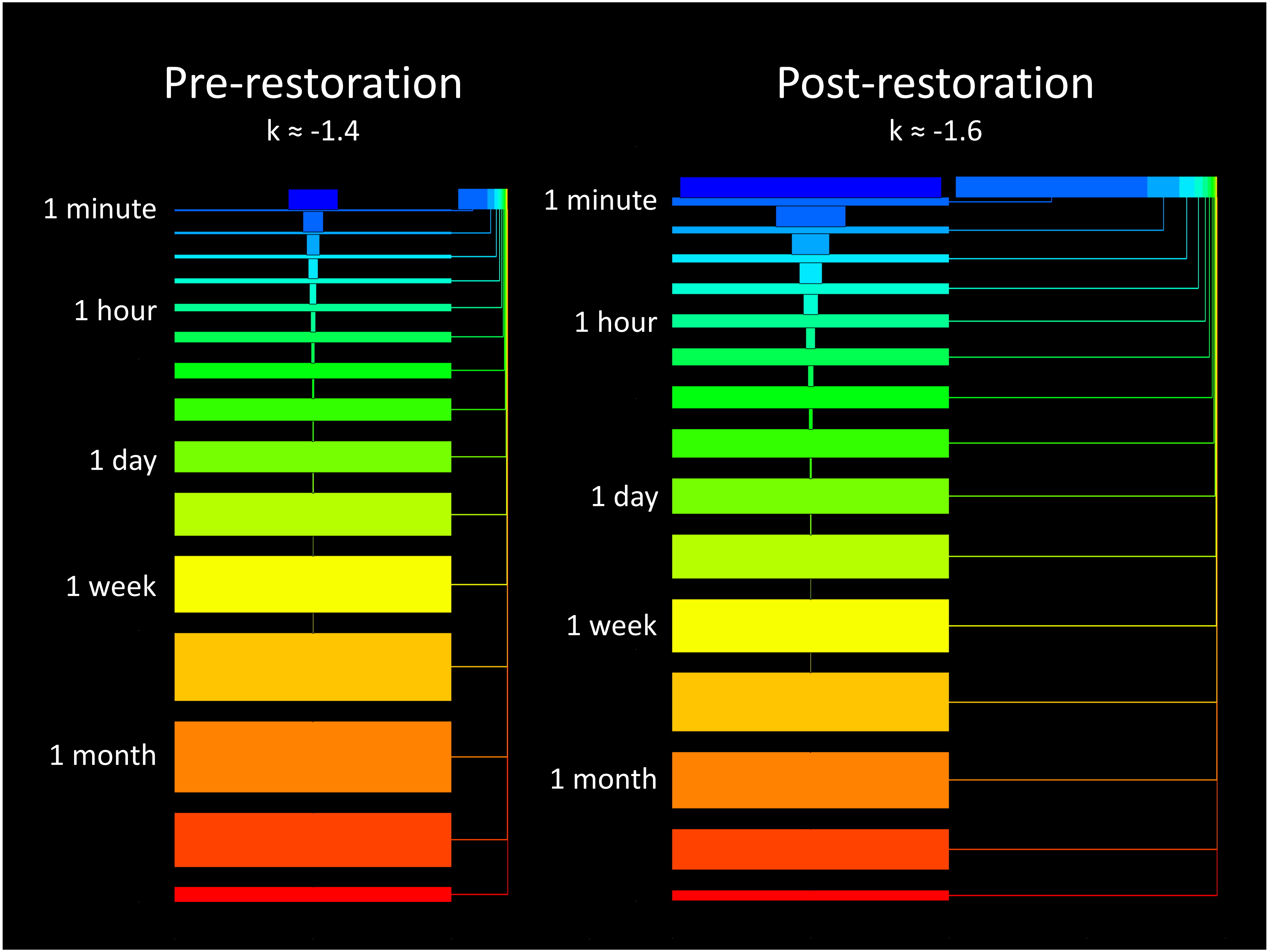


k = -1.6
1 minute
1 hour
1 day
1 week
1 month


Meacham Creek, Oregon, USA
k ≈ -1.6
Residence Time (Days)
0.0 - 20.0
20.0 - 40.0
40.0 - 60.0
60.0 - 80.0
80.0 - 100.0
100.0 - 120.0
120.0 - 140.0
140.0 - 147.0
160.0 - 180.0
180.0 - 200.0
k ≈ -1.4
50 0 50 100 150 200 m
Flow Direction



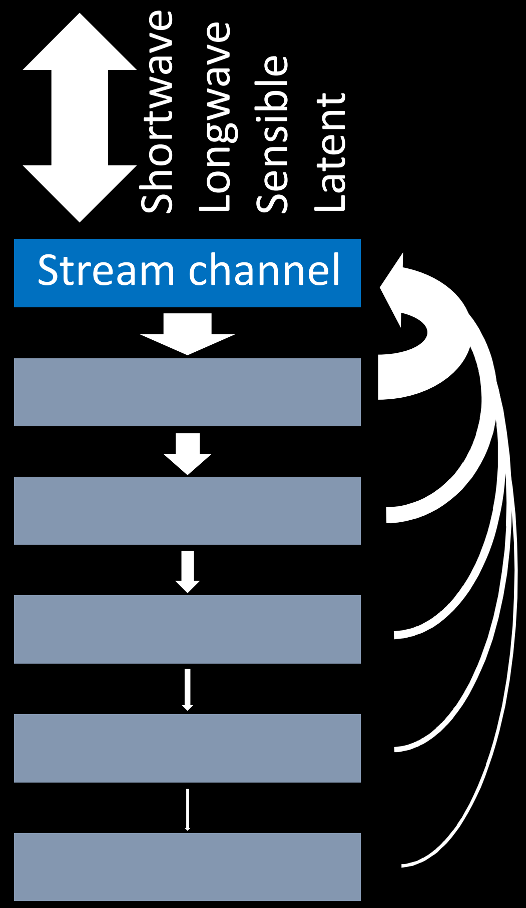
Hyporheic zone increased from ~2m to ~3m in thickness

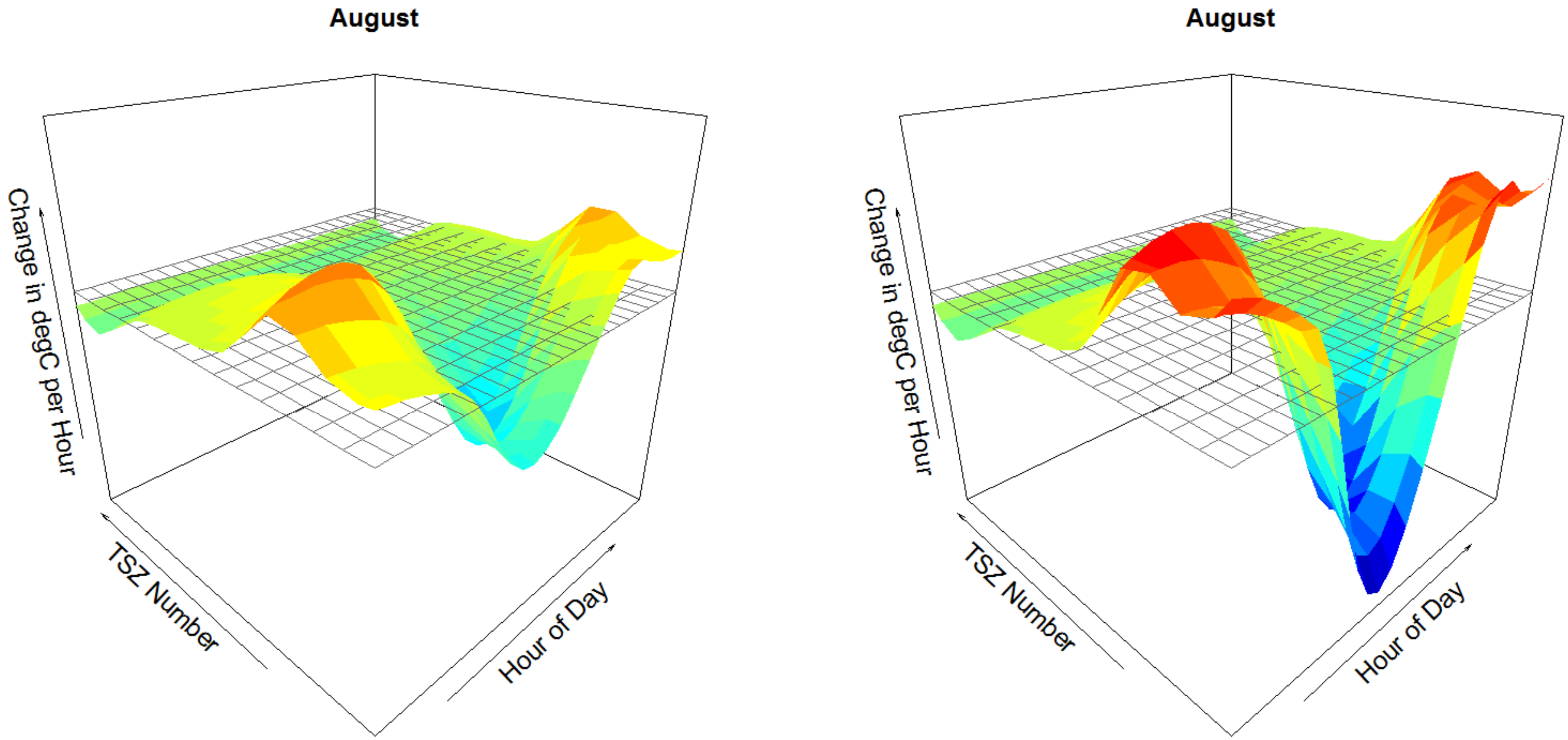


Pre-restoration
k ≈ -1.4
Post-restoration
k ≈ -1.6
1 minute
1 hour
1 day
1 week
1 month
1 minute
1 hour
1 day
1 week
1 month

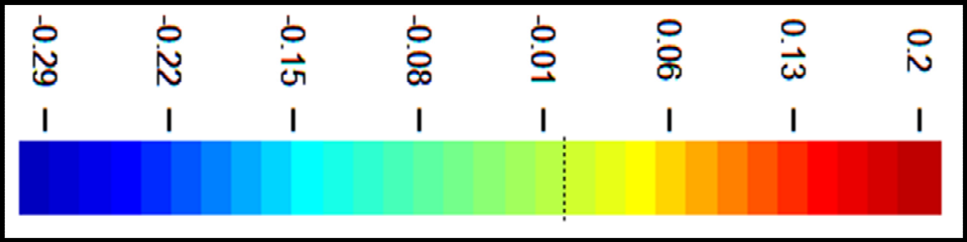
Heat Model

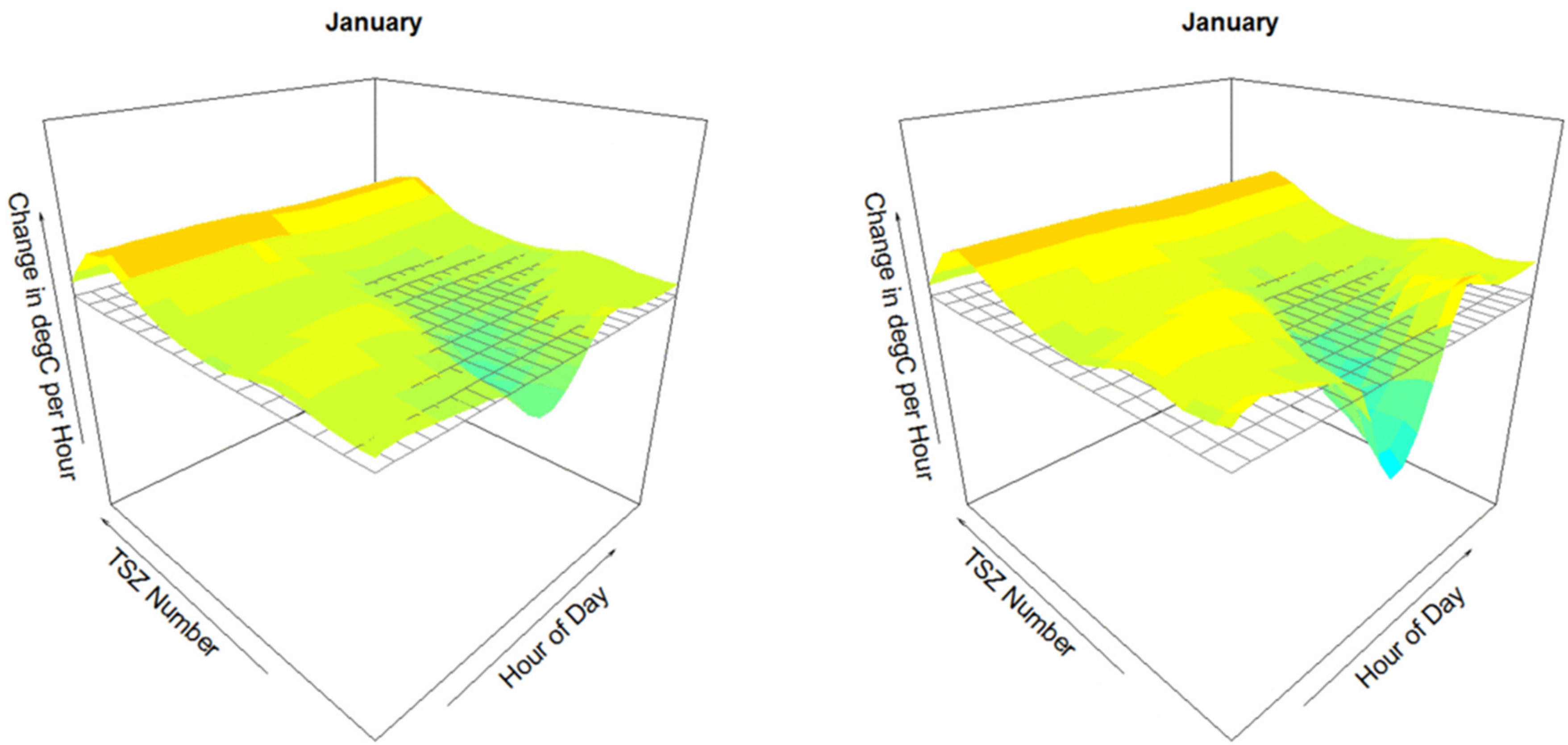
- Atmospheric heat exchange.
- Advection of heat with water among hyporheic “bins” and stream channel.
- Storage of heat in gravel and water within each bin based on bin volume, specific heat of water and sediment, and aquifer porosity.



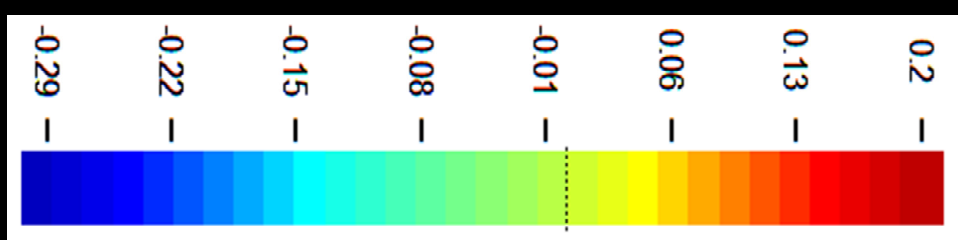


Instantaneous rate of channel water temperature change (degC/hr)



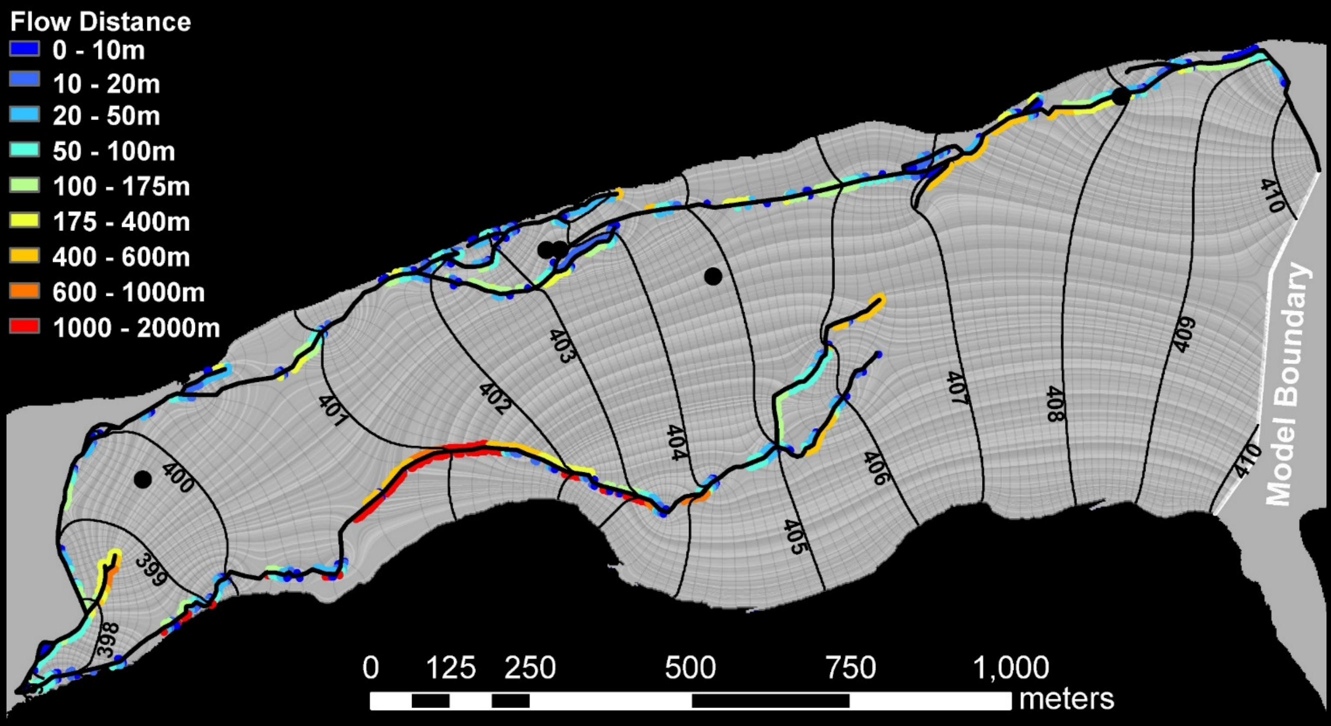


Instantaneous rate of channel water temperature change (degC/hr)



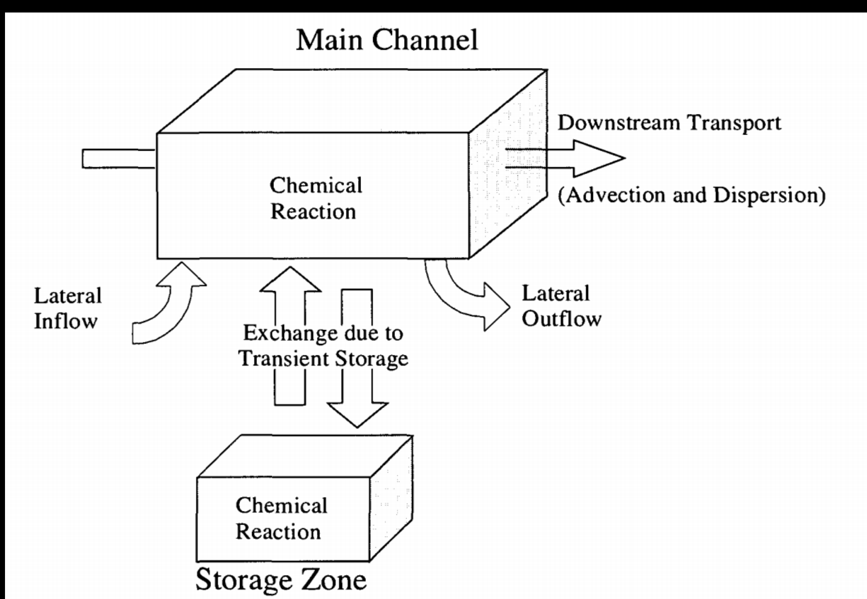
Conclusion

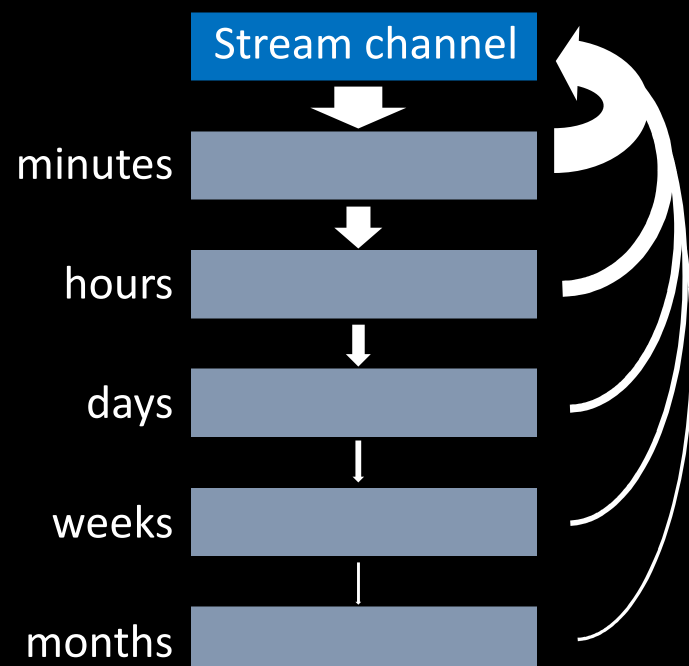
- Hydrology governs the transport and dynamics of energy and solutes in linked riverine/hyporheic hydro-systems. Geomorphology governs the hydrology.



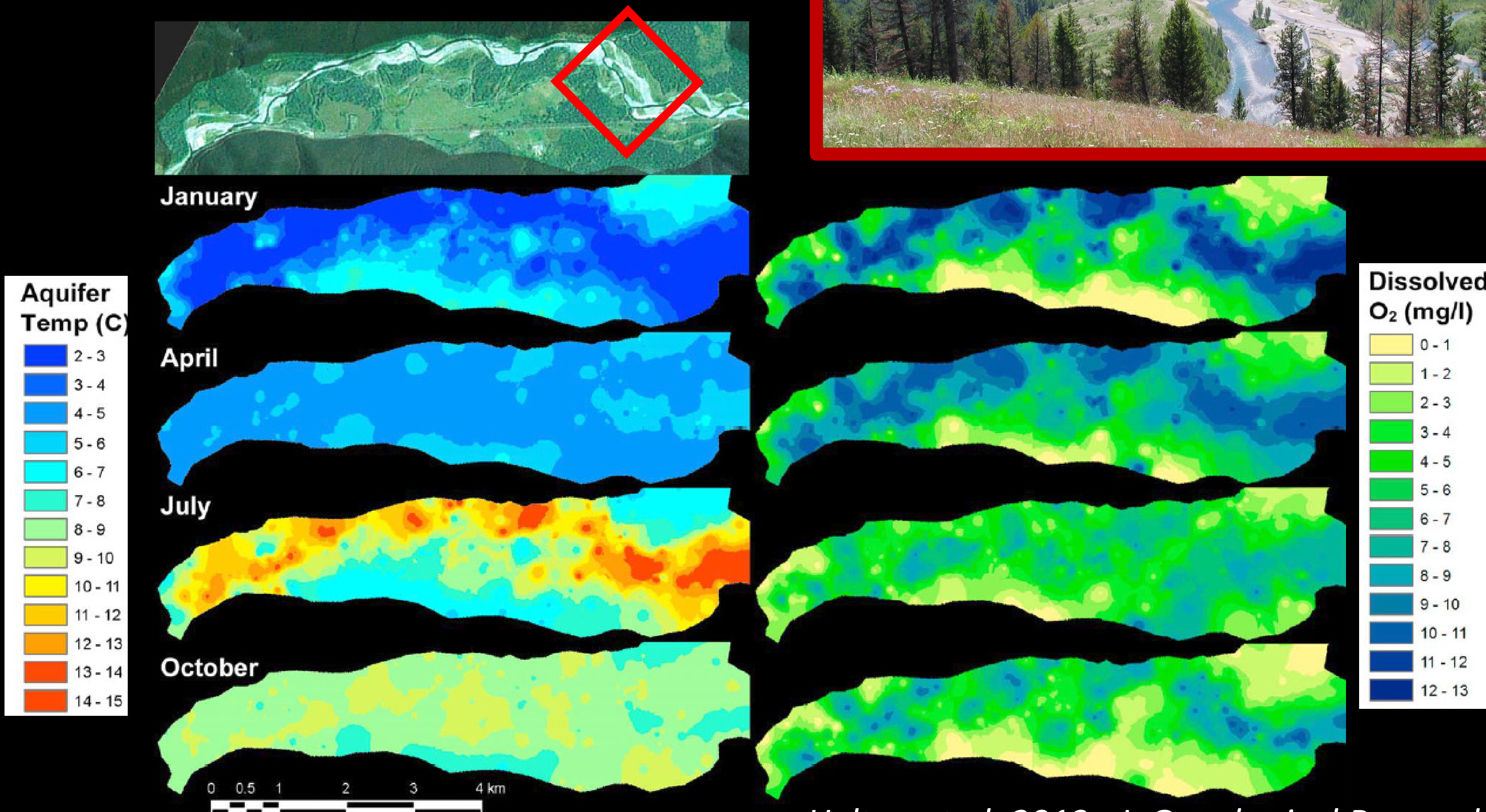
Conclusions

- The parsimony of hydrologic conceptual models enhances or limits our ability to understand (and predict?) physical and biotic responses to land use change and restoration efforts.





Nyack Floodplain
Middle Fork Flathead River, MT



Helton et al. 2012. J. Geophysical Research.

Parting thoughts

- For hillslopes, "flow accumulation" and "upslope accumulated area" are the dominant hydrologic paradigms.
- How do the hydrologic assumptions embedded in these concepts facilitate and limit our understanding of transport/processing?
- How would our understanding change by incorporating residence time distributions or other key aspects of "hydrologic reality?"

OK, let’s review and consider where to go from here.

- Again, this comes mostly from Geoff Poole at Montana State University.

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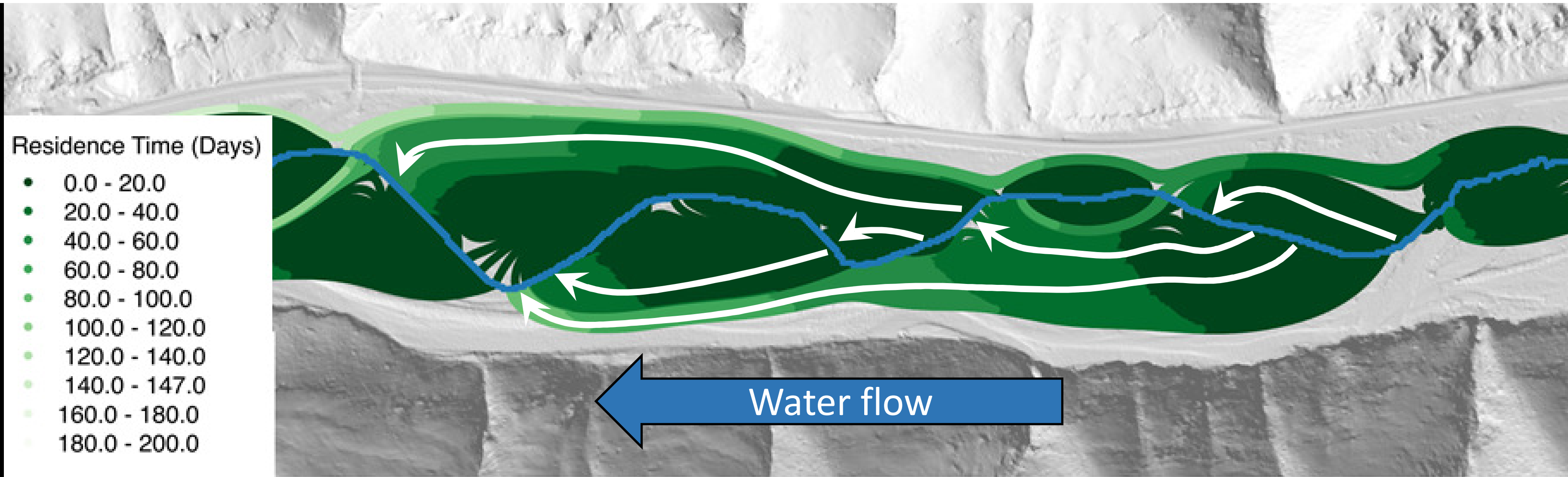
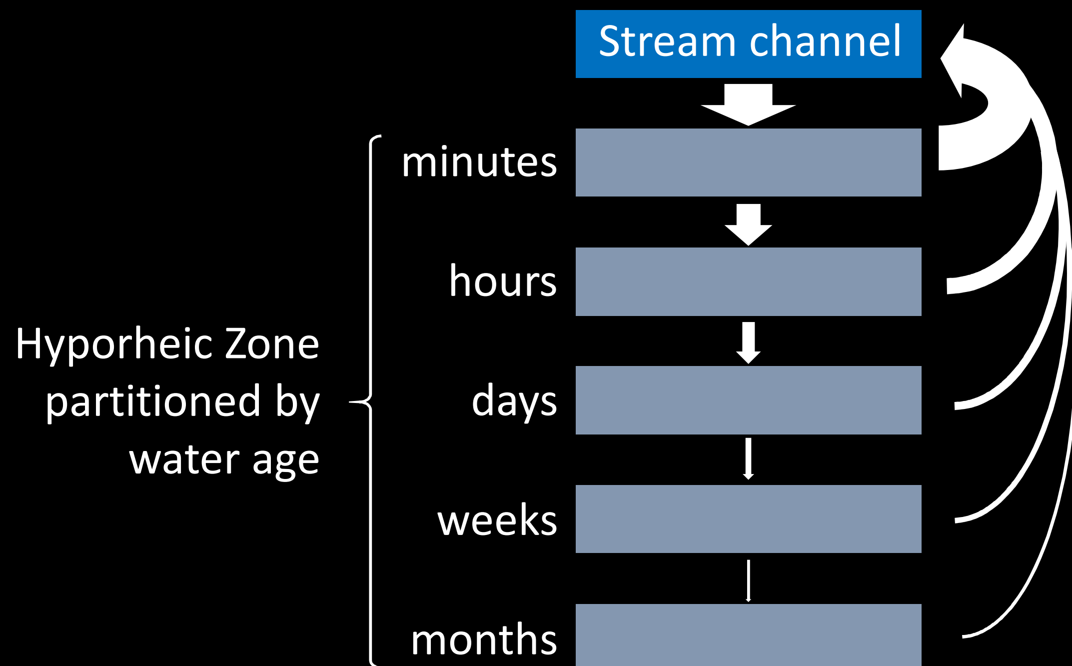
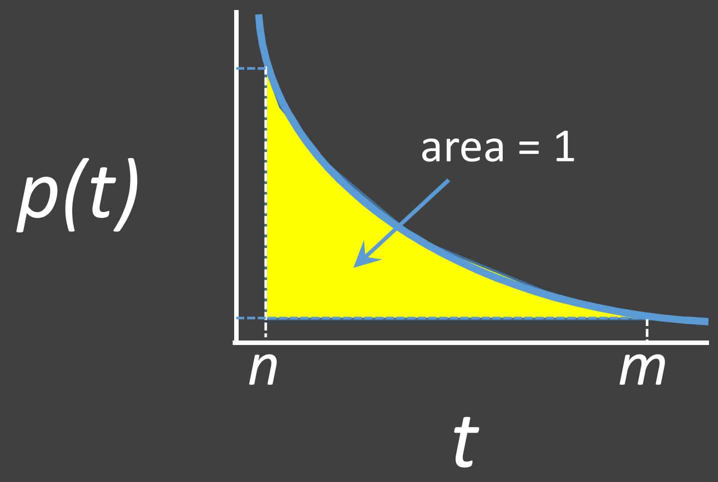


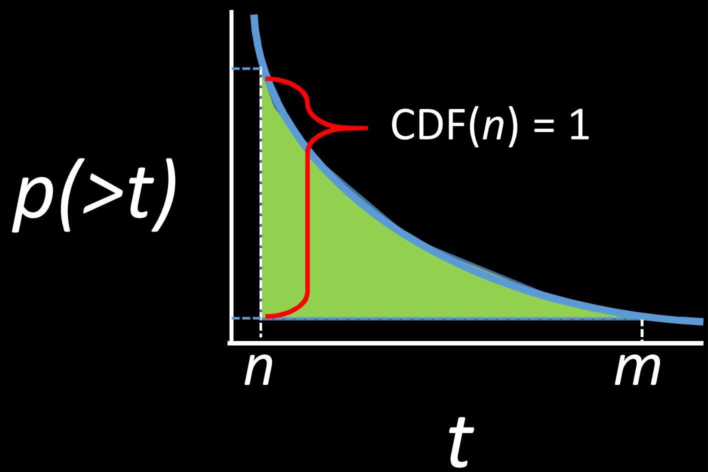
Meacham Creek Restoration Site, OR



Parameterization

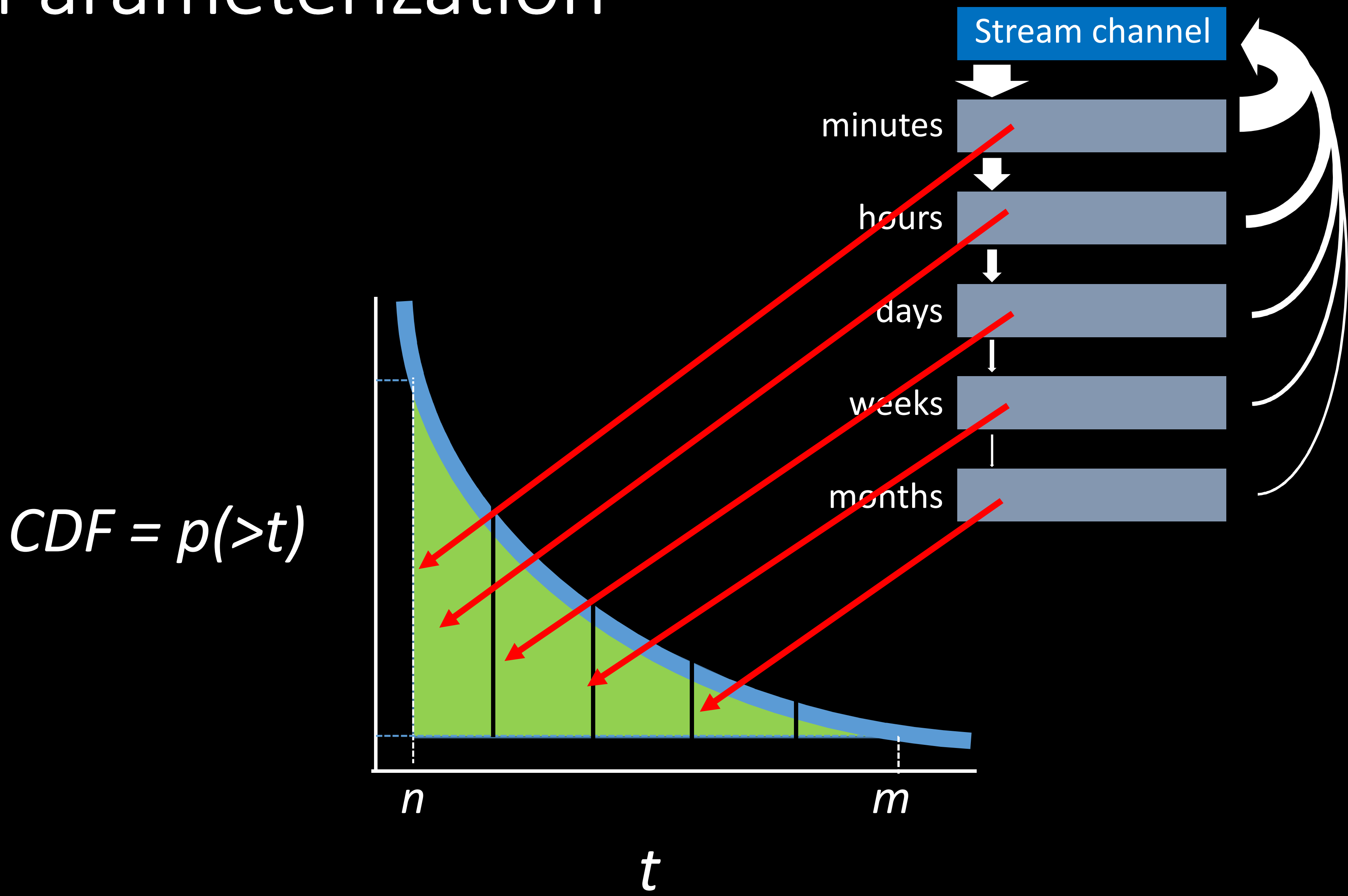
$$PDF(t) = \frac{t^k - m^k}{\int_n^m t^k - m^k}$$





$$CDF(t) = \frac{\frac{(m^{k+1} - t^{k+1})}{k+1} - (m-t)m^k}{\frac{(m^{k+1} - n^{k+1})}{k+1} - (m-n)m^k}$$

Parameterization



Bin Statistics

Using estimates of:

- k
- Size of hyporheic zone
- porosity

	from	to	
1	60.0000	297.3101	1-5 mins
2	297.3101	771.9303	5-13 mins
3	771.9303	1721.1707	13 - 28 mins
4	1721.1707	3619.6515	28 - 60 mins
5	3619.6515	7416.6131	1 - 2 hrs
6	7416.6131	15010.5362	2 - 4 hrs
7	15010.5362	30198.3825	4 - 8 hrs
8	30198.3825	60574.0751	8 - 16 hrs
9	60574.0751	121325.4604	16 - 32 hrs
10	121325.4604	242828.2308	1.4 – 2.8 days
11	242828.2308	485833.7718	2.8 – 5.6 days
12	485833.7718	971844.8537	5.6 – 11.2 days
13	971844.8537	1943867.0174	1.6 – 3.2 weeks
14	1943867.0174	3887911.3450	3.2 – 6.4 weeks
15	3887911.3450	7776000.0000	1.5 – 3.0 months

	from	to	entering	returning	continuing	waterStorage	aquiferStorage	meanWaterAge	meanBinResTime	meanBinFlow
1	60.0000	297.3101	7.500000e-03	5.502590e-03	1.997410e-03	0.8300172	3.3200687	153.5750	93.57499	3.497606e-03
2	297.3101	771.9303	1.997410e-03	1.090049e-03	9.073609e-04	0.6160651	2.4642603	503.8885	206.57841	1.298017e-03
3	771.9303	1721.1707	9.073609e-04	4.400683e-04	4.672926e-04	0.6023560	2.4094241	1194.6289	422.69864	6.345664e-04
4	1721.1707	3619.6515	4.672926e-04	2.148765e-04	2.524161e-04	0.6377230	2.5508921	2573.8862	852.71547	3.359123e-04
5	3619.6515	7416.6131	2.524161e-04	1.132622e-04	1.391540e-04	0.6971001	2.7884003	5331.3482	1711.69674	1.835942e-04
6	7416.6131	15010.5362	1.391540e-04	6.181180e-05	7.734217e-05	0.7723479	3.0893914	10845.0071	3428.39400	1.017060e-04
7	15010.5362	30198.3825	7.734217e-05	3.429757e-05	4.304460e-05	0.8595314	3.4381257	21868.8763	6858.34009	5.659337e-05
8	30198.3825	60574.0751	4.304460e-05	1.918511e-05	2.385948e-05	0.9552084	3.8208338	43904.7065	13706.32400	3.144647e-05
9	60574.0751	121325.4604	2.385948e-05	1.077331e-05	1.308617e-05	1.0539581	4.2158324	87933.2914	27359.21622	1.734871e-05
10	121325.4604	242828.2308	1.308617e-05	6.058818e-06	7.027355e-06	1.1451376	4.5805502	175831.0254	54505.56499	9.424786e-06
11	242828.2308	485833.7718	7.027355e-06	3.404874e-06	3.622481e-06	1.2075150	4.8300599	351017.2000	108188.96915	4.969084e-06
12	485833.7718	971844.8537	3.622481e-06	1.902488e-06	1.719992e-06	1.2008042	4.8032170	698926.7715	213092.99977	2.470734e-06
13	971844.8537	1943867.0174	1.719992e-06	1.039434e-06	6.805585e-07	1.0568364	4.2273455	1383679.1171	411834.26340	1.087255e-06
14	1943867.0174	3887911.3450	6.805585e-07	5.198508e-07	1.607077e-07	0.6938557	2.7754227	2691132.8536	747265.83616	3.569135e-07
15	3887911.3450	7776000.0000	1.607077e-07	1.607077e-07	0.000000e+00	0.1727321	0.6909284	4761392.3806	873481.03566	4.442597e-08

Bin Statistics

entering	returning	continuing
7.500000e-03	5.502590e-03	1.997410e-03
1.997410e-03	1.090049e-03	9.073609e-04
9.073609e-04	4.400683e-04	4.672926e-04
4.672926e-04	2.148765e-04	2.524161e-04
2.524161e-04	1.132622e-04	1.391540e-04
1.391540e-04	6.181180e-05	7.734217e-05
7.734217e-05	3.429757e-05	4.304460e-05
4.304460e-05	1.918511e-05	2.385948e-05
2.385948e-05	1.077331e-05	1.308617e-05
1.308617e-05	6.058818e-06	7.027355e-06
7.027355e-06	3.404874e-06	3.622481e-06
3.622481e-06	1.902488e-06	1.719992e-06
1.719992e-06	1.039434e-06	6.805585e-07
6.805585e-07	5.198508e-07	1.607077e-07
1.607077e-07	1.607077e-07	0.000000e+00

	from	to	entering	returning	continuing	waterStorage	aquiferStorage	meanWaterAge	meanBinResTime	meanBinFlow
1	60.0000	297.3101	7.500000e-03	5.502590e-03	1.997410e-03	0.8300172	3.3200687	153.5750	93.57499	3.497606e-03
2	297.3101	771.9303	1.997410e-03	1.090049e-03	9.073609e-04	0.6160651	2.4642603	503.8885	206.57841	1.298017e-03
3	771.9303	1721.1707	9.073609e-04	4.400683e-04	4.672926e-04	0.6023560	2.4094241	1194.6289	422.69864	6.345664e-04
4	1721.1707	3619.6515	4.672926e-04	2.148765e-04	2.524161e-04	0.6377230	2.5508921	2573.8862	852.71547	3.359123e-04
5	3619.6515	7416.6131	2.524161e-04	1.132622e-04	1.391540e-04	0.6971001	2.7884003	5331.3482	1711.69674	1.835942e-04
6	7416.6131	15010.5362	1.391540e-04	6.181180e-05	7.734217e-05	0.7723479	3.0893914	10845.0071	3428.39400	1.017060e-04
7	15010.5362	30198.3825	7.734217e-05	3.429757e-05	4.304460e-05	0.8595314	3.4381257	21868.8763	6858.34009	5.659337e-05
8	30198.3825	60574.0751	4.304460e-05	1.918511e-05	2.385948e-05	0.9552084	3.8208338	43904.7065	13706.32400	3.144647e-05
9	60574.0751	121325.4604	2.385948e-05	1.077331e-05	1.308617e-05	1.0539581	4.2158324	87933.2914	27359.21622	1.734871e-05
10	121325.4604	242828.2308	1.308617e-05	6.058818e-06	7.027355e-06	1.1451376	4.5805502	175831.0254	54505.56499	9.424786e-06
11	242828.2308	485833.7718	7.027355e-06	3.404874e-06	3.622481e-06	1.2075150	4.8300599	351017.2000	108188.96915	4.969084e-06
12	485833.7718	971844.8537	3.622481e-06	1.902488e-06	1.719992e-06	1.2008042	4.8032170	698926.7715	213092.99977	2.470734e-06
13	971844.8537	1943867.0174	1.719992e-06	1.039434e-06	6.805585e-07	1.0568364	4.2273455	1383679.1171	411834.26340	1.087255e-06
14	1943867.0174	3887911.3450	6.805585e-07	5.198508e-07	1.607077e-07	0.6938557	2.7754227	2691132.8536	747265.83616	3.569135e-07
15	3887911.3450	7776000.0000	1.607077e-07	1.607077e-07	0.000000e+00	0.1727321	0.6909284	4761392.3806	873481.03566	4.442597e-08

Bin Statistics

waterStorage	aquiferStorage
0.8300172	3.3200687
0.6160651	2.4642603
0.6023560	2.4094241
0.6377230	2.5508921
0.6971001	2.7884003
0.7723479	3.0893914
0.8595314	3.4381257
0.9552084	3.8208338
1.0539581	4.2158324
1.1451376	4.5805502
1.2075150	4.8300599
1.2008042	4.8032170
1.0568364	4.2273455
0.6938557	2.7754227
0.1727321	0.6909284

	from	to	entering	returning	continuing	waterStorage	aquiferStorage	meanWaterAge	meanBinResTime	meanBinFlow
1	60.0000	297.3101	7.500000e-03	5.502590e-03	1.997410e-03	0.8300172	3.3200687	153.5750	93.57499	3.497606e-03
2	297.3101	771.9303	1.997410e-03	1.090049e-03	9.073609e-04	0.6160651	2.4642603	503.8885	206.57841	1.298017e-03
3	771.9303	1721.1707	9.073609e-04	4.400683e-04	4.672926e-04	0.6023560	2.4094241	1194.6289	422.69864	6.345664e-04
4	1721.1707	3619.6515	4.672926e-04	2.148765e-04	2.524161e-04	0.6377230	2.5508921	2573.8862	852.71547	3.359123e-04
5	3619.6515	7416.6131	2.524161e-04	1.132622e-04	1.391540e-04	0.6971001	2.7884003	5331.3482	1711.69674	1.835942e-04
6	7416.6131	15010.5362	1.391540e-04	6.181180e-05	7.734217e-05	0.7723479	3.0893914	10845.0071	3428.39400	1.017060e-04
7	15010.5362	30198.3825	7.734217e-05	3.429757e-05	4.304460e-05	0.8595314	3.4381257	21868.8763	6858.34009	5.659337e-05
8	30198.3825	60574.0751	4.304460e-05	1.918511e-05	2.385948e-05	0.9552084	3.8208338	43904.7065	13706.32400	3.144647e-05
9	60574.0751	121325.4604	2.385948e-05	1.077331e-05	1.308617e-05	1.0539581	4.2158324	87933.2914	27359.21622	1.734871e-05
10	121325.4604	242828.2308	1.308617e-05	6.058818e-06	7.027355e-06	1.1451376	4.5805502	175831.0254	54505.56499	9.424786e-06
11	242828.2308	485833.7718	7.027355e-06	3.404874e-06	3.622481e-06	1.2075150	4.8300599	351017.2000	108188.96915	4.969084e-06
12	485833.7718	971844.8537	3.622481e-06	1.902488e-06	1.719992e-06	1.2008042	4.8032170	698926.7715	213092.99977	2.470734e-06
13	971844.8537	1943867.0174	1.719992e-06	1.039434e-06	6.805585e-07	1.0568364	4.2273455	1383679.1171	411834.26340	1.087255e-06
14	1943867.0174	3887911.3450	6.805585e-07	5.198508e-07	1.607077e-07	0.6938557	2.7754227	2691132.8536	747265.83616	3.569135e-07
15	3887911.3450	7776000.0000	1.607077e-07	1.607077e-07	0.000000e+00	0.1727321	0.6909284	4761392.3806	873481.03566	4.442597e-08

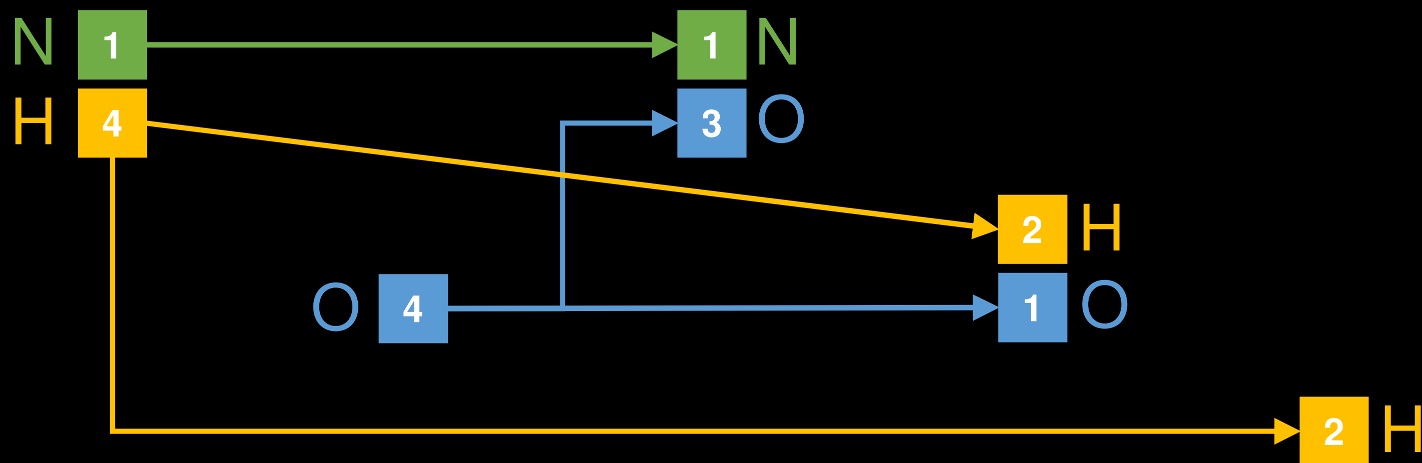
Bin Statistics

meanWaterAge	meanBinResTime	meanBinFlow
153.5750	93.57499	3.497606e-03
503.8885	206.57841	1.298017e-03
1194.6289	422.69864	6.345664e-04
2573.8862	852.71547	3.359123e-04
5331.3482	1711.69674	1.835942e-04
10845.0071	3428.39400	1.017060e-04
21868.8763	6858.34009	5.659337e-05
43904.7065	13706.32400	3.144647e-05
87933.2914	27359.21622	1.734871e-05
175831.0254	54505.56499	9.424786e-06
351017.2000	108188.96915	4.969084e-06
698926.7715	213092.99977	2.470734e-06
1383679.1171	411834.26340	1.087255e-06
2691132.8536	747265.83616	3.569135e-07
4761392.3806	873481.03566	4.442597e-08

	from	to	entering	returning	continuing	waterStorage	aquiferStorage	meanWaterAge	meanBinResTime	meanBinFlow
1	60.0000	297.3101	7.500000e-03	5.502590e-03	1.997410e-03	0.8300172	3.3200687	153.5750	93.57499	3.497606e-03
2	297.3101	771.9303	1.997410e-03	1.090049e-03	9.073609e-04	0.6160651	2.4642603	503.8885	206.57841	1.298017e-03
3	771.9303	1721.1707	9.073609e-04	4.400683e-04	4.672926e-04	0.6023560	2.4094241	1194.6289	422.69864	6.345664e-04
4	1721.1707	3619.6515	4.672926e-04	2.148765e-04	2.524161e-04	0.6377230	2.5508921	2573.8862	852.71547	3.359123e-04
5	3619.6515	7416.6131	2.524161e-04	1.132622e-04	1.391540e-04	0.6971001	2.7884003	5331.3482	1711.69674	1.835942e-04
6	7416.6131	15010.5362	1.391540e-04	6.181180e-05	7.734217e-05	0.7723479	3.0893914	10845.0071	3428.39400	1.017060e-04
7	15010.5362	30198.3825	7.734217e-05	3.429757e-05	4.304460e-05	0.8595314	3.4381257	21868.8763	6858.34009	5.659337e-05
8	30198.3825	60574.0751	4.304460e-05	1.918511e-05	2.385948e-05	0.9552084	3.8208338	43904.7065	13706.32400	3.144647e-05
9	60574.0751	121325.4604	2.385948e-05	1.077331e-05	1.308617e-05	1.0539581	4.2158324	87933.2914	27359.21622	1.734871e-05
10	121325.4604	242828.2308	1.308617e-05	6.058818e-06	7.027355e-06	1.1451376	4.5805502	175831.0254	54505.56499	9.424786e-06
11	242828.2308	485833.7718	7.027355e-06	3.404874e-06	3.622481e-06	1.2075150	4.8300599	351017.2000	108188.96915	4.969084e-06
12	485833.7718	971844.8537	3.622481e-06	1.902488e-06	1.719992e-06	1.2008042	4.8032170	698926.7715	213092.99977	2.470734e-06
13	971844.8537	1943867.0174	1.719992e-06	1.039434e-06	6.805585e-07	1.0568364	4.2273455	1383679.1171	411834.26340	1.087255e-06
14	1943867.0174	3887911.3450	6.805585e-07	5.198508e-07	1.607077e-07	0.6938557	2.7754227	2691132.8536	747265.83616	3.569135e-07
15	3887911.3450	7776000.0000	1.607077e-07	1.607077e-07	0.000000e+00	0.1727321	0.6909284	4761392.3806	873481.03566	4.442597e-08

Future Directions – Hydrologic controls on Biogeochemistry

$$NH_4^+ + 2O_2 \longrightarrow NO_3^- + H_2O + 2H^+$$



Biogeochemistry that we must learn to model accurately.

- Methane oxidation
- Aerobic heterotrophy
- Denitrification
- Sulfide oxidation
- Nitrification
- Sulfate Reduction
- Methanogenesis
- Biotic Assimilation of:

  HS, NH4, SO4, DOM, NO3, CH4, CO2