Improving Paleohydrologic Source-to-Sink Estimates by Merging Big Data and the Fulcrum Approach*

Nicole Wilson[1] and John Holbrook[1]

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Abstract

Quantifying source-to-sink sediment flux for stratigraphic systems is critical for accurate basin models, but all available methods are hampered by low precision and most require data not readily attained by common subsurface studies. The Fulcrum approach uses the variables of channel bankfull thickness and grain size to calculate sediment bankfull discharge and converts this to an annual sediment volume. The fulcrum approach uses commonly collected data but similarly yields only approximate flux estimates. In order to calculate a more precise source-to-sink estimate for long basin durations, the amount of time the fluvial systems runs at bankfull flow and the annual proportion of sediment discharged during this bankfull flow must also be determined. By categorizing fluvial systems by attributes such as drainage area and paleoclimate at the time of discharge, a more specified and accurate bankfull flow duration and total bankfull sediment discharge is estimated. We constructed a database that stores and categorizes these data. Daily stream gauge data spanning decades is used in conjunction with measured bankfull values from literature to populate the datasets for the database and derive stream specific data attributes. This bankfull flux searchable database evaluates stream gauge data for modern fluvial systems according to classes such as climate setting and is also a useful tool for identifying analog stream data scaled to drainage basin and channel size. It evaluates designated parameters of days within a year that the river runs at bankfull flow, as well as the yearly proportion of sediment discharged over bankfull duration. The database can thus yield a more accurate value for duration at bankfull flow and sediment discharge at bankfull from modern rivers that can be used as an analog for stratigraphic rivers with interpreted climate and size parameters. Preliminary results show a key breakdown in bankfull duration, with arid and temperate dry season rivers on the order of a fraction of day per year and wet temperate climates tending to be an order of magnitude longer and boreal climates still longer. Categorizing stratigraphic rivers by known climate and other parameters, can lower the total error in sediment flux from paleohydrology by a factor.

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IMPROVING PALEOHYDROLOGIC SOURCE-TO-SINK ESTIMATES BY MERGING BIG DATA AND THE FULCRUM APPROACH

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Texas Christian University
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Dr. John Holbrook

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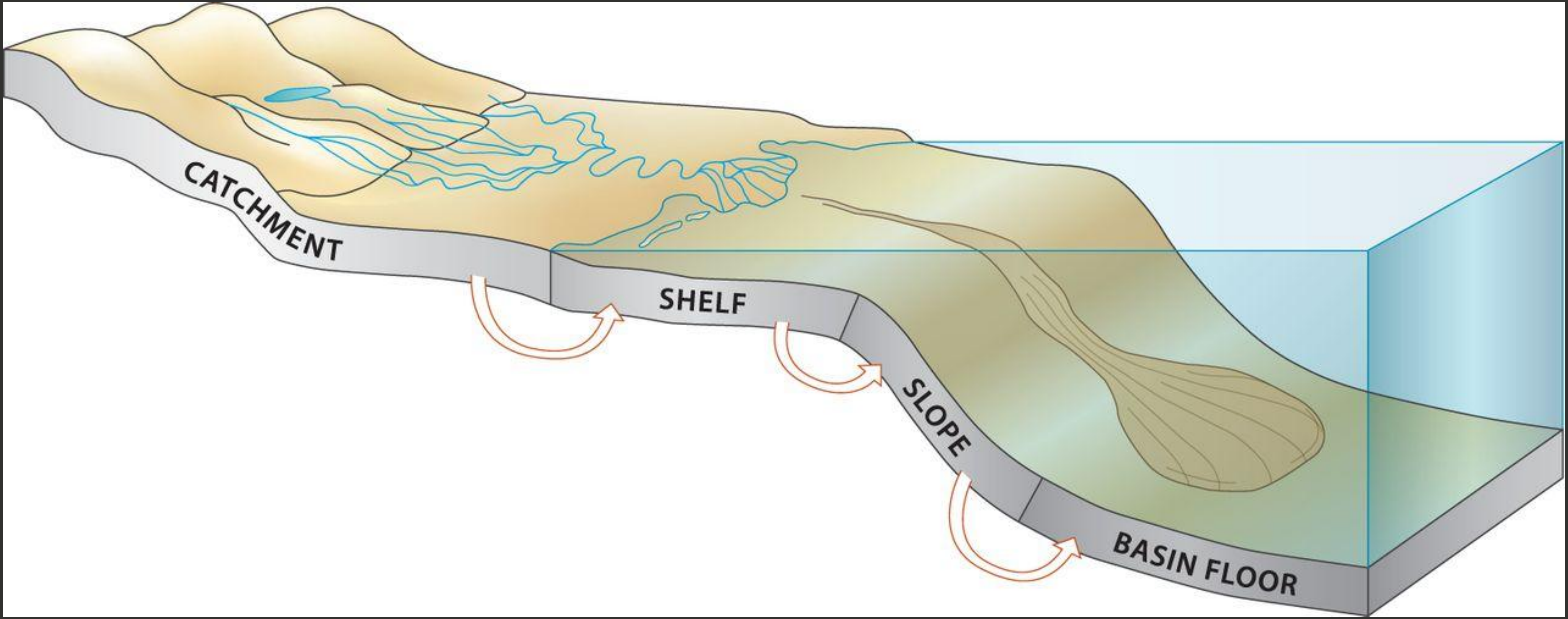
Source-to-sink



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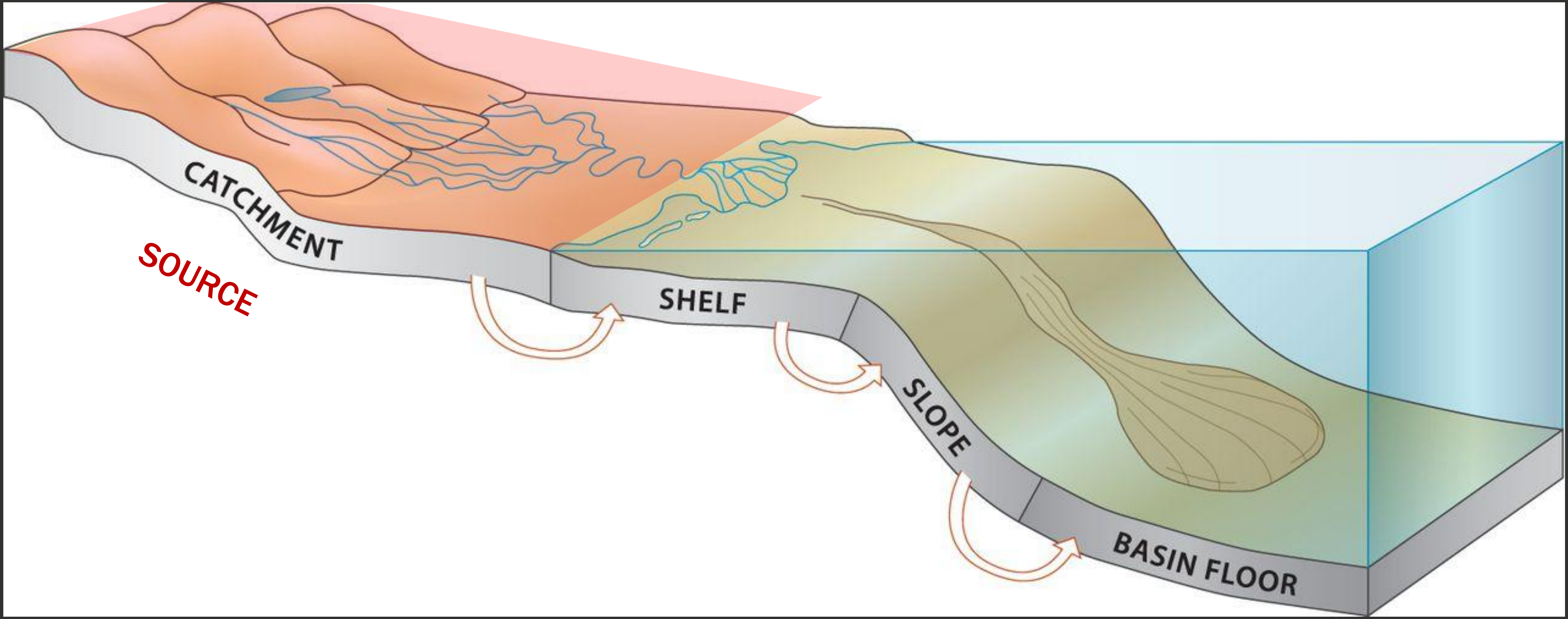
Source-to-sink



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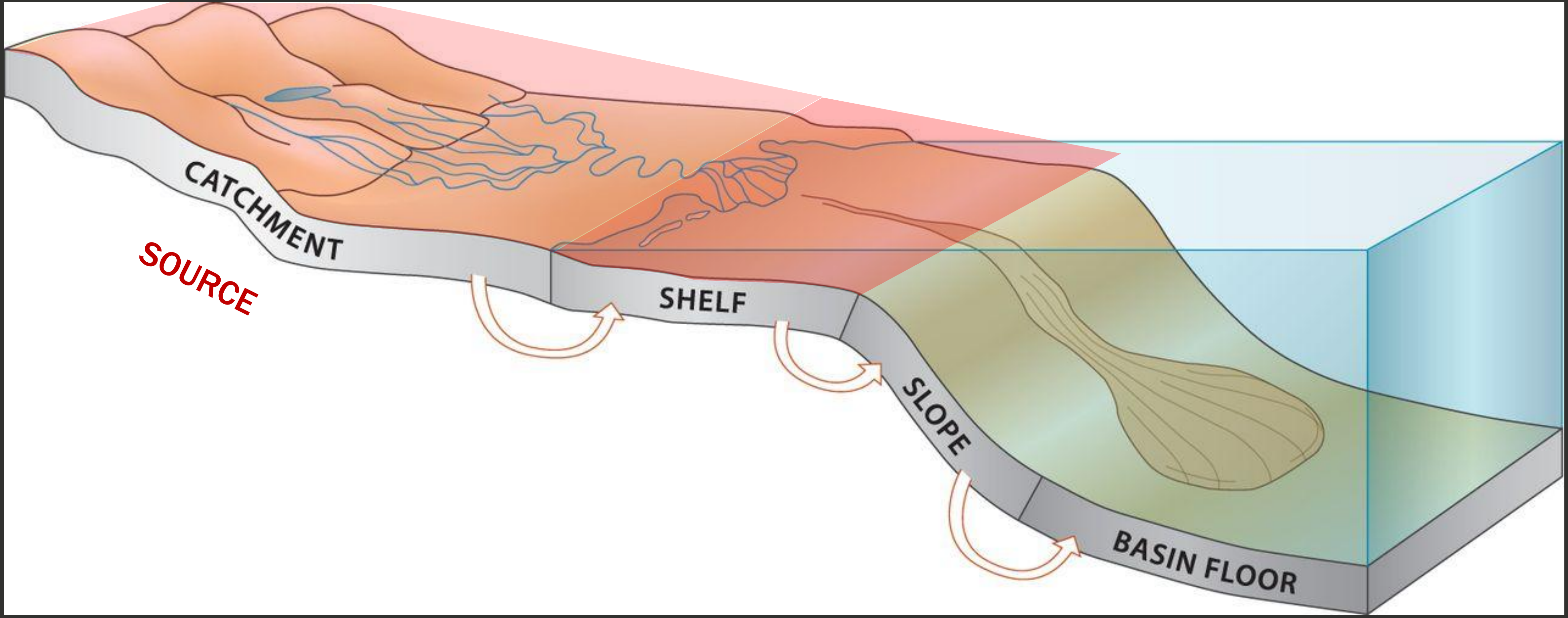

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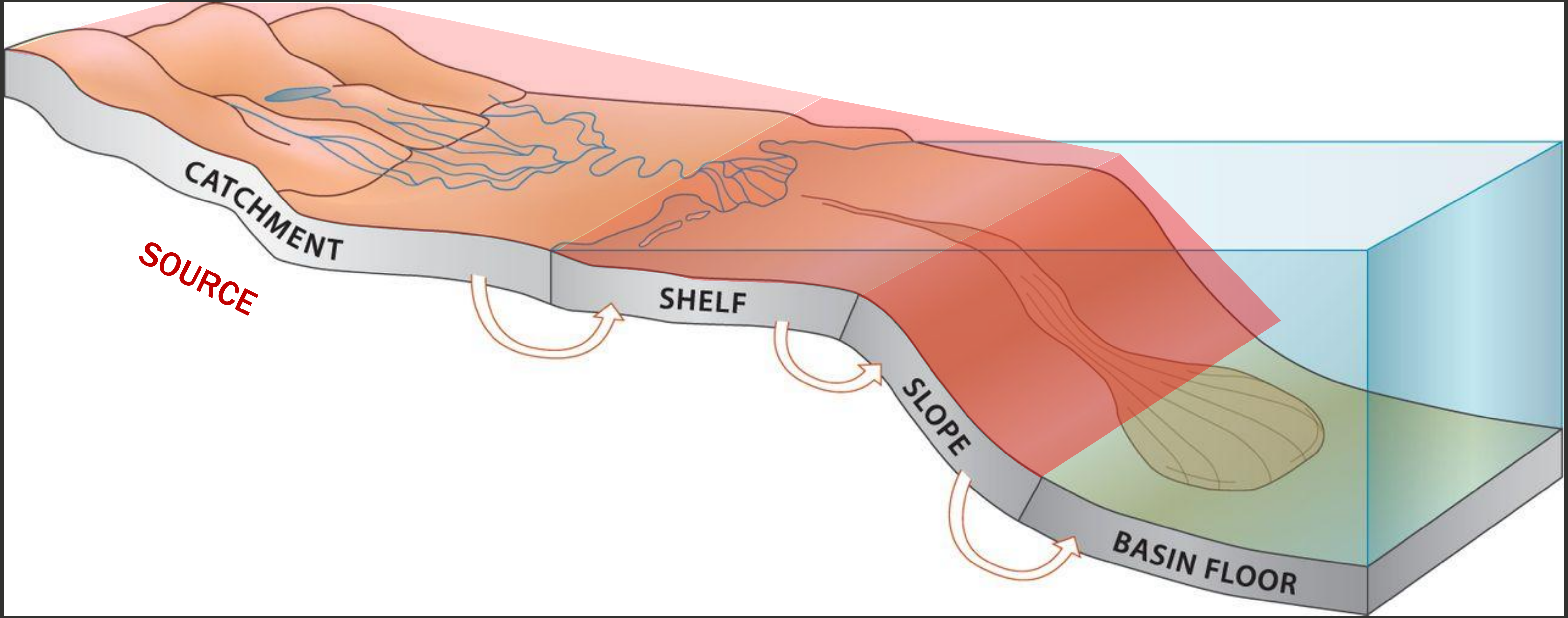

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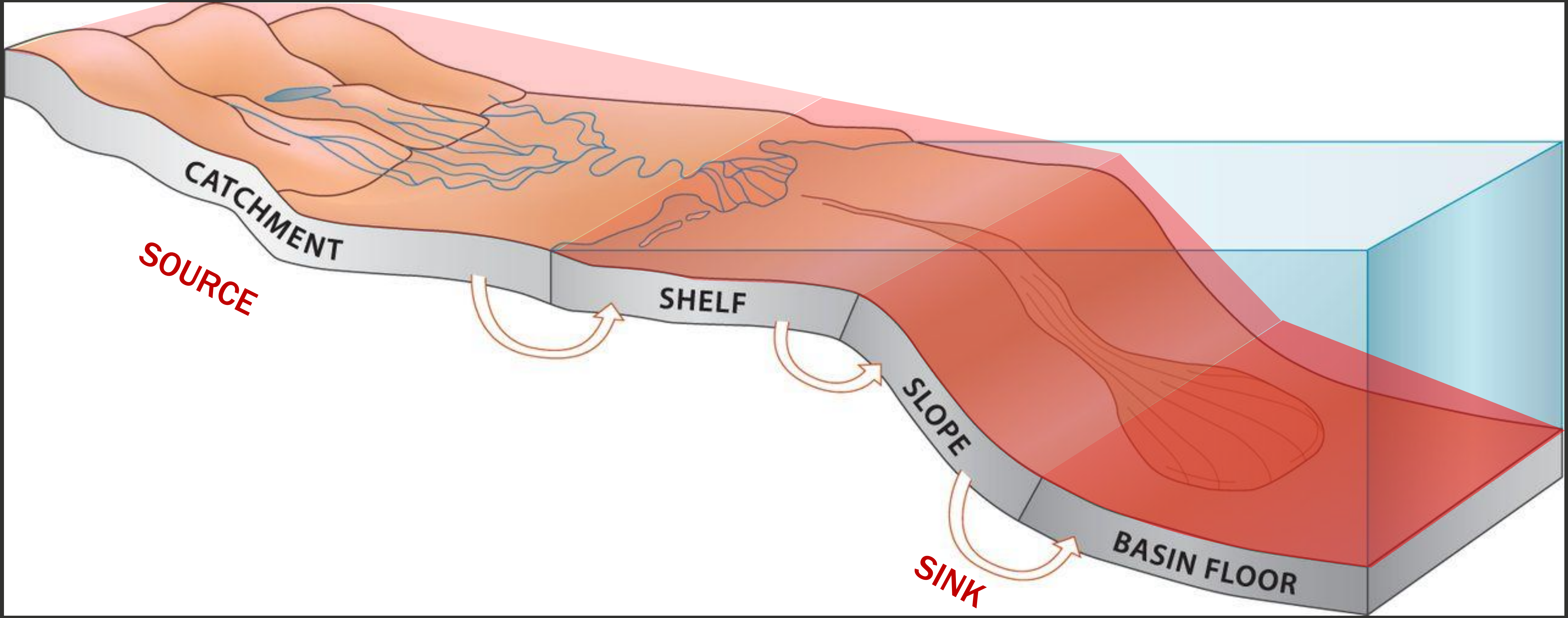

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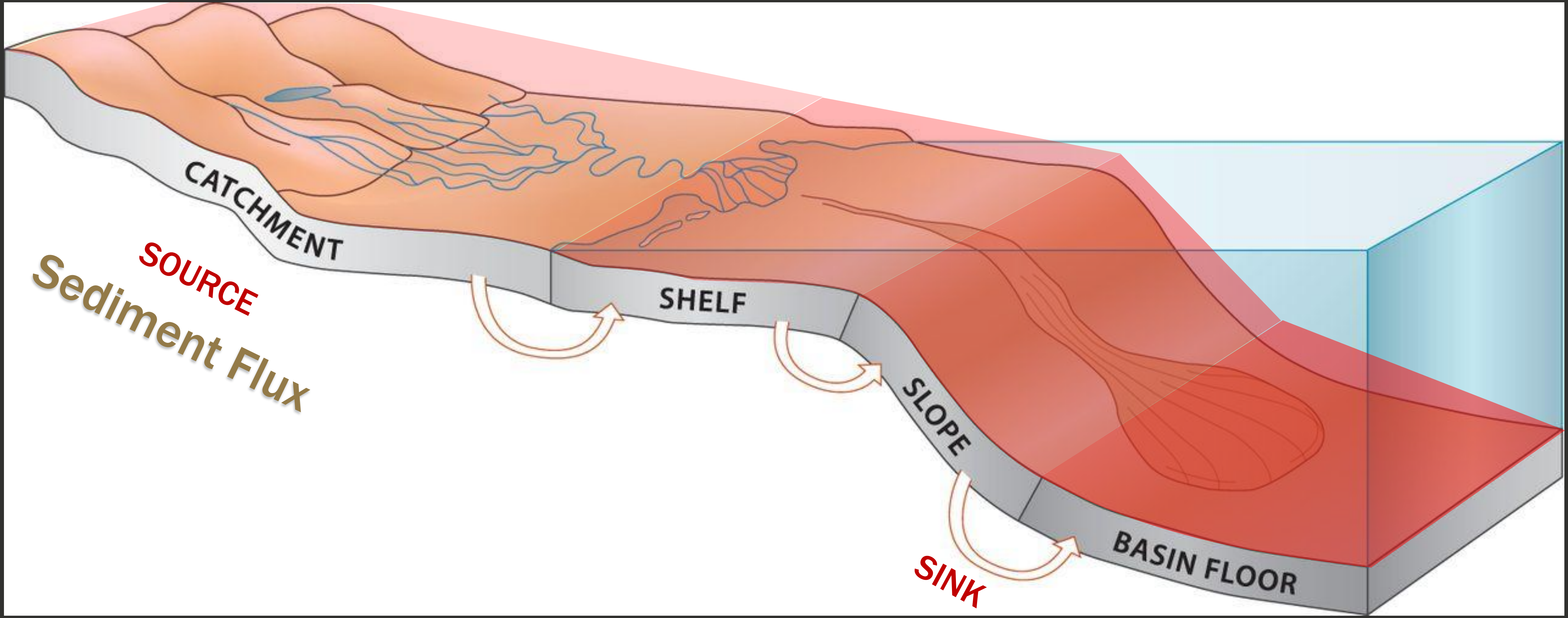

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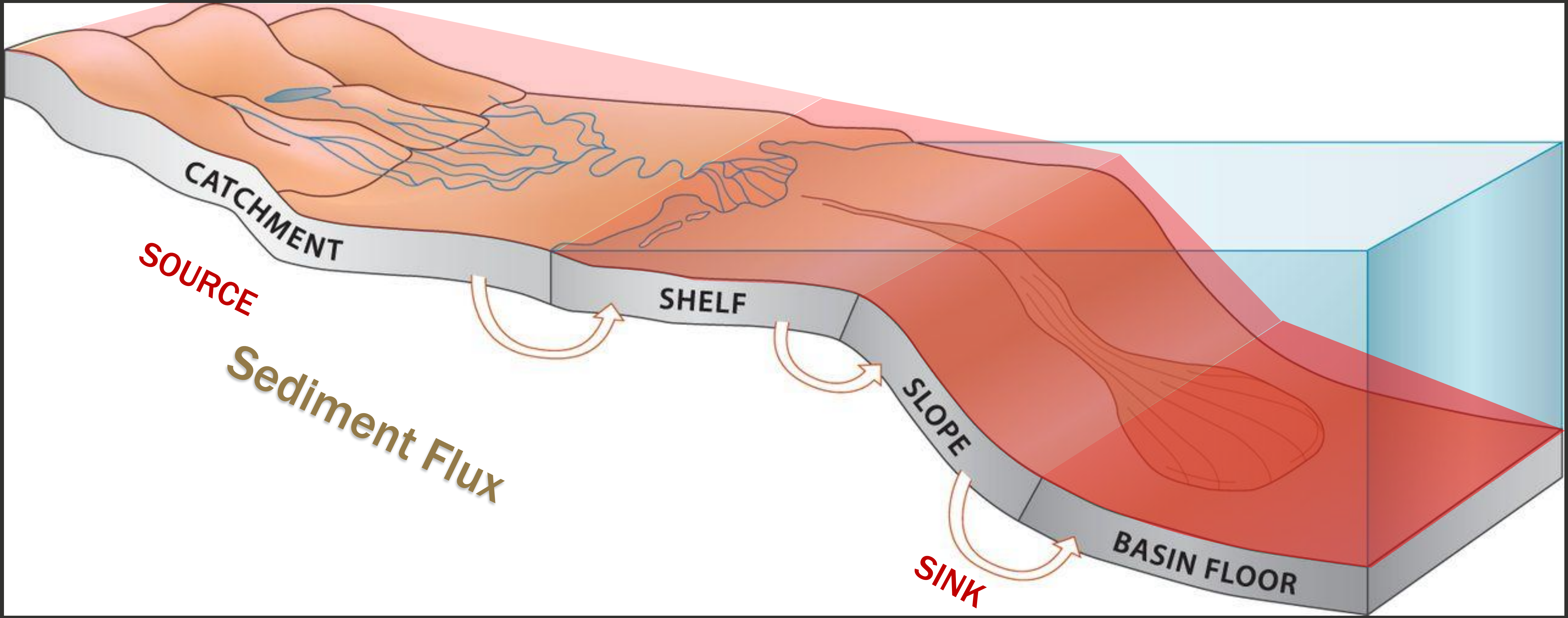

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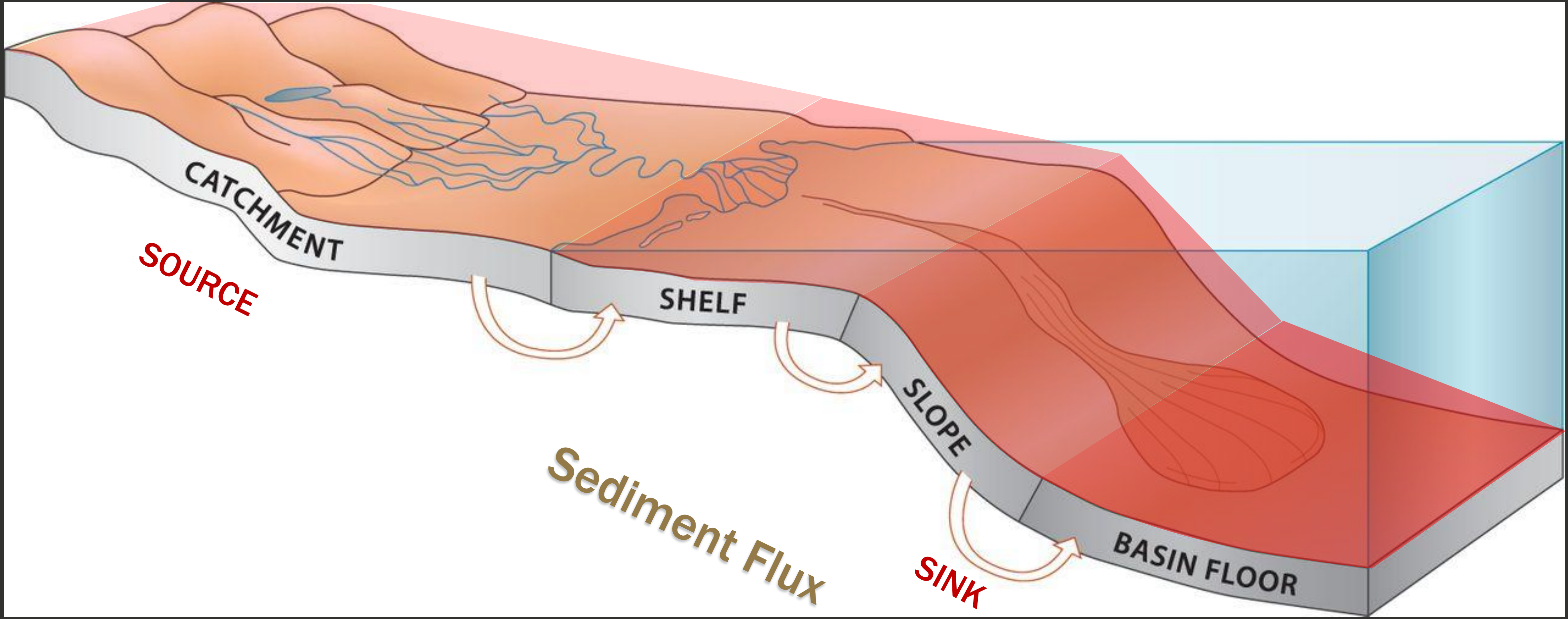

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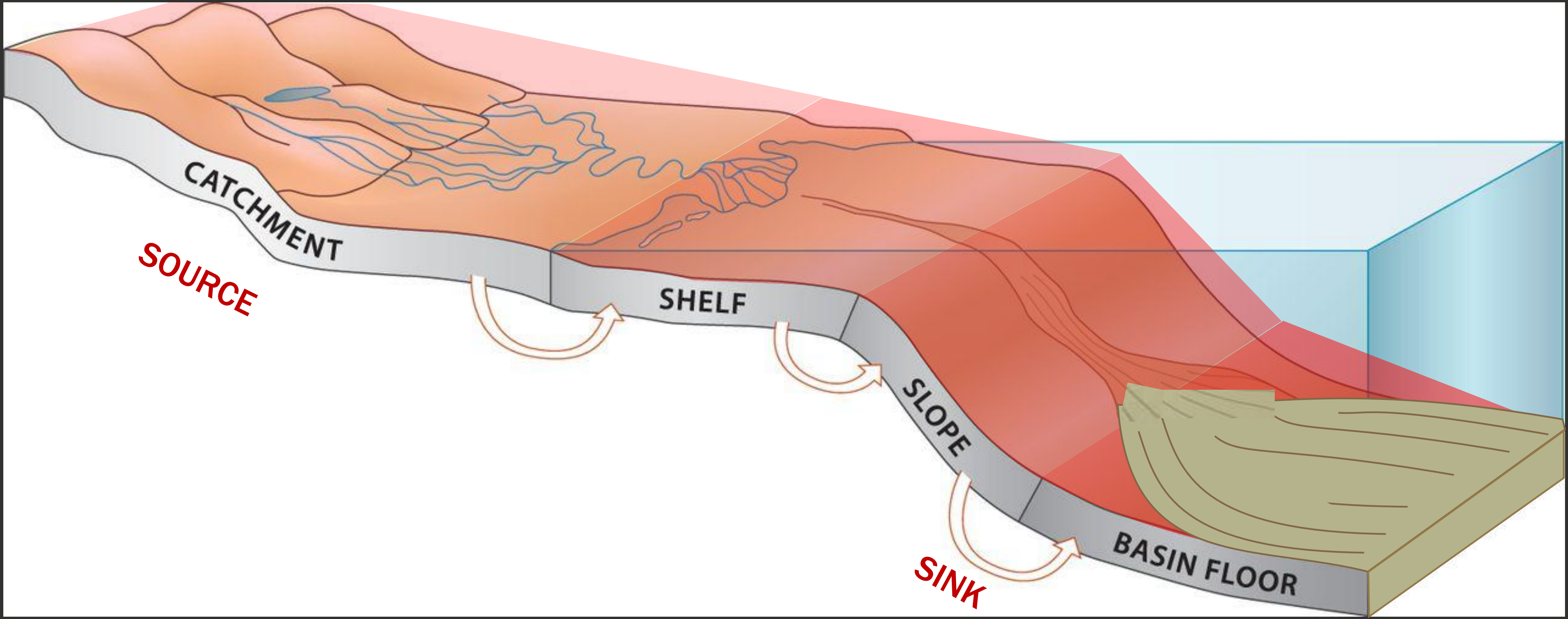

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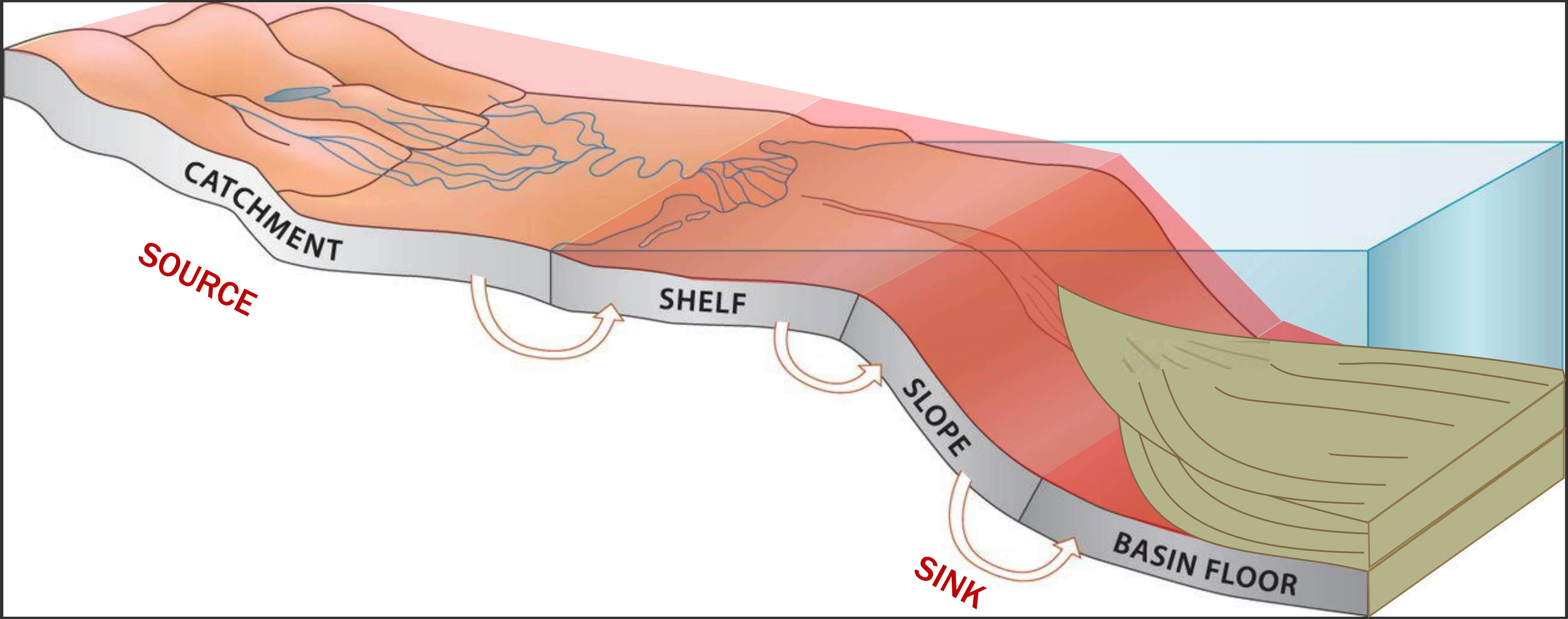

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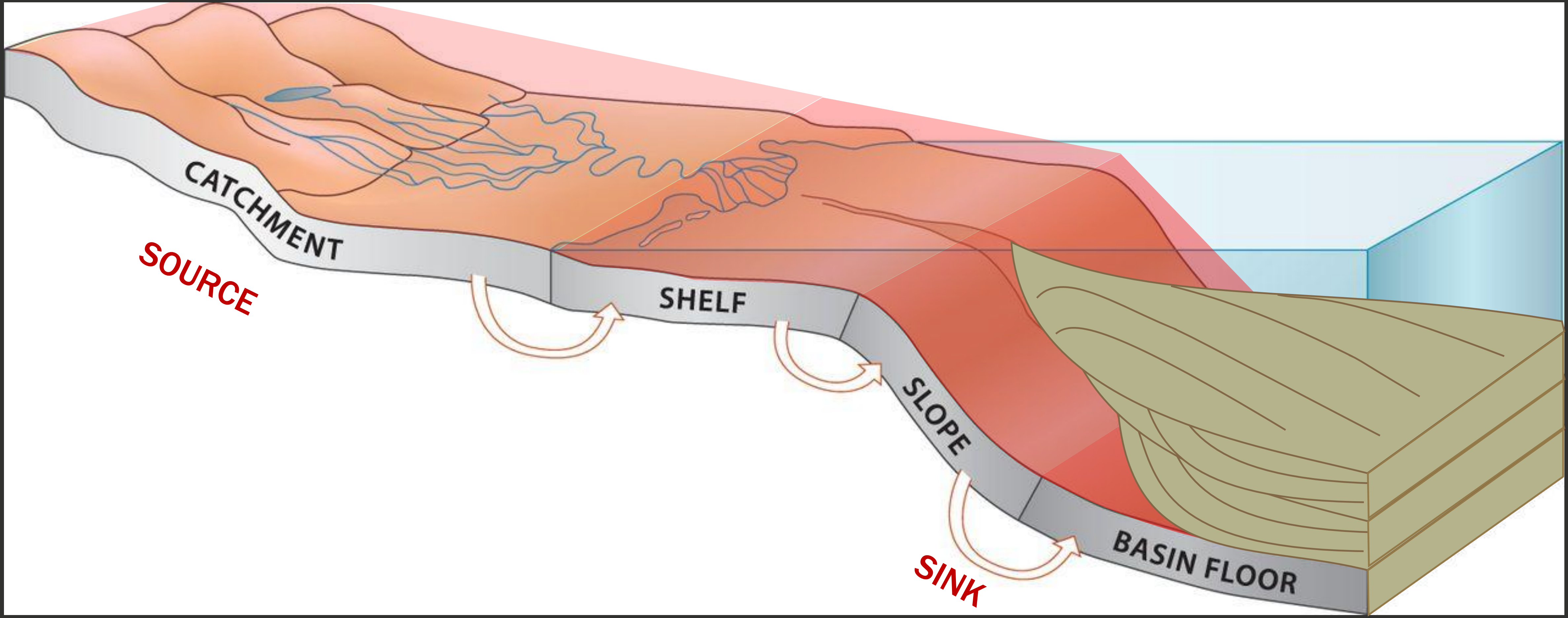

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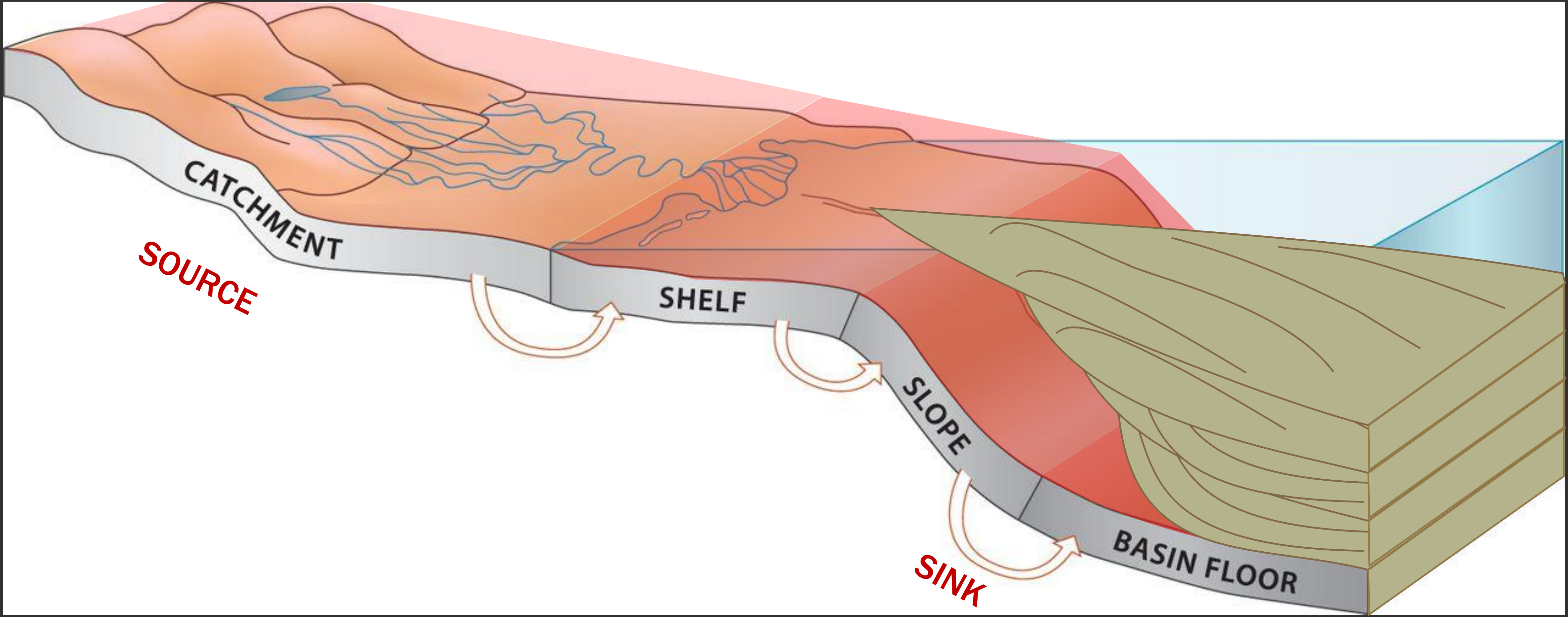

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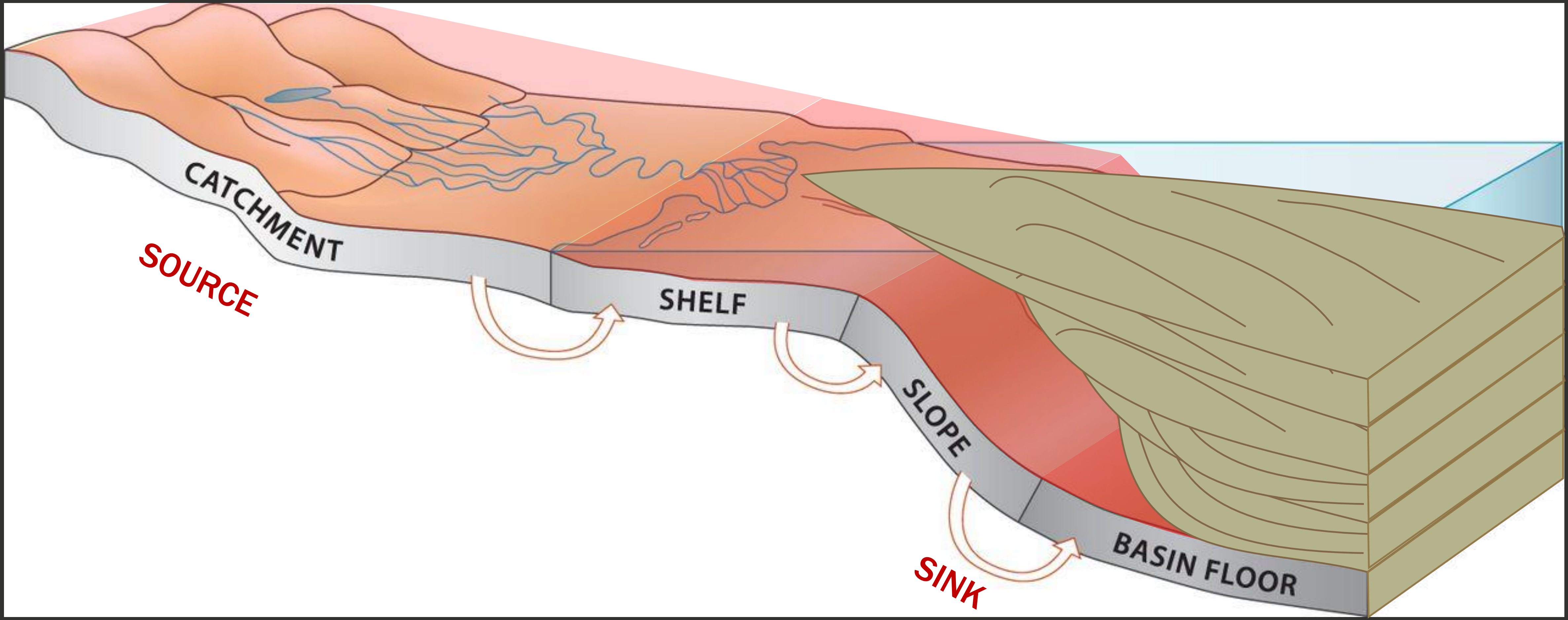

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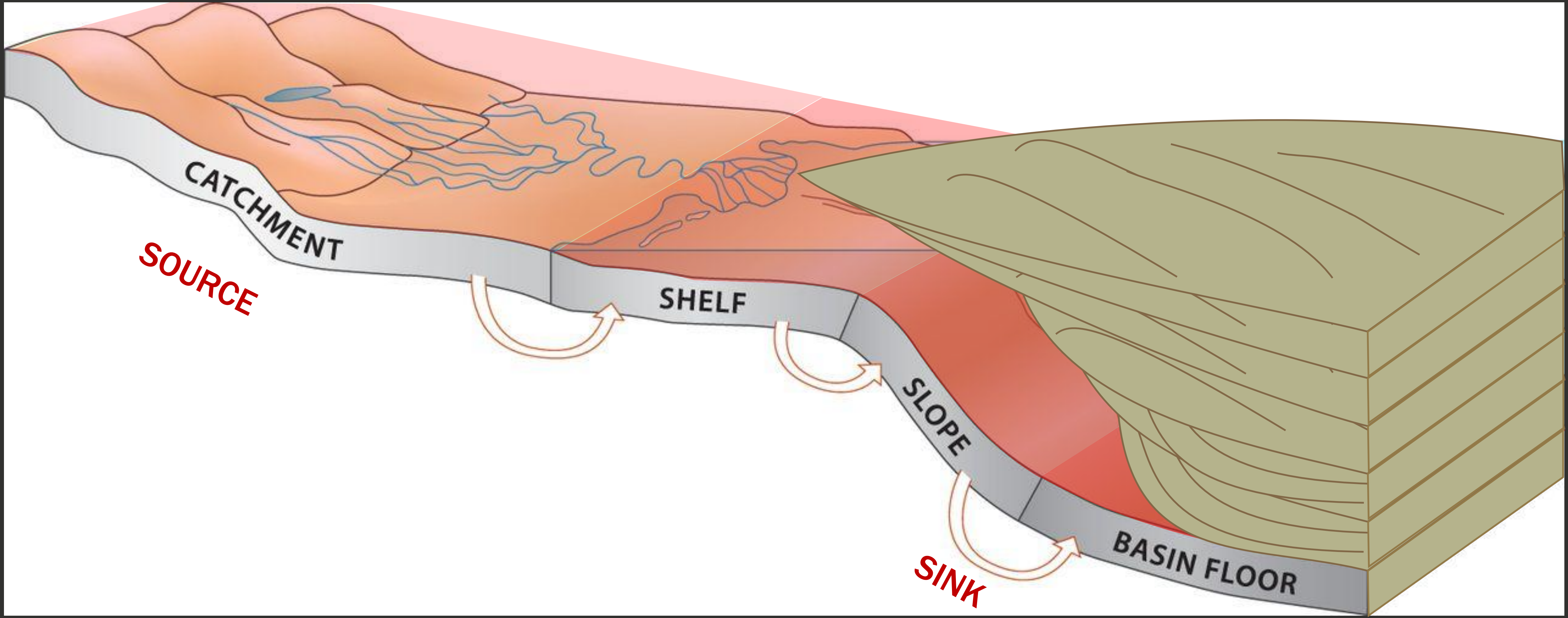

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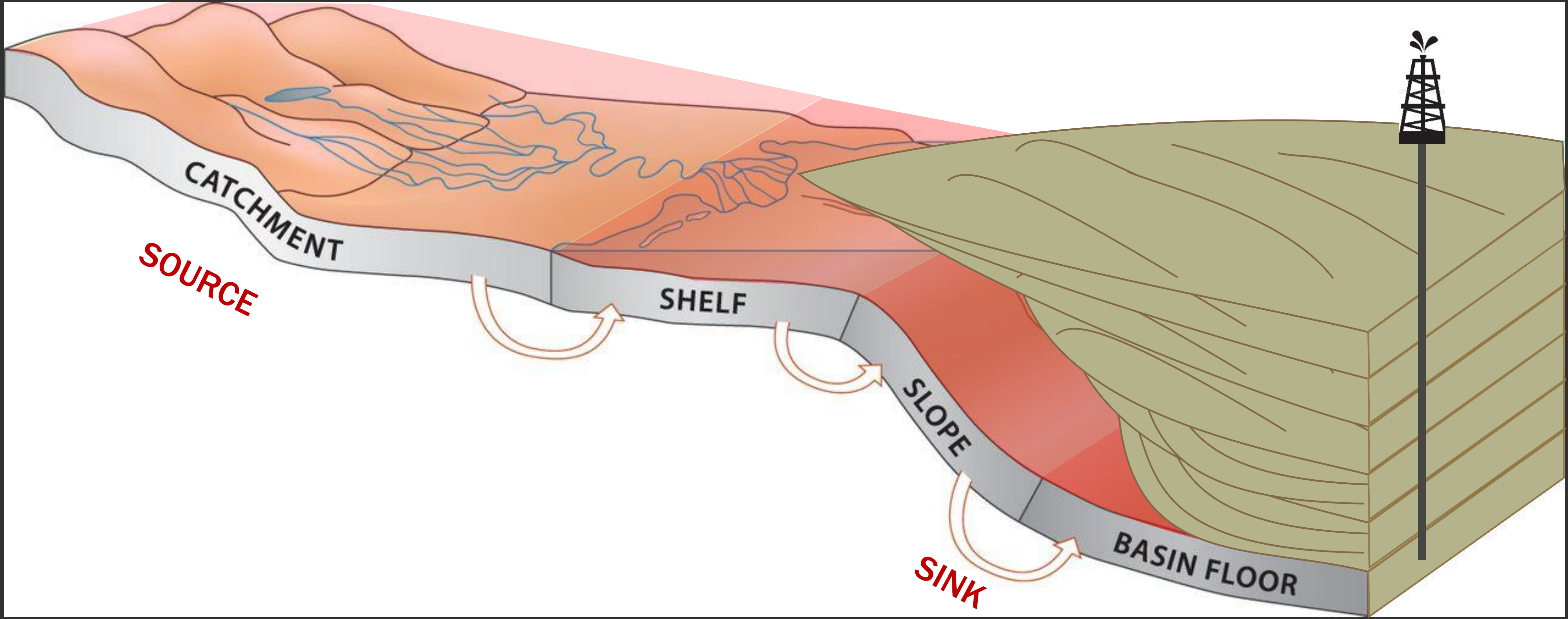

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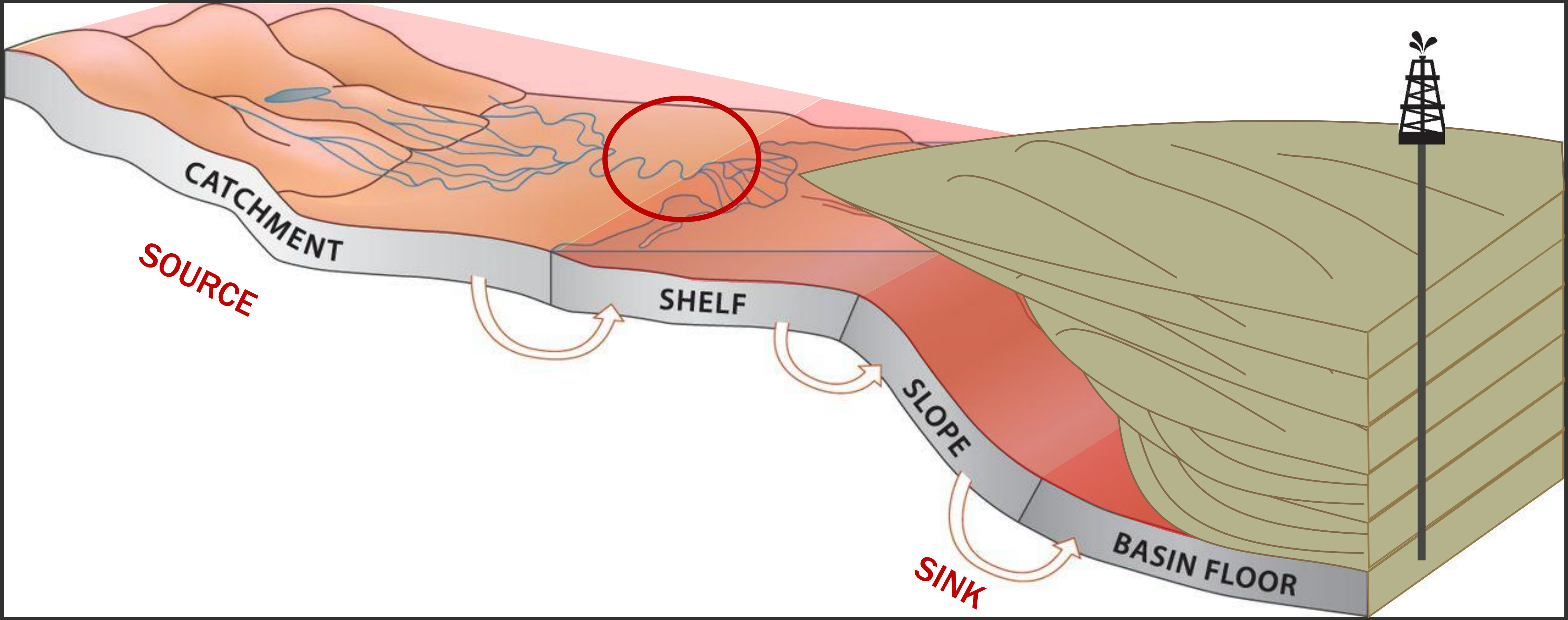

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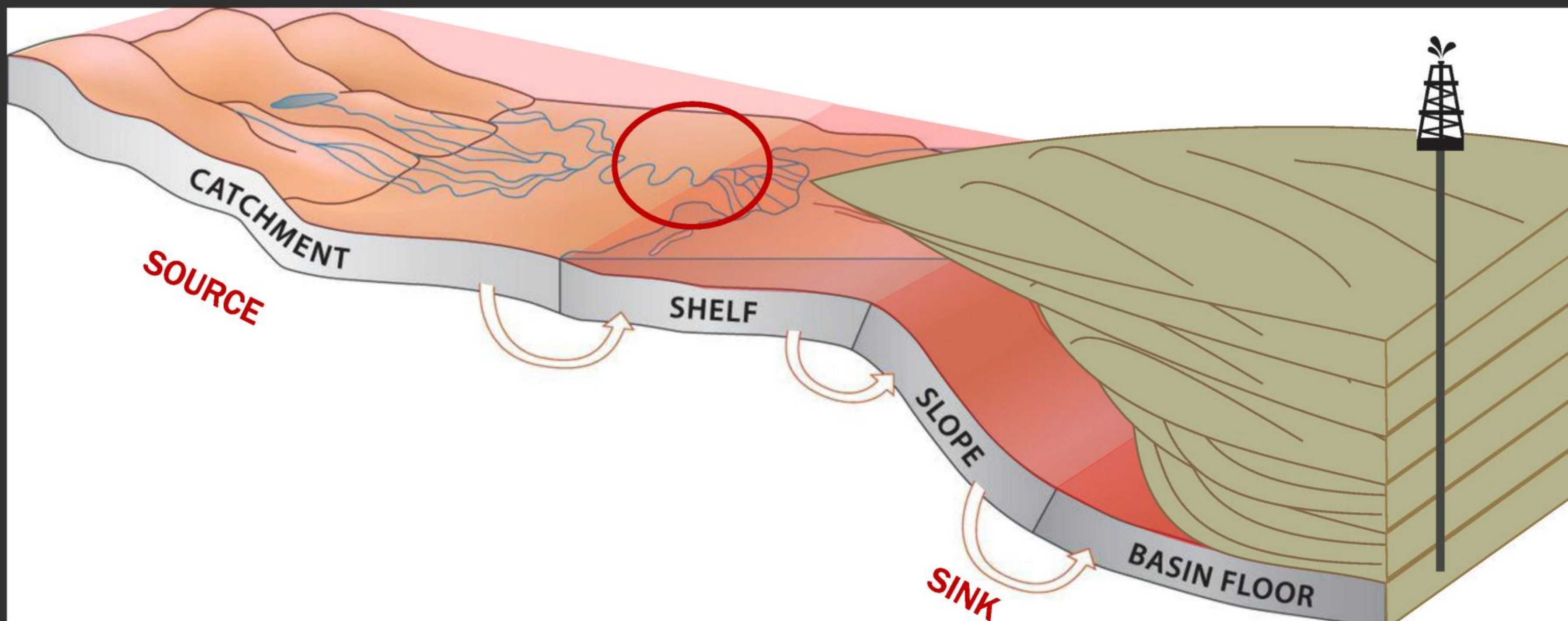

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Presenter’s notes: Source-to-sink is the concept that evaluates the full journey of each grain, from the moment it is sourced from the highest peak through ultimate deposition in the deepest basin sink. Source-to-sink was first introduced conceptually by Meade (1972,1982) (*Presenter’s notes continued on next slide.*)

(*Presenter's notes continued from previous slide*.)

and is defined as any erosional-depositional system where sediment is eroded, transported and deposited (Somme et al 2009). This system is comprised of a series of segments including: catchment or drainage area, shelf, slope and basin floor. Each segment can be independently affected by variables such as regional climate and tectonics (e.g. Wolman & Miller, 1960; Blum & Tornquist, 2000) and yet they are interrelated in that erosion or deposition within one segment will be manifested in morphological alteration within another (Moore, 1969).

The ability to understand how each segment of this system interdepends and accurately estimate sediment flux through the source-to-sink system is critical to understanding ancient hydrocarbon systems or impacts of sediment flux on modern communities (Martinsen et al,2010).

Whether applied to validating a source-to-sink flux interpretation, or facilitating a more complete basin fill analysis by supporting estimates on sediment supply, the need to most accurately estimate sediment flux is evident (e.g. Holbrook and Wanas, 2014; Hutton and Syvitski, 2008; Kettner and Syvitski, 2008; Parker et al, 2008; Whittaker et al. 2010). Refining estimates on sediment flux is particularly significant within continental basin reservoirs where fluvial sandstones are common hydrocarbon targets for exploration (Bohacs, 2012).

Established Methods

- Established methods for determining sediment flux from source to sink include:
  - Grain Sequestration
  - Catchment Approaches
  - Accumulated Basin Volume
  - Fulcrum Approach

(https://www.tes.com/lessons/V_fhRwq4swfO4Q/the-life-of-water-by-emmanuel-m)

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(https://www.britannica.com/science/rock-geology)

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(http://www.globalrivers.org/wp-content/uploads/2014/09/AmazonBasin_DrainageNetwork_0720014b.jpg)

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(https://eoimages.gsfc.nasa.gov/images/imagerecords/3000/3309/landsat_lakeeyre_lrg.jpg)

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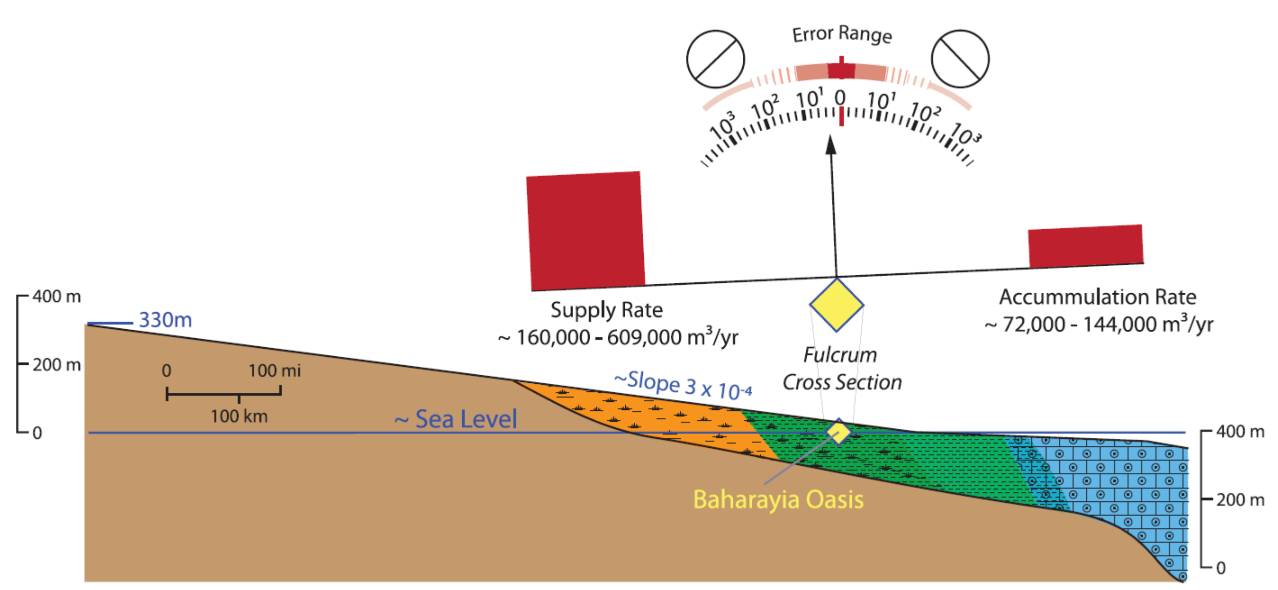


(Holbrook and Wanas, 2014)

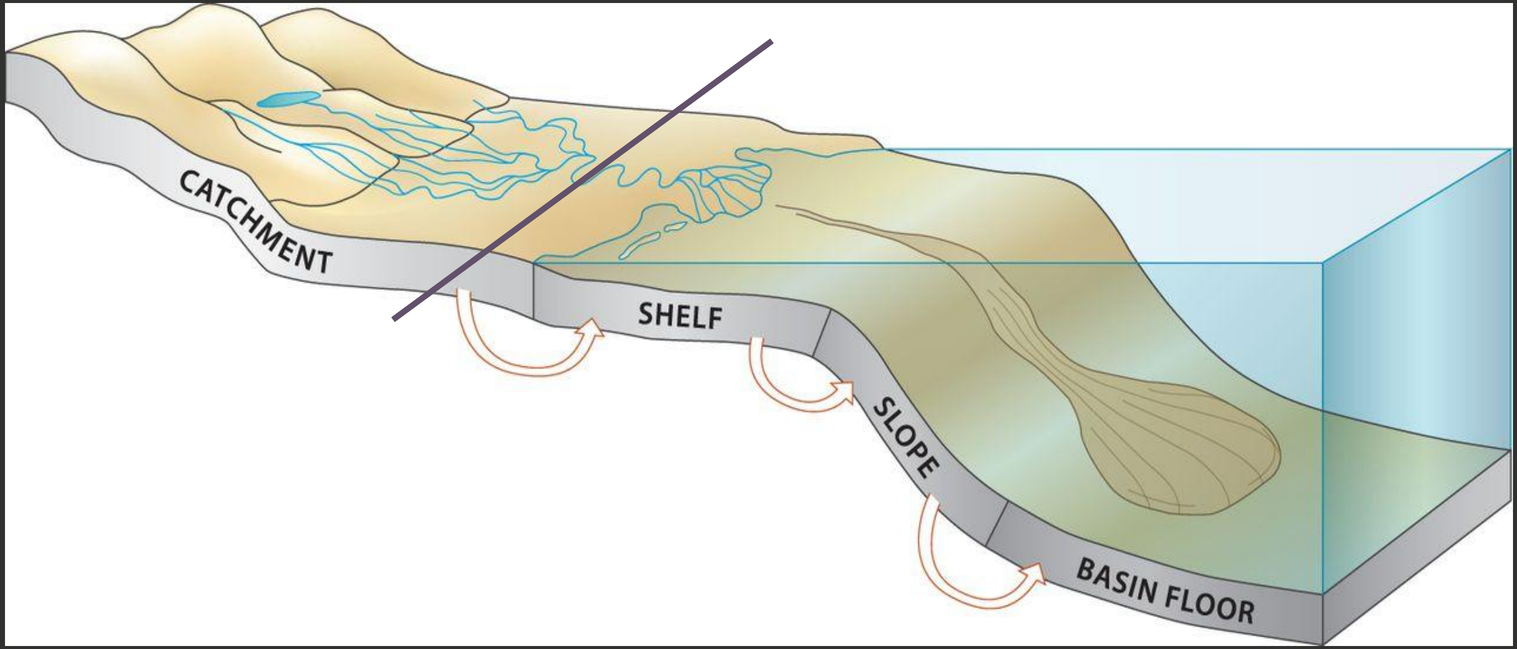
Fulcrum Approach

Pros

- Uses readily available data such as channel bankfull/ thickness and grain size.

Cons

- Calculations currently rely on generic default values, only accurate within an order of magnitude.



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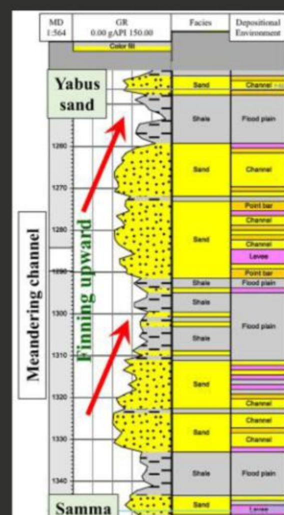

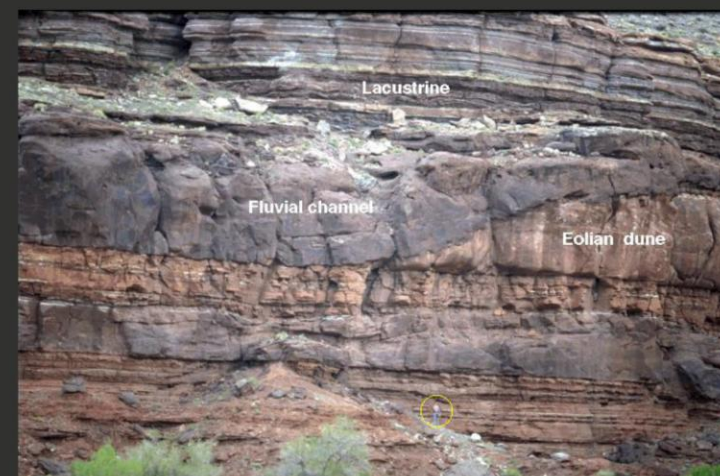

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Presenter's notes: 4Based on the assumption that for sediment to be moved from source to sink it must pass through a cross sectional point, meaning by estimating the amount of sediment passing through this fulcrum point the amount of sediment moving from the source to the sink can be determined (Holbrook and Wanas, 2014). (*Presenter's notes continued on next slide.*)

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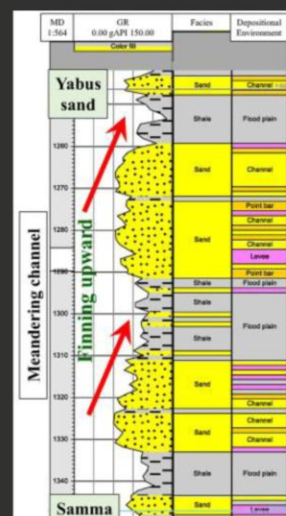

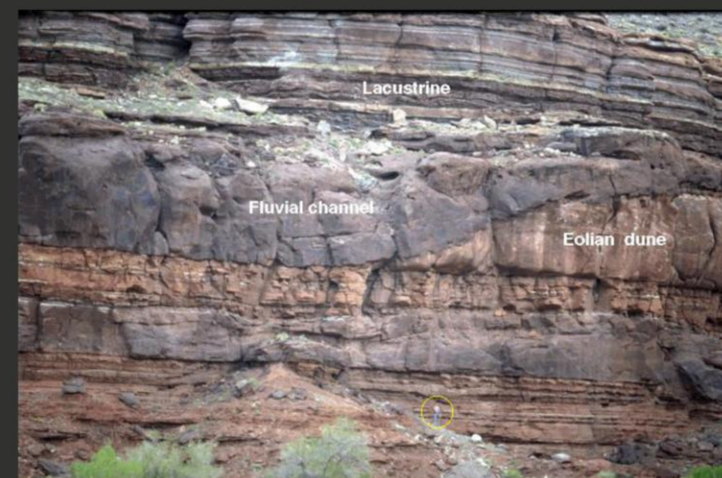

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The basis for the Fulcrum approach is the assumption that for sediment to be moved from source to sink it must pass through a cross sectional point, meaning by estimating the amount of sediment passing through this fulcrum point the amount of sediment moving from the source to the sink can be determined (Holbrook and Wanas, 2014). While there are several established methods for determining sediment flux from source to sink all methods have limitations and are only accurate within an order of magnitude.

The accuracy of the Fulcrum approach relies on estimating the duration of time a stream runs at bankfull flow (t_{bd}) and the proportion of sediment discharged during this flow (b). Mean annual sediment discharge (Q_{mas}) is estimated for a channel by multiplying the variables of (t_{bd}) and (b) against a calculated value for bankfull sediment discharge (Q_{bts}), with full methods for calculation of (Q_{bts}) provided in Holbrook and Wanas (2014) (Equation 1).

$$Q_{mas}=Q_{bts}(t_{bd})b$$

Improving the Fulcrum Approach

How to improve the accuracy of this approach?

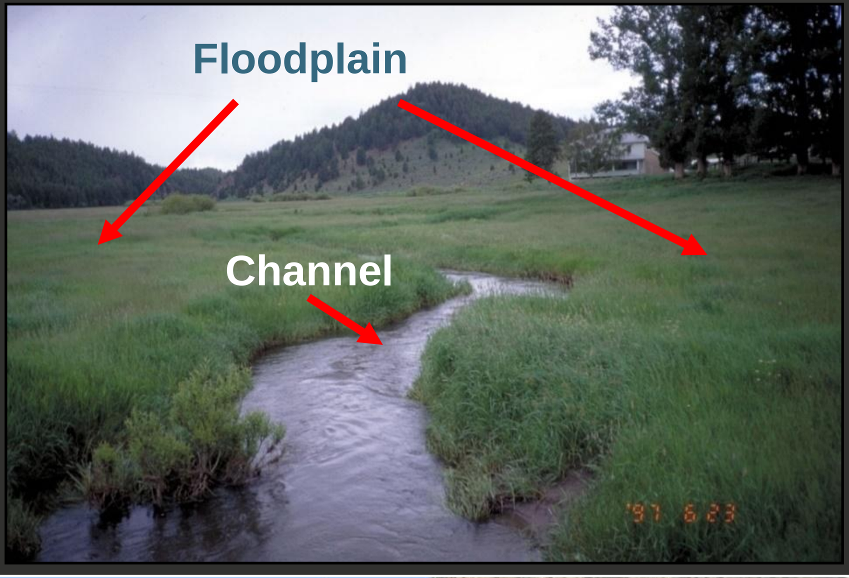
$$Q_{mas}=Q_{bts}(t_{bd})b$$

Q_{mas} = Mean annual sediment discharge

Q_{bts} = Bankfull sediment discharge (Q_{bts})

t_{bd} = Duration of time a stream runs at bankfull flow

b = Inverse of the proportion of the total annual sediment load



(Courtesy of R. Harrison & S. Horne)

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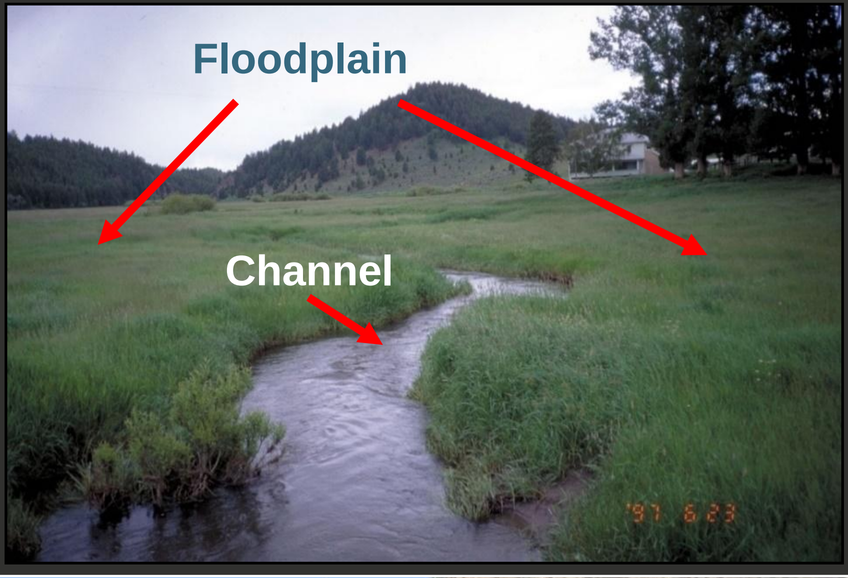

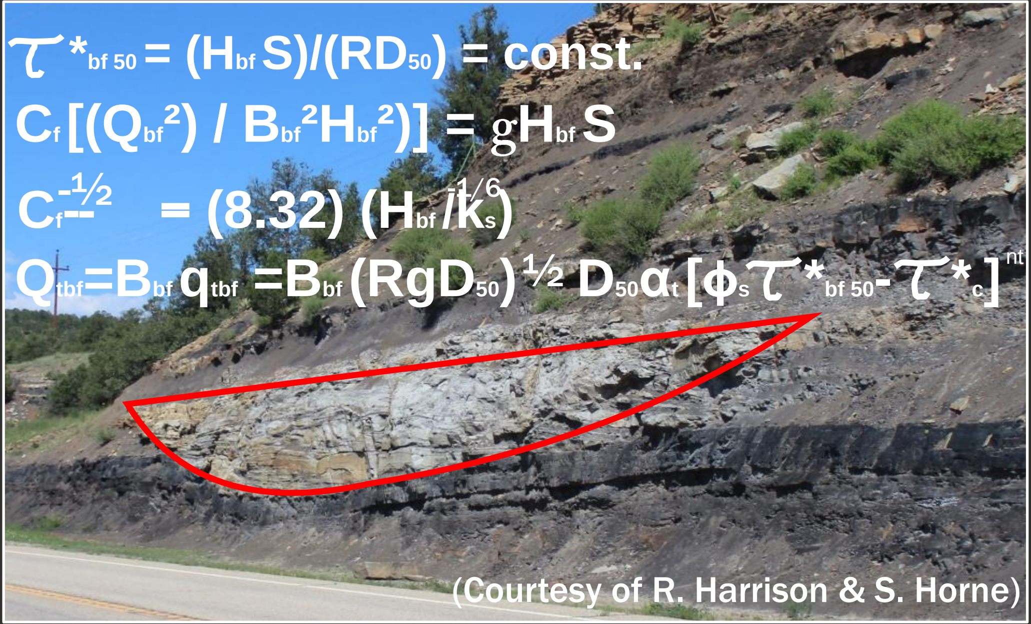

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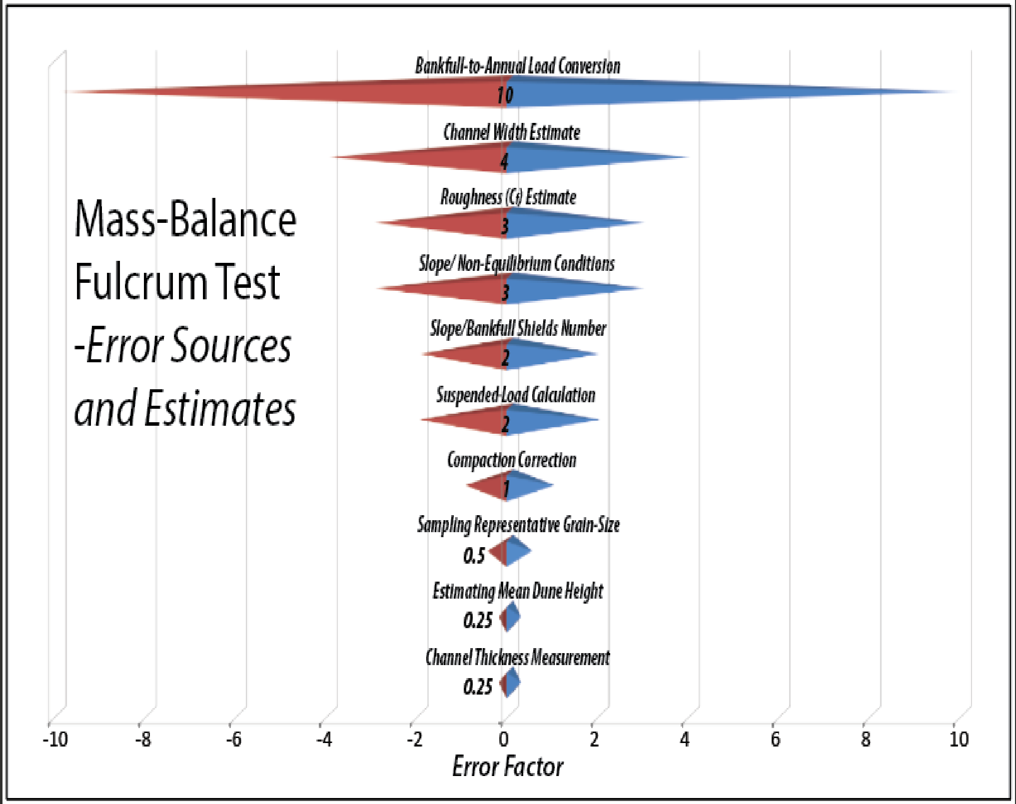

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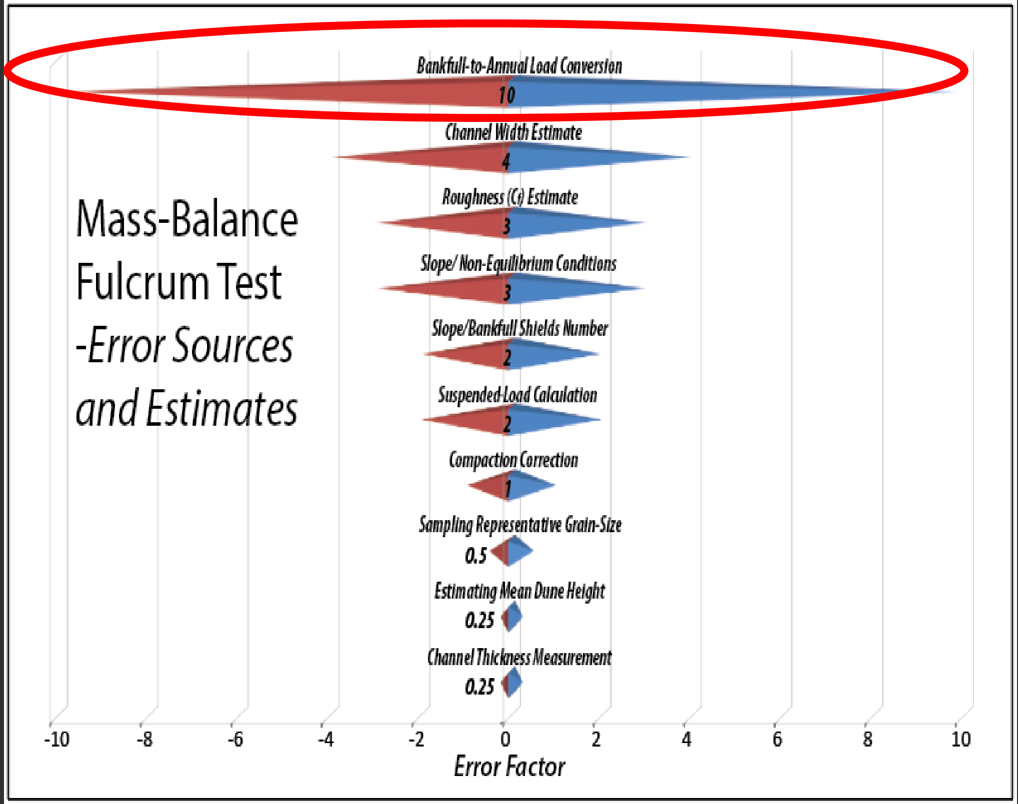

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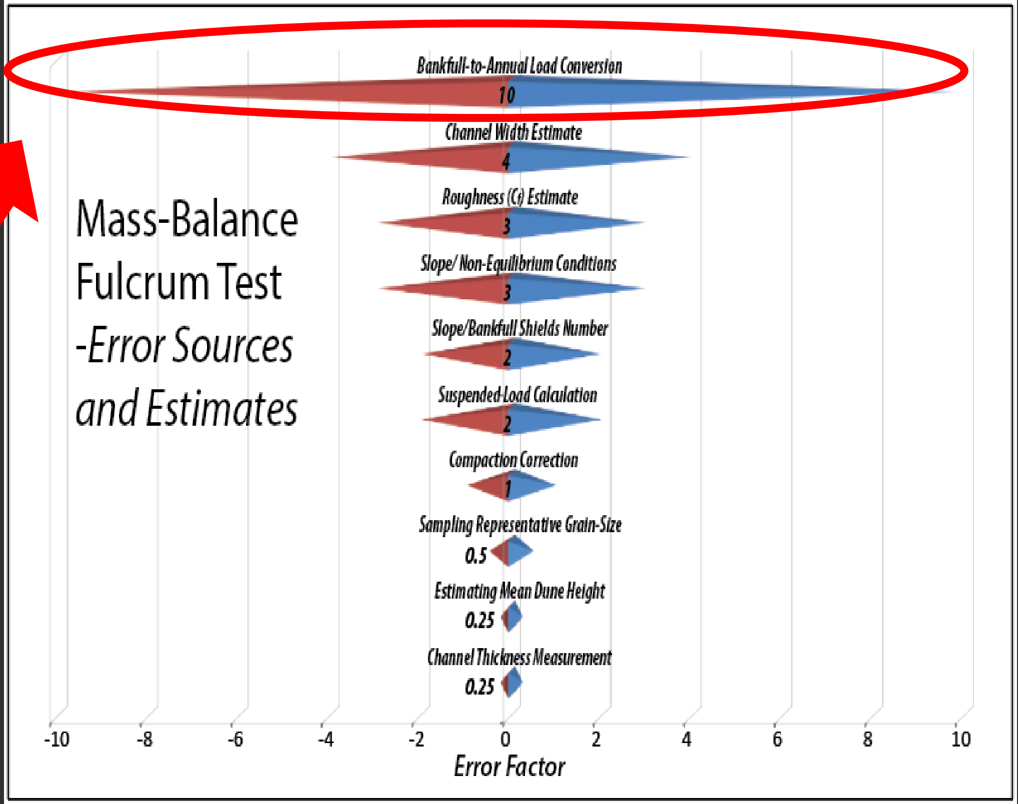

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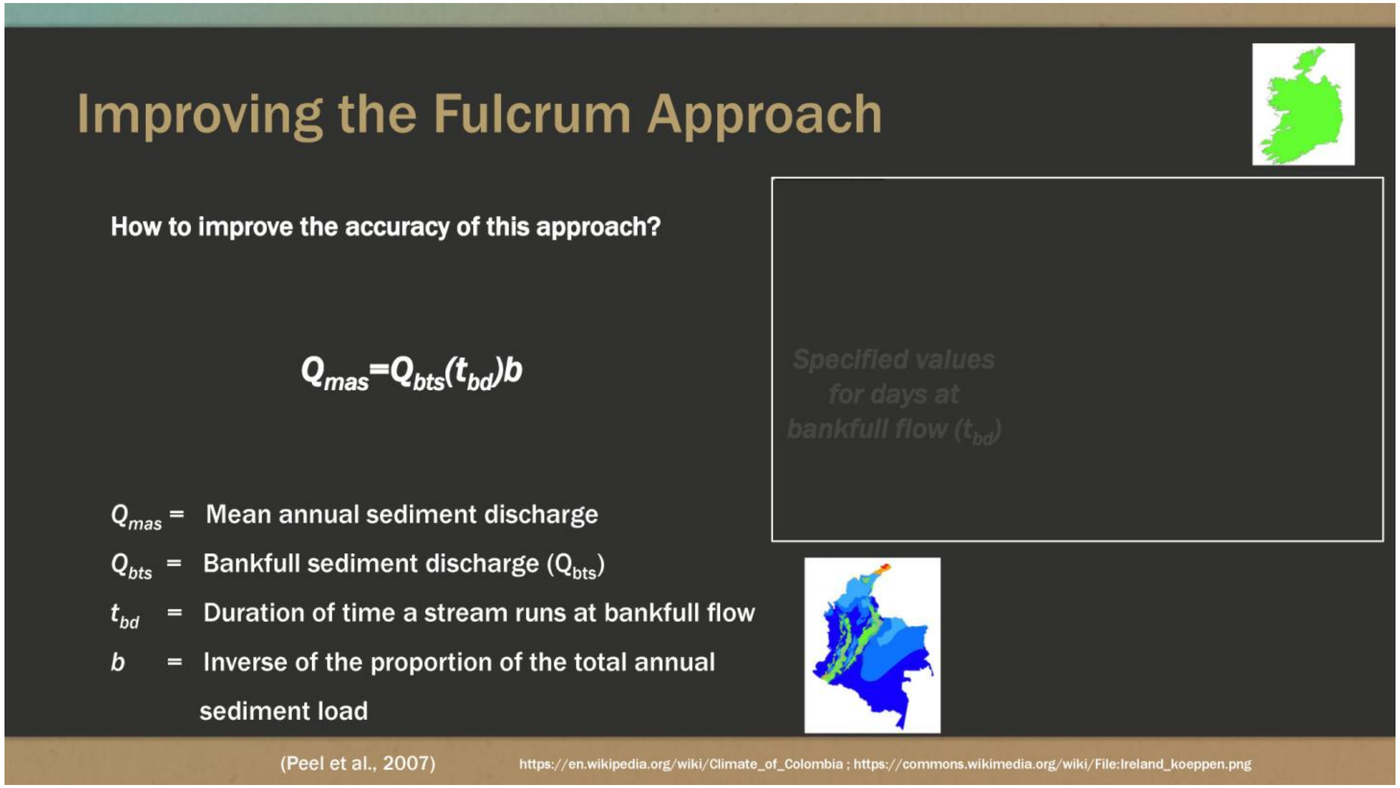
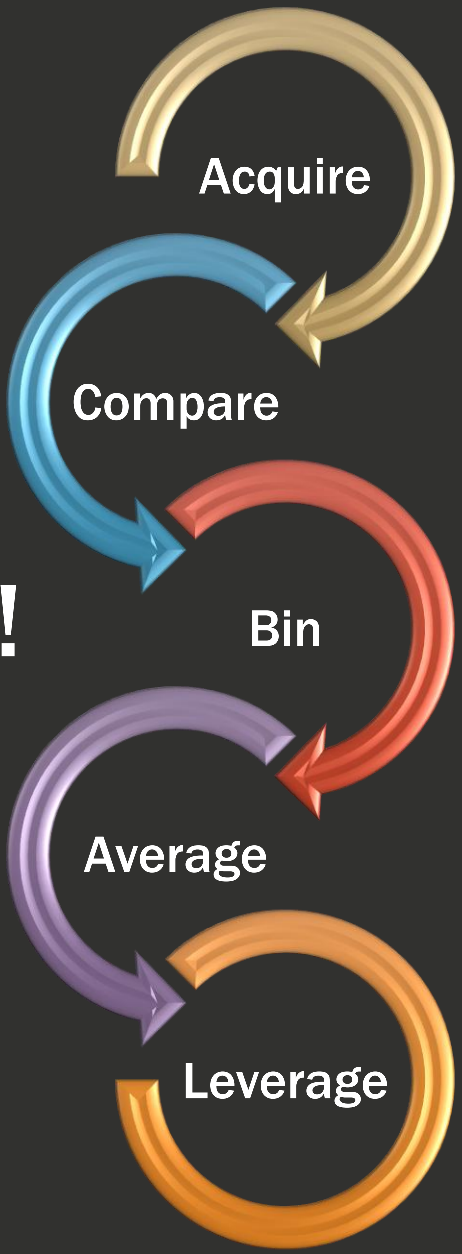


Presenter's notes: The accuracy of the Fulcrum approach relies on estimating the duration of time a stream runs at bankfull flow (t_{bd}) and the proportion of sediment discharged during this flow (b). Mean annual sediment discharge (Q_{mas}) is estimated for a channel by multiplying the variables of (t_{bd}) and (b) against a calculated value for bankfull sediment discharge (Q_{bts}), with full methods for calculation of (Q_{bts}) provided in Holbrook and Wanas (2014) (Equation 1).

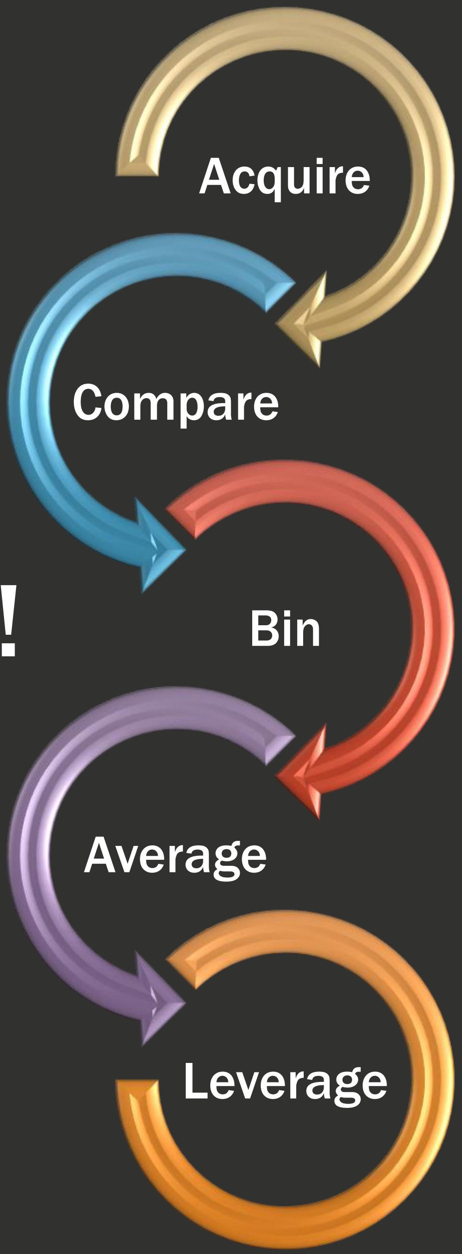
$$Q_{mas}=Q_{bts}(t_{bd})b$$

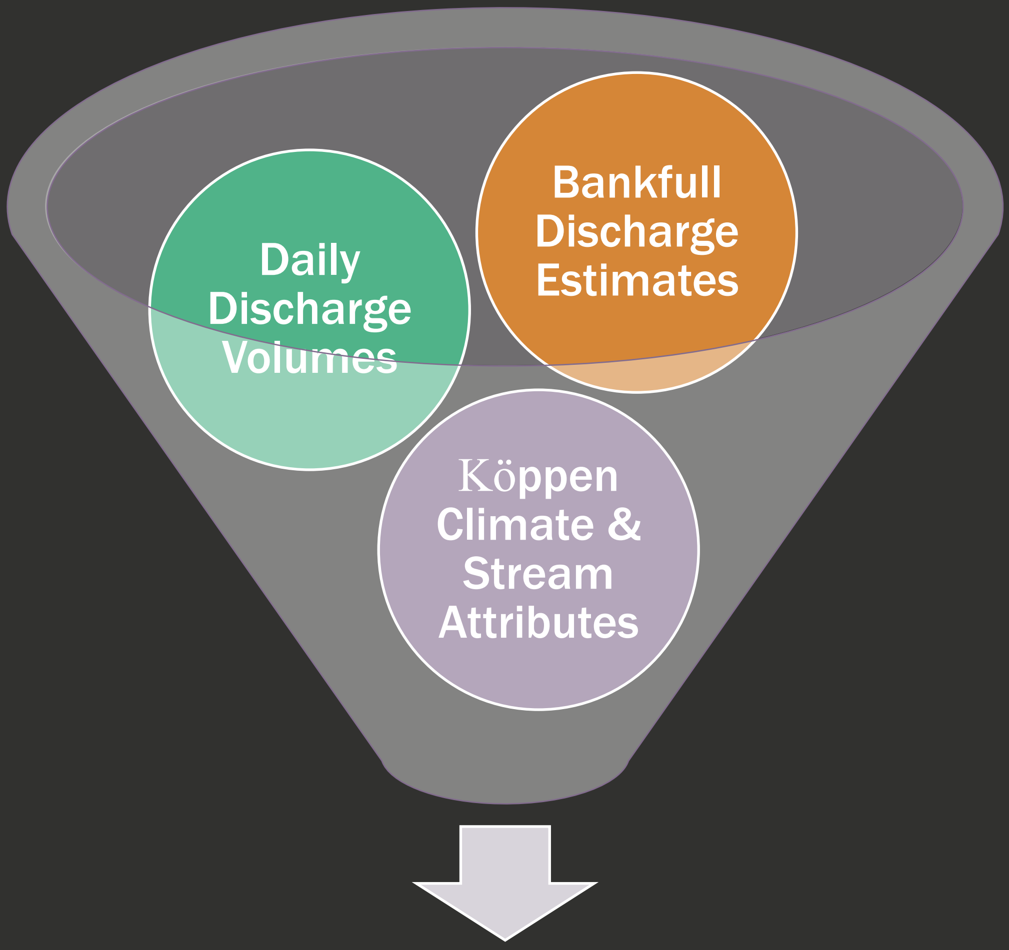
Bankfull flow is defined as the channel forming flow (Wolman and Miller, 1960) that fills the channel to the top of the river banks on the brink of spilling onto the floodplain (Williams, 1978). The effective discharge of a stream is defined as the averaged discharge that transports the largest percentage of the sediment annually (Andrews, 1980). Effective and bankfull discharge are not the same but do generally converge on the same value (Andrews, 1980). The bankfull channel dimension is determined by the flood that has sufficient erosive power and reoccurs often enough to be the dominating force shaping the channel, and the effective discharge is the most erosive flood, denoting these discharges would be similar.

Through DATA!



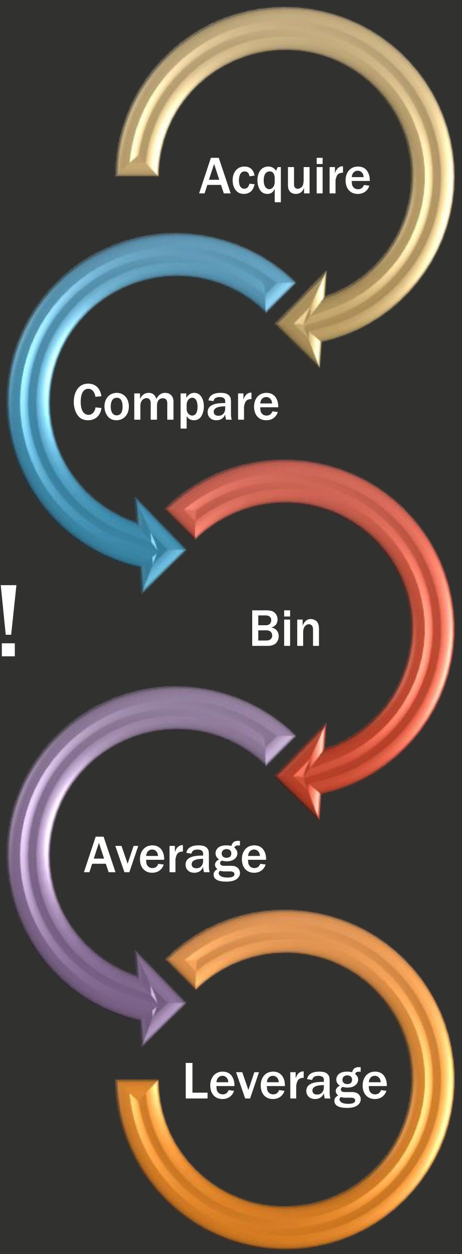
Through DATA!





RAFTER Database

Through DATA!

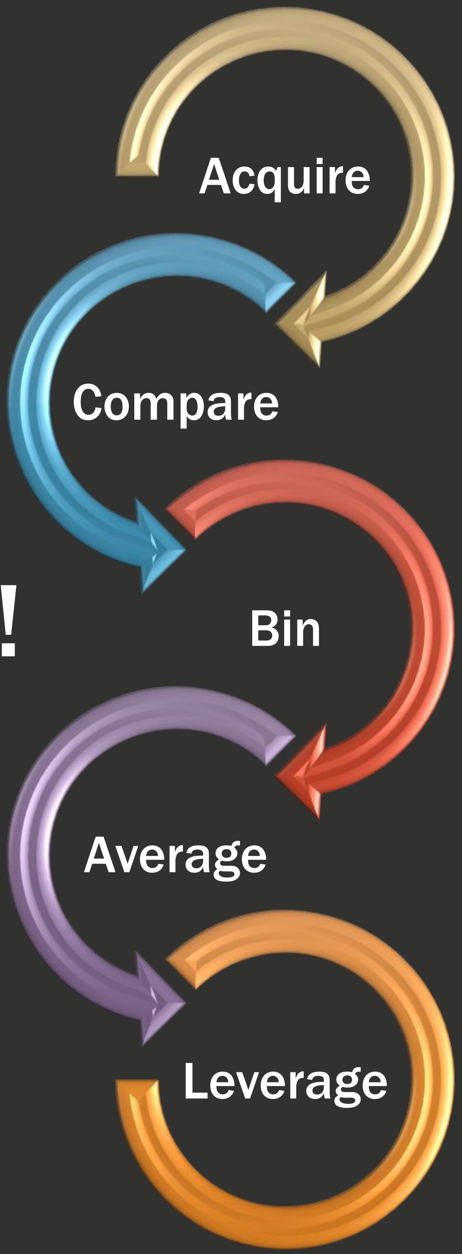


- Compare collected bankfull discharge data to actual daily discharge values recorded at stream gauging sites.
- Derive number of days annually each stream runs at bankfull flow.

Site Number 03254550

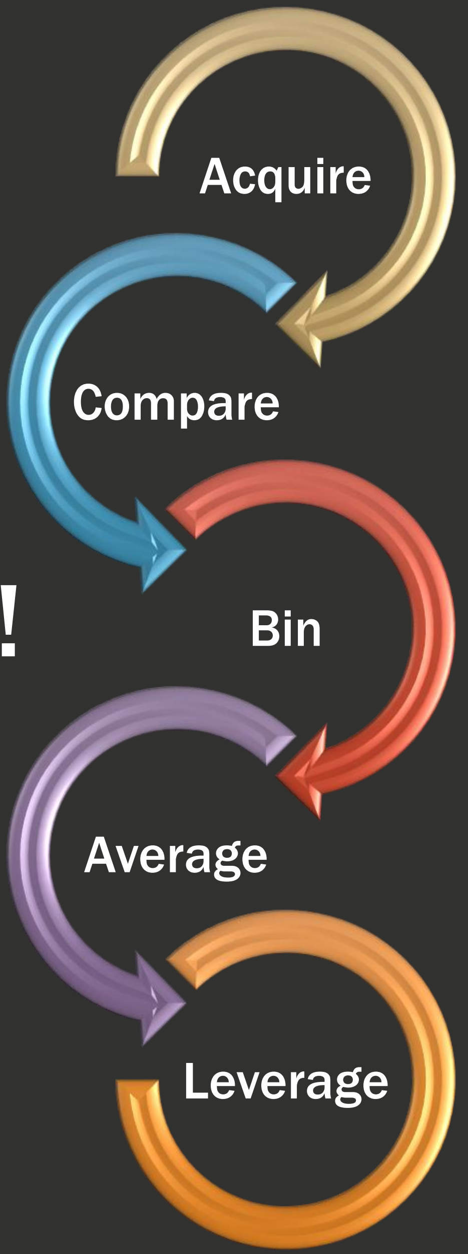
Site Name: Banklick Creek
Bankfull Discharge: 21.21 m^3/sec
Bankfull Channel Width: 21.96 m
Bankfull Channel Depth: .98 m

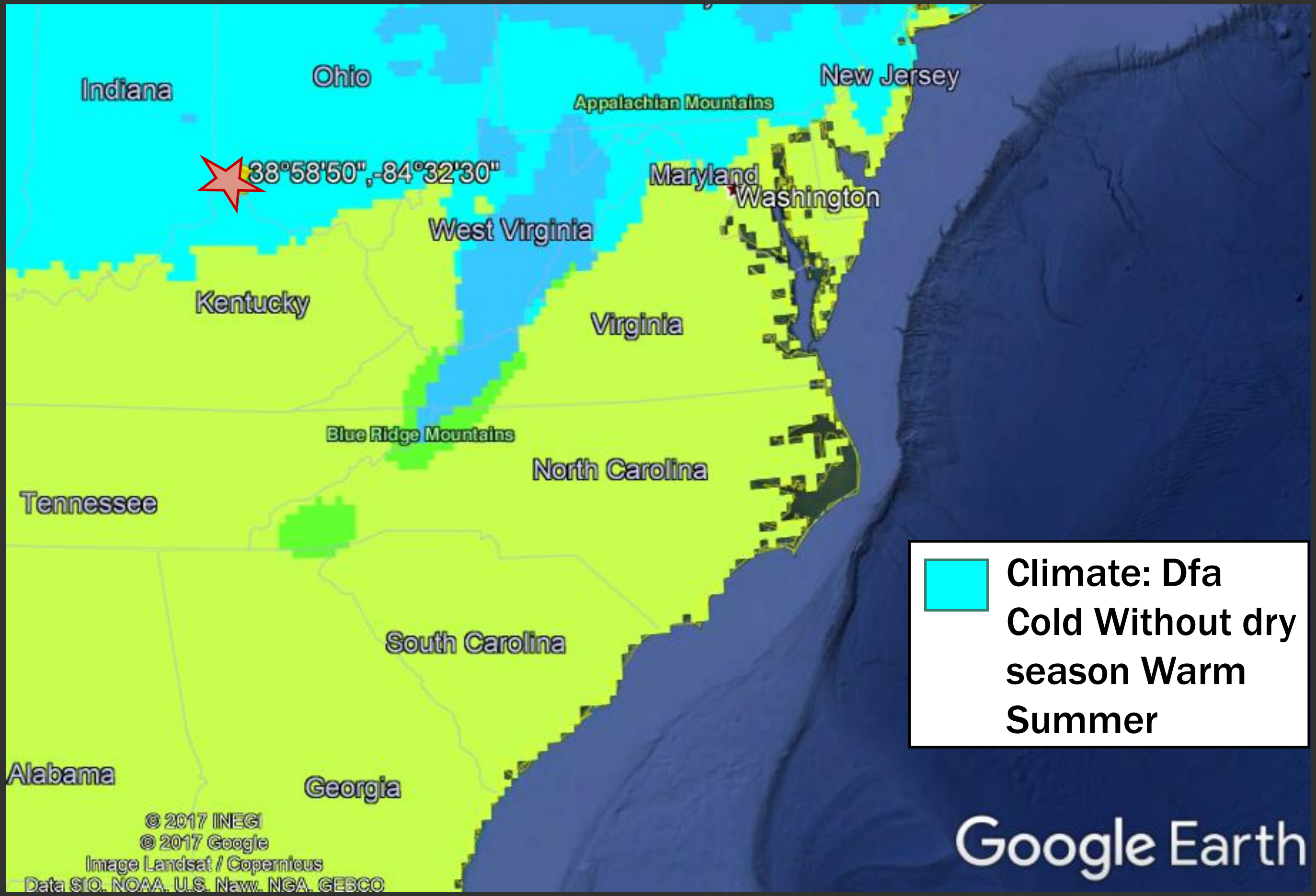
Through DATA!



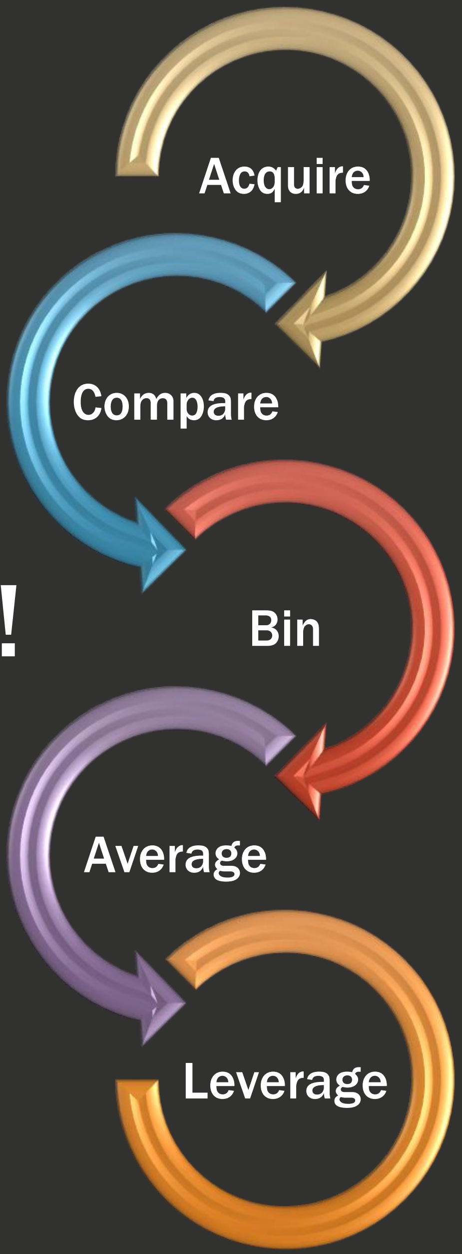
SITE NUMBER 03254550 ANNUAL OCCURENCES WITHIN 10% OF BANKFULL FLOW (DAYS)	YEAR
2	2000
2	2001
0	2002
1	2003
0	2004
1	2005
0	2006
0	2007
1	2008
0	2009
1	2010
2	2011
1	2012
3	2013
1	2014
1	2015
0	2016
Annual Average 0.94 (Days)	

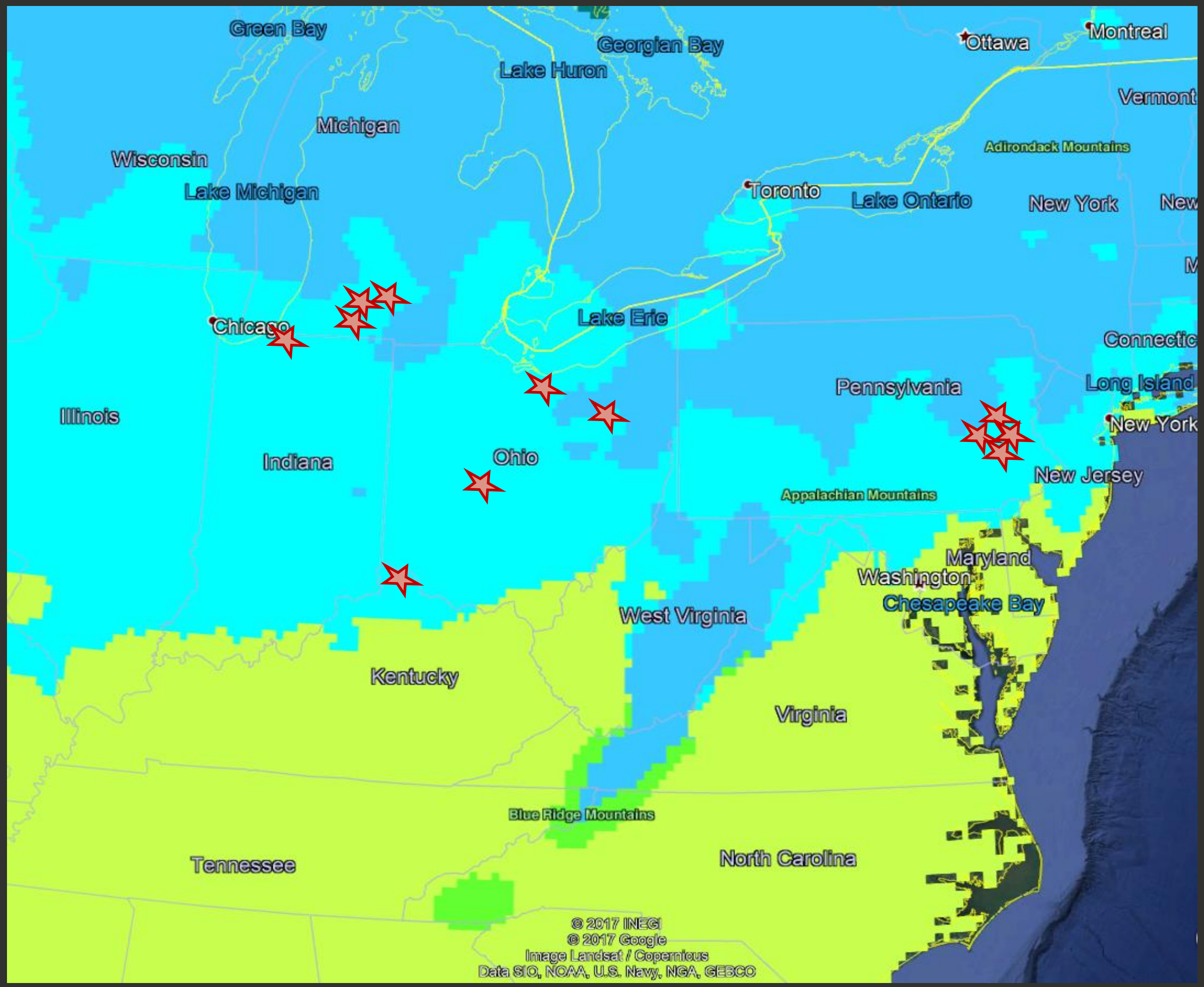
Through DATA!



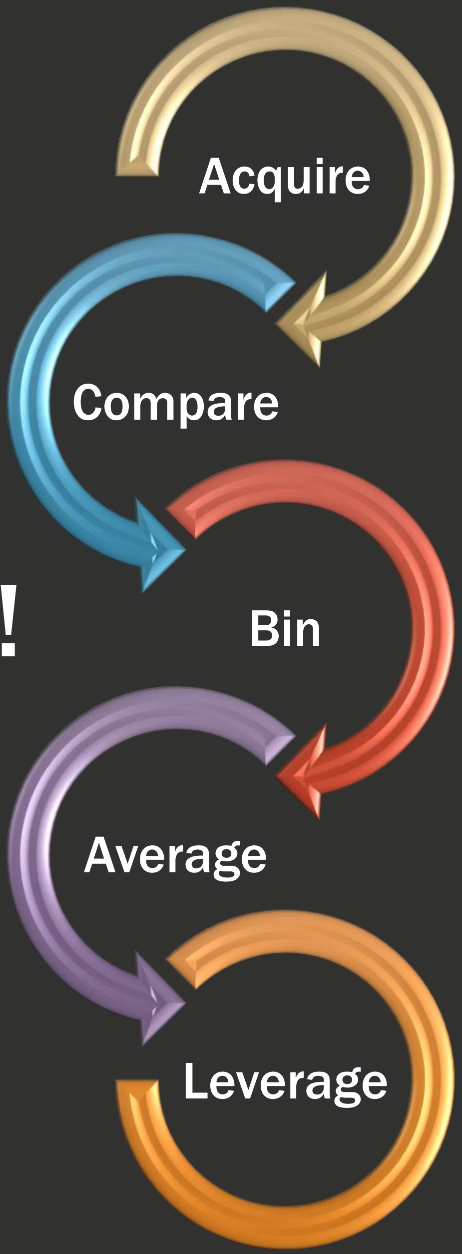


Through DATA!





Through DATA!



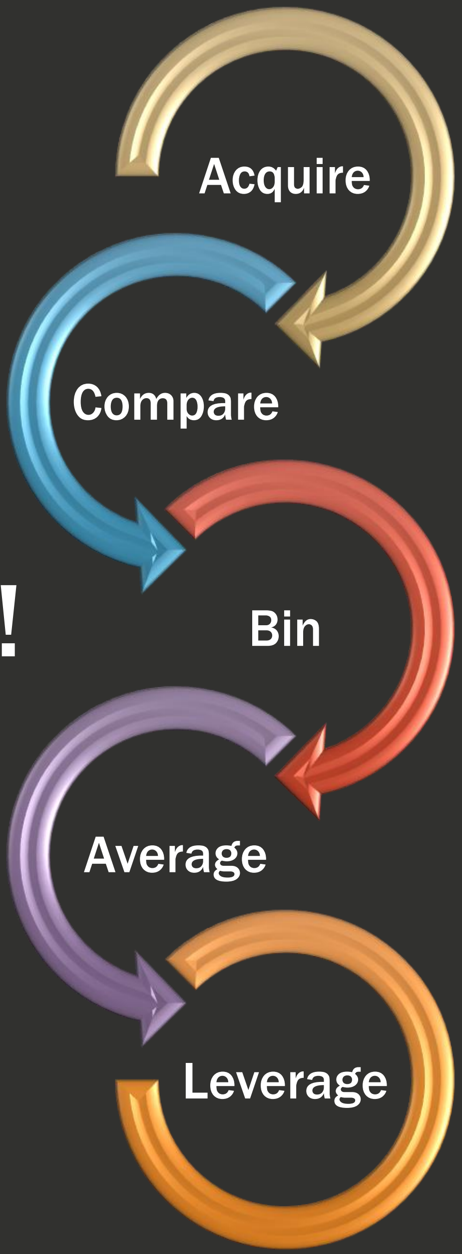
Example Query:

Climate : Dfa (Cold Without dry season Warm Summer)

Drainage Area > 50 km^2 and <260 km^2

t_{bd} = Streams runs at bankfull flow 5.7 days a year

Through DATA!



$$Q_{mas}=Q_{bs}(t_{bd})b$$

Q_{mas} = Mean annual sediment discharge

Q_{bts} = Bankfull sediment discharge (Q_{bts})

t_{bd} = Duration of time a stream runs at bankfull flow

b = Inverse of the proportion of the total annual sediment load

Data Inventory

Number of Sites Acquired	Data Source
51	HYDAT: The Water Survey of Canada (WSC)
7	IDEAM: Institute of Hydrology, Meteorology and Environmental Studies: Colombia
39	OPW: The Office of Public Works: Ireland
514	USGS: United States Geological Survey : National Water Information System
Total Site Count: 611	

Data Inventory

Number of Sites in Study	Data Source
46	HYDAT: The Water Survey of Canada (WSC)
7	IDEAM: Institute of Hydrology, Meteorology and Environmental Studies: Colombia
39	OPW: The Office of Public Works: Ireland
432	USGS: United States Geological Survey : National Water Information System
Total Site Count: 524	

Data Inventory

Number of Sites in the Study	Stream Size
451	Small: Drainage Area < 2,000 km^2
67	Medium: Drainage Area 2,001- 30,000 km^2
6	Large: Drainage Area > 30,000 km^2

Data Inventory

Number of Sites	Köppen Climate Classification	Major Climate	Climate Description
5	Af	Tropical	Tropical Rainforest
5	Am	Tropical	Tropical Monsoon
1	Aw	Tropical	Tropical Savannah
17	BSh	Arid	Arid Steppe Hot
35	BSk	Arid	Arid Steppe Cold
4	BWh	Arid	Arid Desert Hot
2	BWk	Arid	Arid Desert Cold
90	Cfa	Temperate	Temperate Without dry season Hot Summer
41	Cfb	Temperate	Temperate Without dry season Warm Summer
8	Csa	Temperate	Temperate Dry Summer Hot Summer
36	Csb	Temperate	Temperate Dry Summer Warm Summer
83	Dfa	Cold	Cold Without dry season Hot Summer
158	Dfb	Cold	Cold Without dry season Warm Summer
12	Dfc	Cold	Cold Without dry season Cold Summer
7	Dsa	Cold	Cold Dry Summer Hot Summer
17	Dsb	Cold	Cold Dry Summer Warm Summer
3	ET	Polar	Tundra

Data Inventory

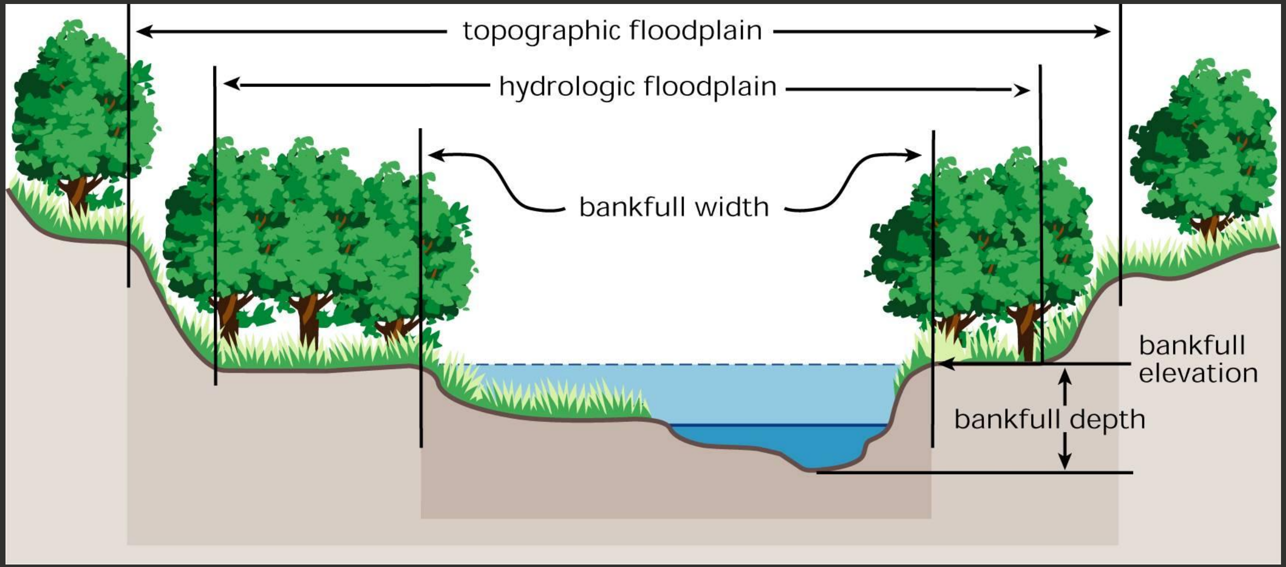
- Spatial Attributes
  - Drainage Area
  - Mean Bankfull-Channel Depth
  - Bankfull-Channel Cross-sectional Area
- Temporal Attribute
  - Bankfull Duration
- Climate Categories
  - Major Climate
  - Köppen Climate

(https://[illegible]sin_DrainageNetwork_072014b.jpg)

(Peel et al., 2007)

Data Inventory

- Spatial Attributes
  - Drainage Area
  - Mean Bankfull-Channel Depth
  - Bankfull-Channel Cross-sectional Area
- Temporal Attribute
  - Bankfull Duration
- Climate Categories
  - Major Climate
  - Köppen Climate



(https://www.globalsurface.../Internet/FSE_MEDIA/2014... Basin_DrainageNetwork_072014b.jpg)

(Peel et al., 2007)

Data Inventory

- Spatial Attributes
  - Drainage Area
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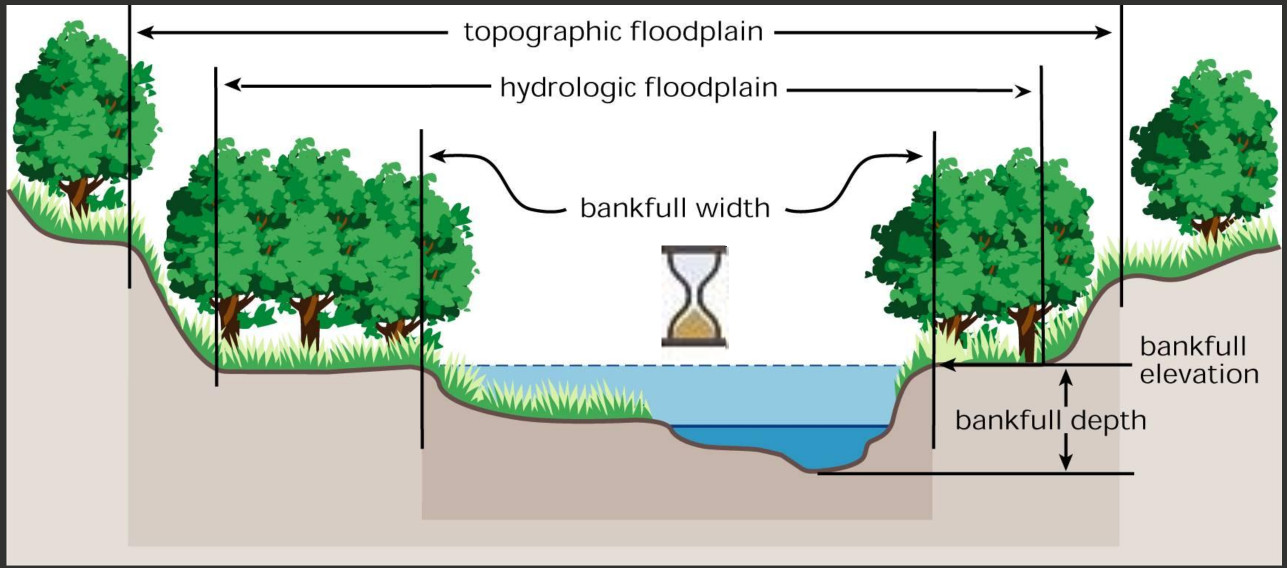

(https://www.[illegible]_DrainageNetwork_072014b.jpg)

(Peel et al., 2007)

Data Inventory

- Spatial Attributes
  - Drainage Area
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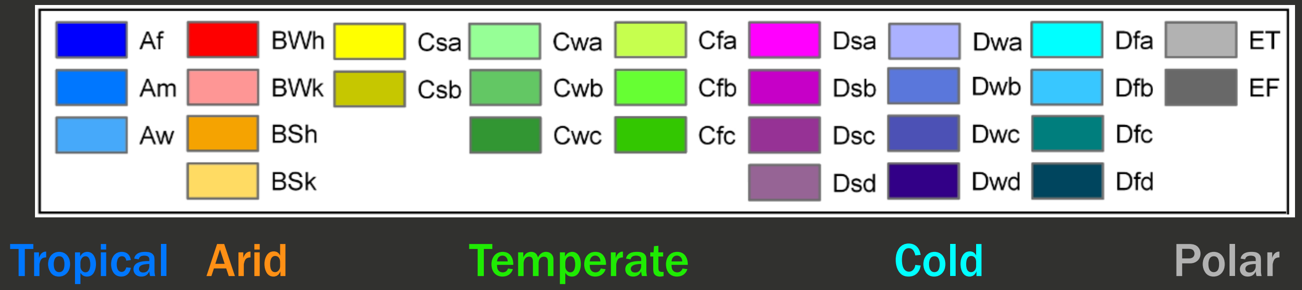

(https://www…_DrainageNetwork_072014b.jpg)

(Peel et al., 2007)

Accessibility: RAFTER Database

```
select sd.SITE_ID,sd.SITE_NAME,rs.STATE_NAME, rc.COUNTRY_NAME,sd.DRAINAGE_AREA_KM, sd.DRAINAGE_AREA_MI,
rcl.CLIMATE_CODE, AVG_WITHIN_10, AVG_WITHIN_20
from SED_BANK_PRD_2017_11_19.dbo.STREAM_DESC_DATA sd
join SED_BANK_PRD_2017_11_19.dbo.BANKFUL_DISCHARGE_LIT bl
on bl.SITE_ID=sd.SITE_ID
join SED_BANK_PRD_2017_11_19.dbo.REF_CLIMATE_LOCATION cl
on sd.county_id=cl.county_Id
and sd.[STATE_ID]= cl.STATE_ID
and sd.COUNTRY_ID=cl.COUNTRY_ID
and  sd.[CLIMATE_ID]=cl.[CLIMATE_ID]
join SED_BANK_PRD_2017_11_19.dbo.REF_CLIMATE rcl
on rcl.CLIMATE_ID=cl.CLIMATE_ID
join SED_BANK_PRD_2017_11_19.dbo.REF_STATE rs
on rs.STATE_ID=sd.S
 join SED_BANK_PRD_  17_11_  ).dbo REF_COU  RY rc
on rc.COUNTRY_ID=sd  OUNTR  _ID
where AVG_WITHIN_10  s nc  null
and cl.CLIMATE_ID='  '
and DRAINAGE_AREA_M_ '100' and D  AREA_MI>
```

100 %

Results | Messages

	SITE_ID	SITE_NAME	STATE_NAME	COUNTRY_NAME	DRAINAGE_AREA_KM	DRAINAGE_AREA_MI	CLIMATE_CODE	AVG_WITHIN_10	AVG_WITHIN_20
1	01450500	Aquashicola Creek at Palmerton PA	Pennsylvania	United States	198.6522330000	76.7000000000	Dfa	0.4285714286	0.9480519481
2	01451800	Jordan Creek near Schnecksville PA	Pennsylvania	United States	137.2694700000	53.0000000000	Dfa	0.2400000000	0.6200000000
3	01452000	Jordan Creek at Allentown PA	Pennsylvania	United States	196.3212420000	75.8000000000	Dfa	0.4027777778	0.8472222222
4	01469500	Little Schuylkill River at Tamaqua PA	Pennsylvania	United States	111.1105710000	42.9000000000	Dfa	0.6494845361	1.1958762887
5	03260700	Bokengehalas Creek near De Graff OH	Ohio	United States	94.0166370000	36.3000000000	Dfa	0.4545454545	0.8787878788
6	04096015	GALIEN RIVER NEAR SAWYER MI	Michigan	United States	209.0121930000	80.7000000000	Dfa	5.4705882353	9.9411764706
7	04096515	SOUTH BRANCH HOG CREEK NEAR ALLEN MI	Michigan	United States	126.1325130000	48.7000000000	Dfa	11.7872340426	24.3617021277
8	04097170	PORTAGE RIVER AT W AVENUE NEAR VICKSBURG MI	Michigan	United States	176.6373180000	68.2000000000	Dfa	14.2631578947	29.4736842105
9	04104945	WANADOGA CREEK NEAR BATTLE CREEK MI	Michigan	United States	125.0965170000	48.3000000000	Dfa	19.6363636364	44.7272727273
10	04105700	AUGUSTA CREEK NEAR AUGUSTA MI	Michigan	United States	100.7506110000	38.9000000000	Dfa	14.4807692308	34.7307692308
11	04199155	Old Woman Creek at Berlin Rd near Huron OH	Ohio	United States	57.2387790000	22.1000000000	Dfa	0.5925925926	0.8518518519
12	04206220	Yellow Creek at Botzum OH	Ohio	United States	79.5126930000	30.7000000000	Dfa	0.0000000000	0.0000000000

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R.A.F.T.E.R.

River Analogues and Fulcrum Transport Estimates Repository

River Analogues

- Select parameters of climate, drainage area and/or channel size to query a database of over 600 streams and return all analogous rivers based on the designated attributes.

Go

Stream Specific Bankfull Duration (t_{bd})

- Query a database of over 500 streams, selecting stream specific attributes of climate, drainage area and/or channel size to calculate an average annual days at bankfull duration t_{bd} value.

Go

Fulcrum Theory Approach Sediment Flux Estimates

- Leverage the Fulcrum approach to estimate source-to-sink sediment flux calculations using readily available data in the rock record of channel fill thickness and grainsize.
- Derive sediment flux estimates using a default value for the variable of average annual days of bankfull duration t_{bd} or query adatabase of over 500 streams to input a more stream specific t_{bd} value based on selected parameters of climate, drainage area and/or channel size.

Go

Helpful Links

1. Holbrook and Wanas, 2014 (pdf)
2. Original Fulcrum Theory Approach (xlsx)
3. Dr Holbrook's Home Page
4. Fluvial Research Group Main Page
5. References (pdf)

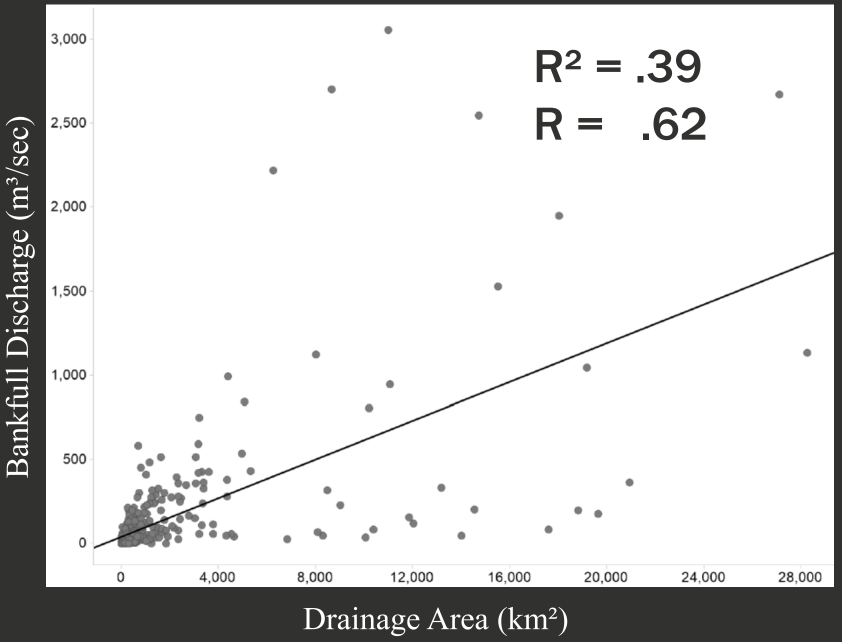
For best user experience, please use Google Chrome Browser and update your browsers to the latest version.

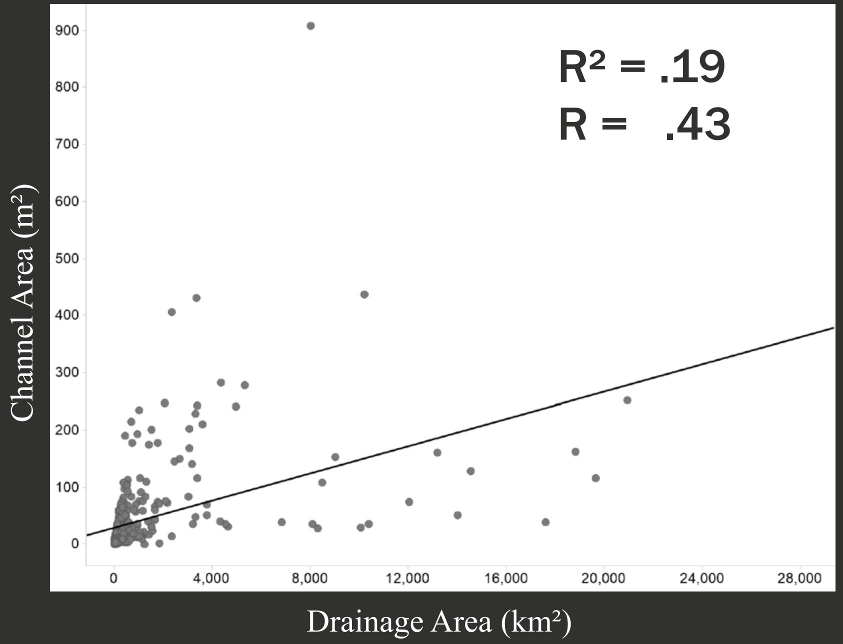
RAFTER

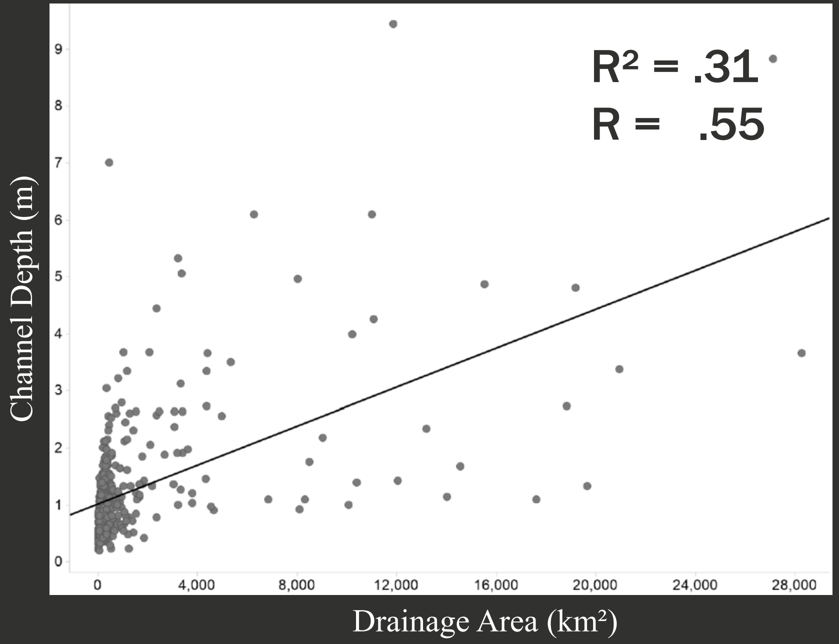
Contact

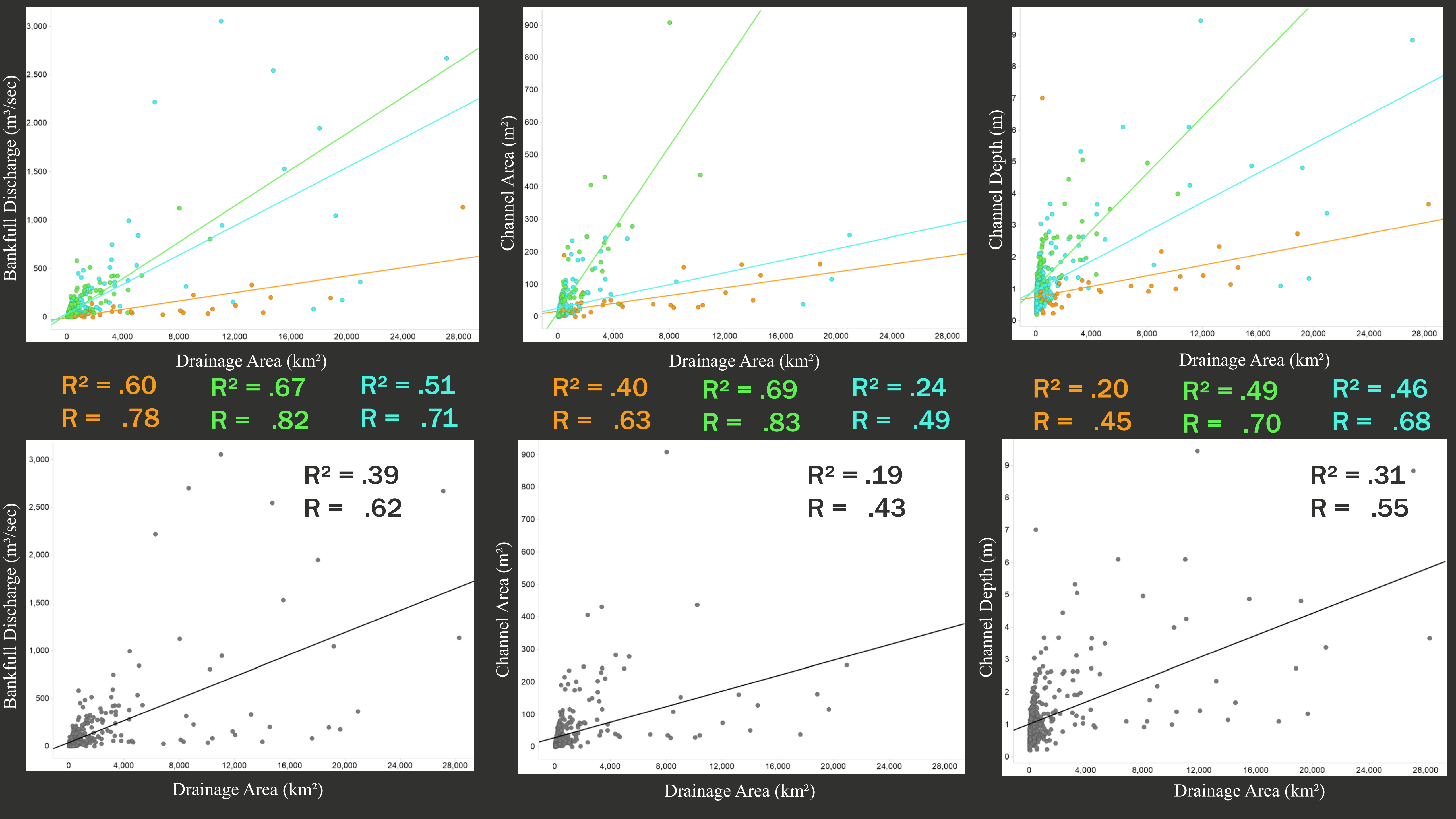
School of Geology, Energy & the Environment
TCU College of Science & Engineering

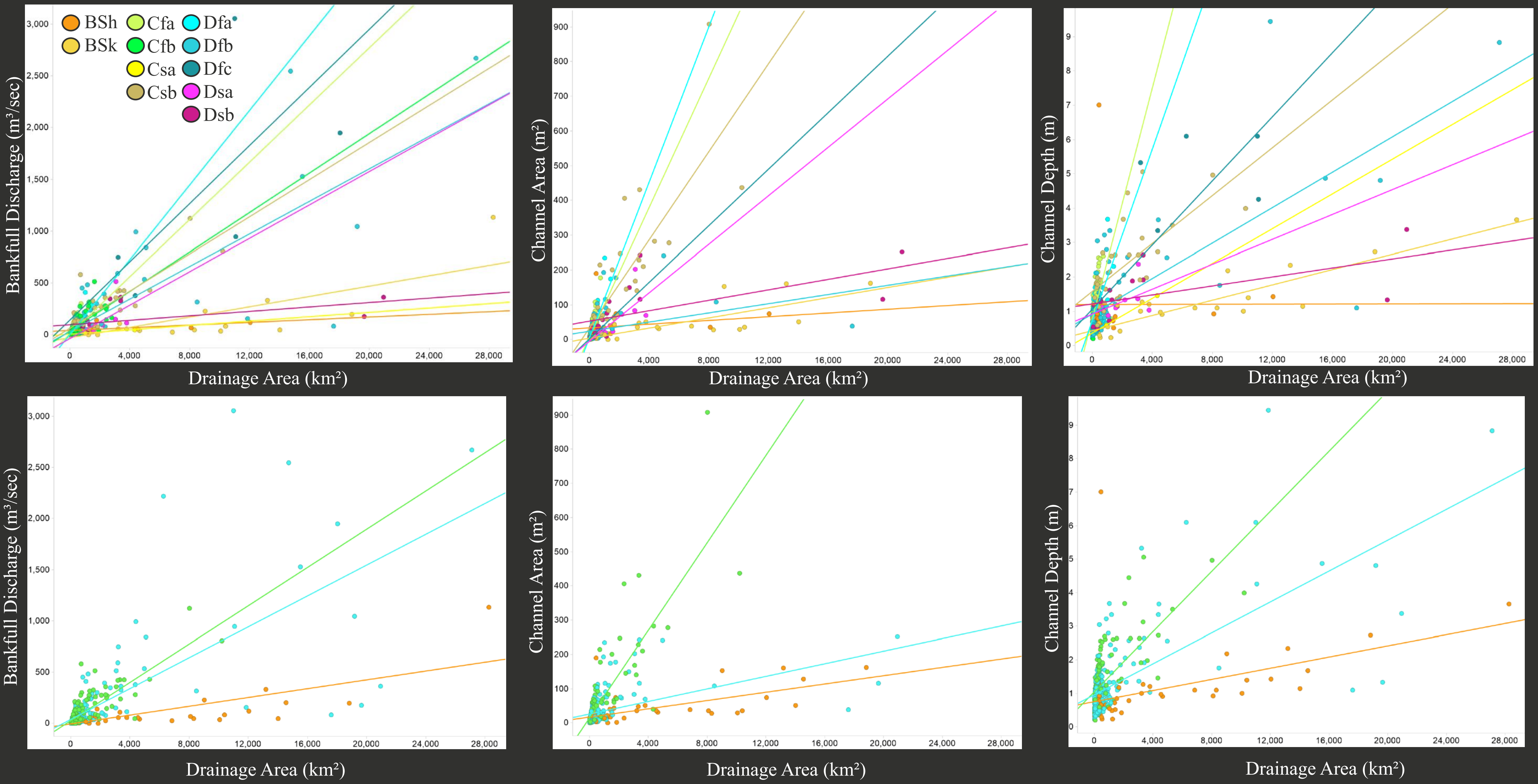
Results: Drainage Area vs. Bankfull Discharge and Channel Dimensions








Bankfull Discharge (m³/sec)
Drainage Area (km²)
Channel Area (m²)
Drainage Area (km²)
Channel Depth (m)
Drainage Area (km²)
R² = .60
R = .78
R² = .67
R = .82
R² = .51
R = .71
R² = .40
R = .63
R² = .69
R = .83
R² = .24
R = .49
R² = .20
R = .45
R² = .49
R = .70
R² = .46
R = .68
Bankfull Discharge (m³/sec)
R² = .39
R = .62
Drainage Area (km²)
Channel Area (m²)
R² = .19
R = .43
Drainage Area (km²)
Channel Depth (m)
R² = .31
R = .55
Drainage Area (km²)

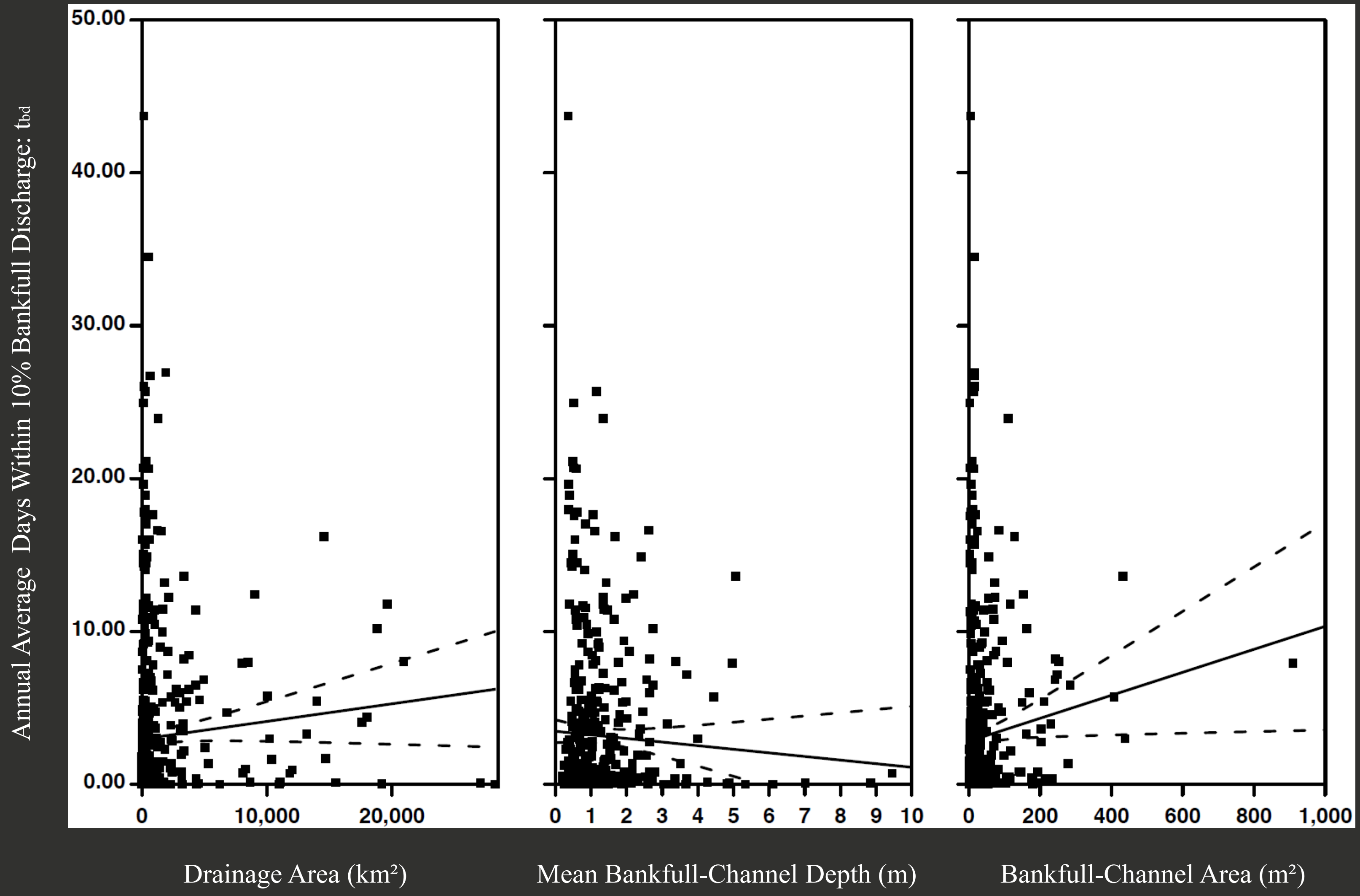


R^2 = .60 | R^2 = .67 | R^2 = .51
R = .78 | R = .82 | R = .71

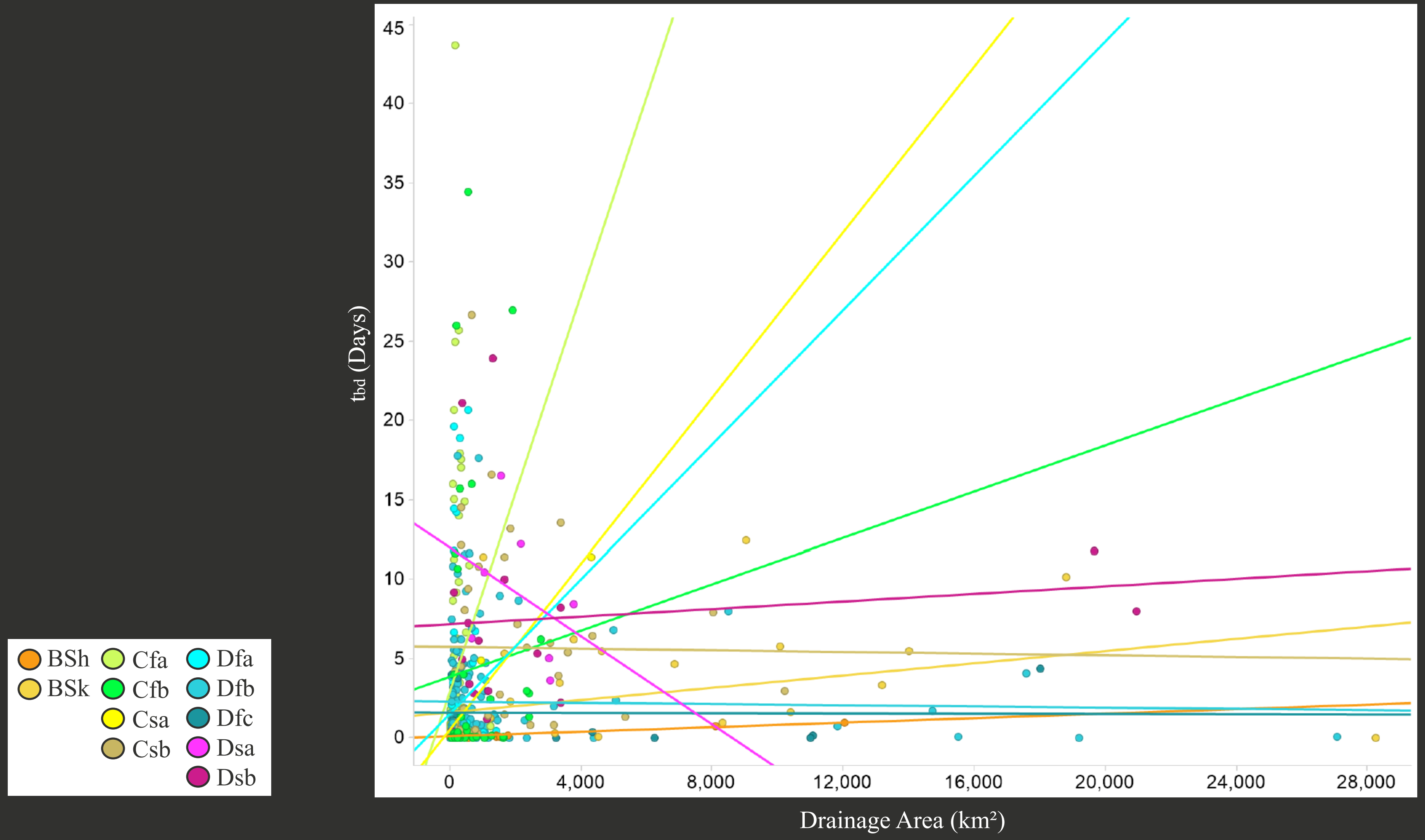
R^2 = .40 | R^2 = .69 | R^2 = .24
R = .63 | R = .83 | R = .49

R^2 = .20 | R^2 = .49 | R^2 = .46
R = .45 | R = .70 | R = .68

Bankfull Duration (t_{bd}) vs. spatial attributes



Bankfull Duration (t_{bd}) vs. spatial attributes



Bankfull Duration (t_{bd}) vs. spatial attributes

Dependent	Independent	R	R^2	Adjusted R^2	Std. Error of the Estimate
t_{bd} (Days)	DA (km^2) D_{bf} (m) A_{bf} (m^2)	0.200972	0.04039	0.033486	5.09156
t_{bd} (Days)	D_{bf} (m) A_{bf} (m^2)	0.156586	0.024519	0.019929	5.09692
t_{bd} (Days)	DA (km^2) A_{bf} (m^2)	0.103189	0.010648	0.006738	5.39108
t_{bd} (Days)	DA (km^2) D_{bf} (m)	0.138192	0.019097	0.014404	5.14157

No Correlation ✕

Between Bankfull Duration

& Spatial Attributes

(Drainage Area & Channel Dimensions)

Bankfull Duration (t_{bd}) vs. climate alone

Category	Dependent	p-value	FStat	Critical F	n
Major Climate	t_{bd} (Days)	5.08E-03	3.7527	2.39	518
Köppen Climate		3.94E-06	3.56222	1.66	518

Bankfull Duration (t_{bd}) vs. climate alone

Category	Dependent	p-value	FStat	Critical F	n
Major Climate	t_{bd} (Days)	5.08E-03	3.7527	2.39 ✓	518
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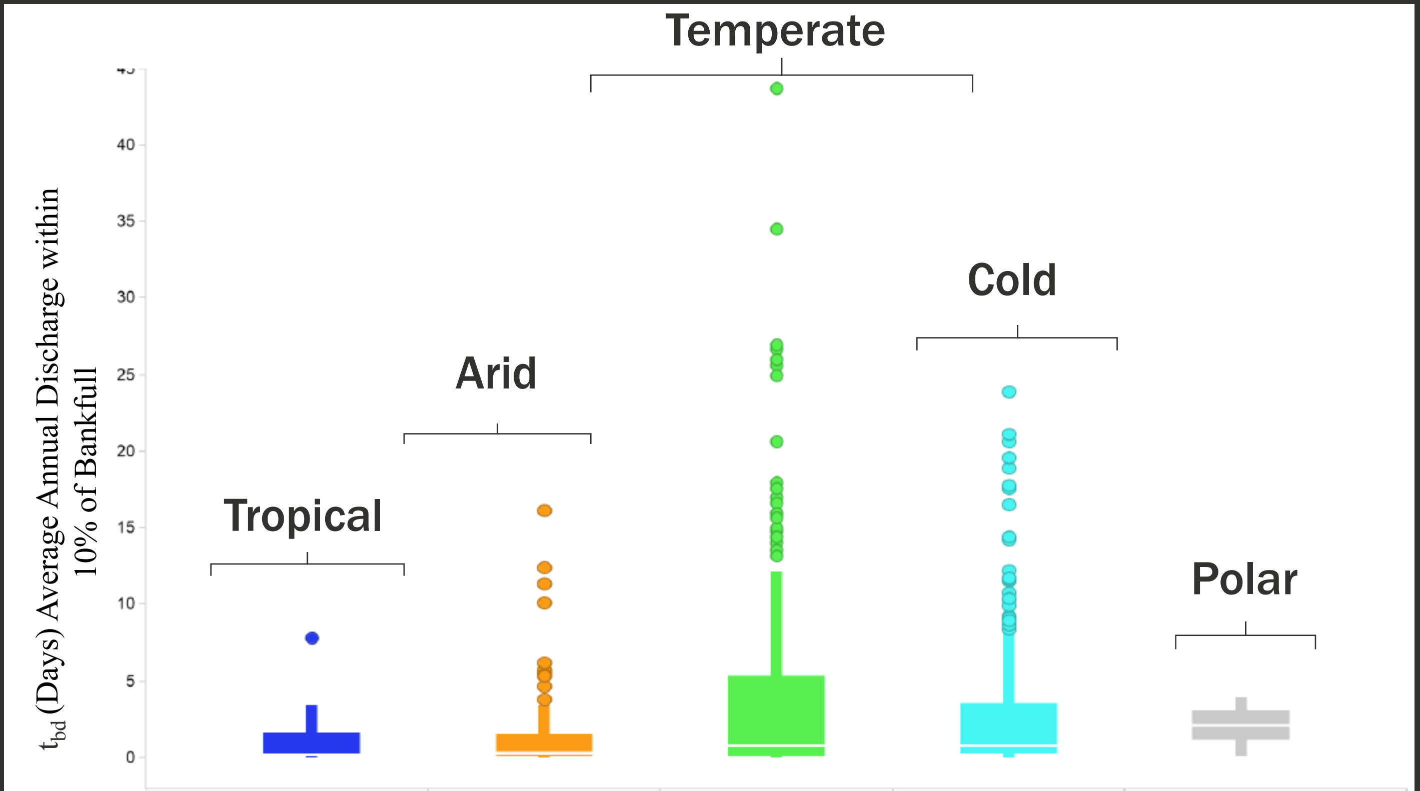
Köppen Climate		3.94E-06	3.56222	1.66 ✓	518

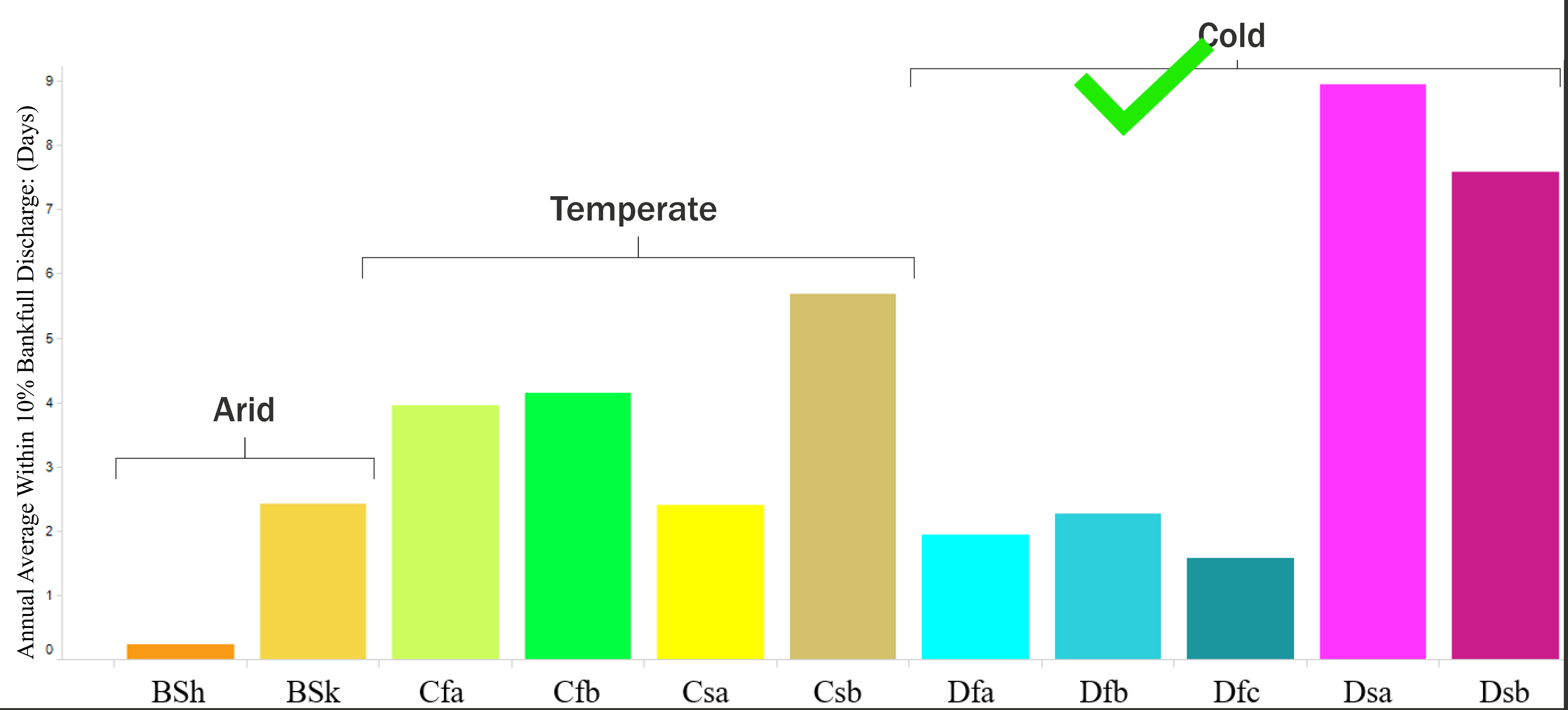
Bankfull Duration (t_{bd}) vs. Major climate



	A	B	C	D	E
Count	11	58	175	271	3
Avg	1.41	1.88	4.29	2.64	2.07
Median	0.18	0.26	0.75	0.78	2.14
Outliers	1	11	21	24	0
StdDev	2.39	3.46	7.21	4.18	1.90
U95	2.82	2.77	5.35	3.14	4.22
L95	0.00	0.99	3.22	2.14	-0.08

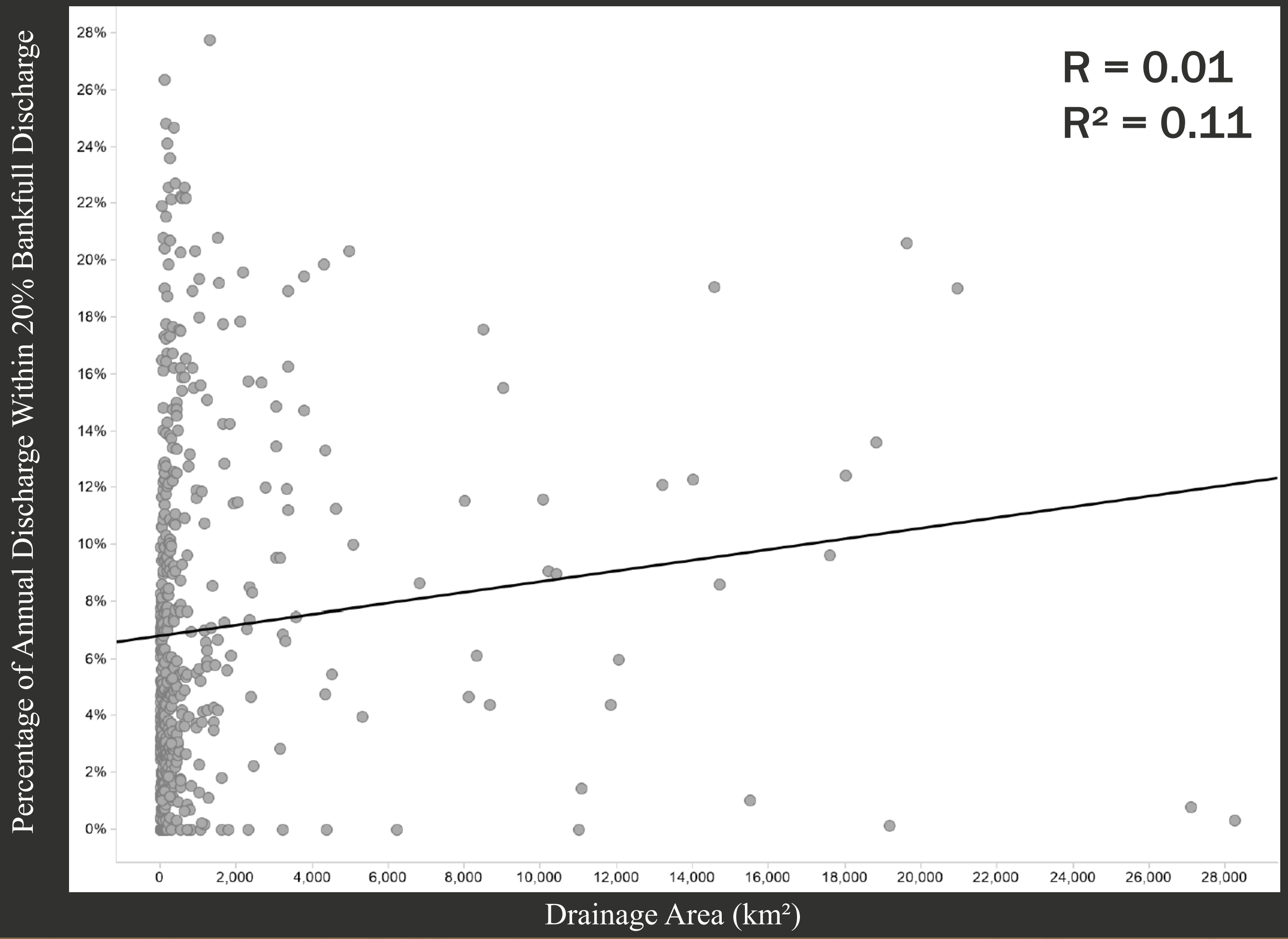
- Arid
- Temperate
- Cold
- Tropical
- Polar

Bankfull Duration (t_{bd}) vs. by Köppen climate

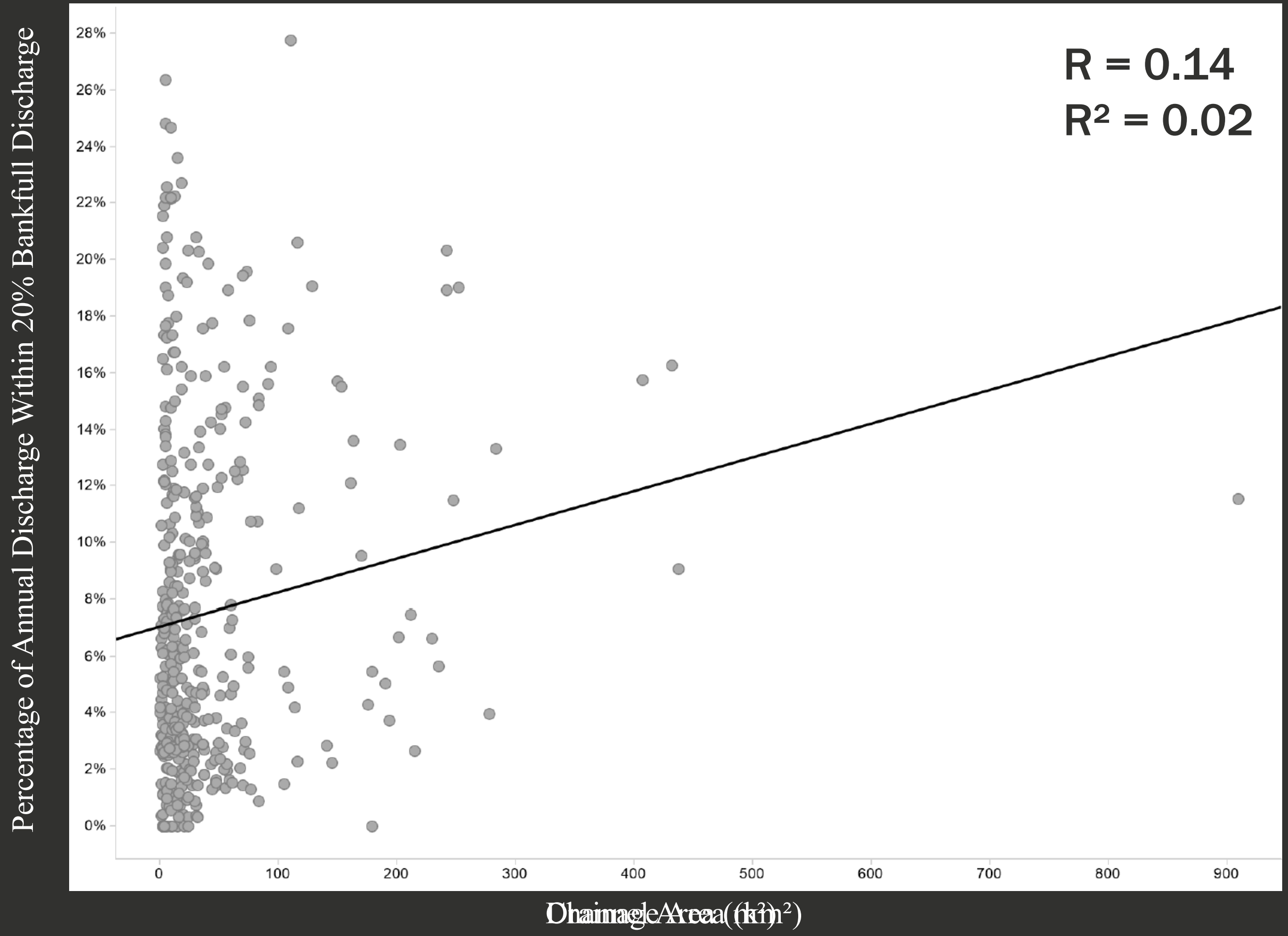


Correlation ✓
Between Bankfull Duration and Major & Köppen Climate

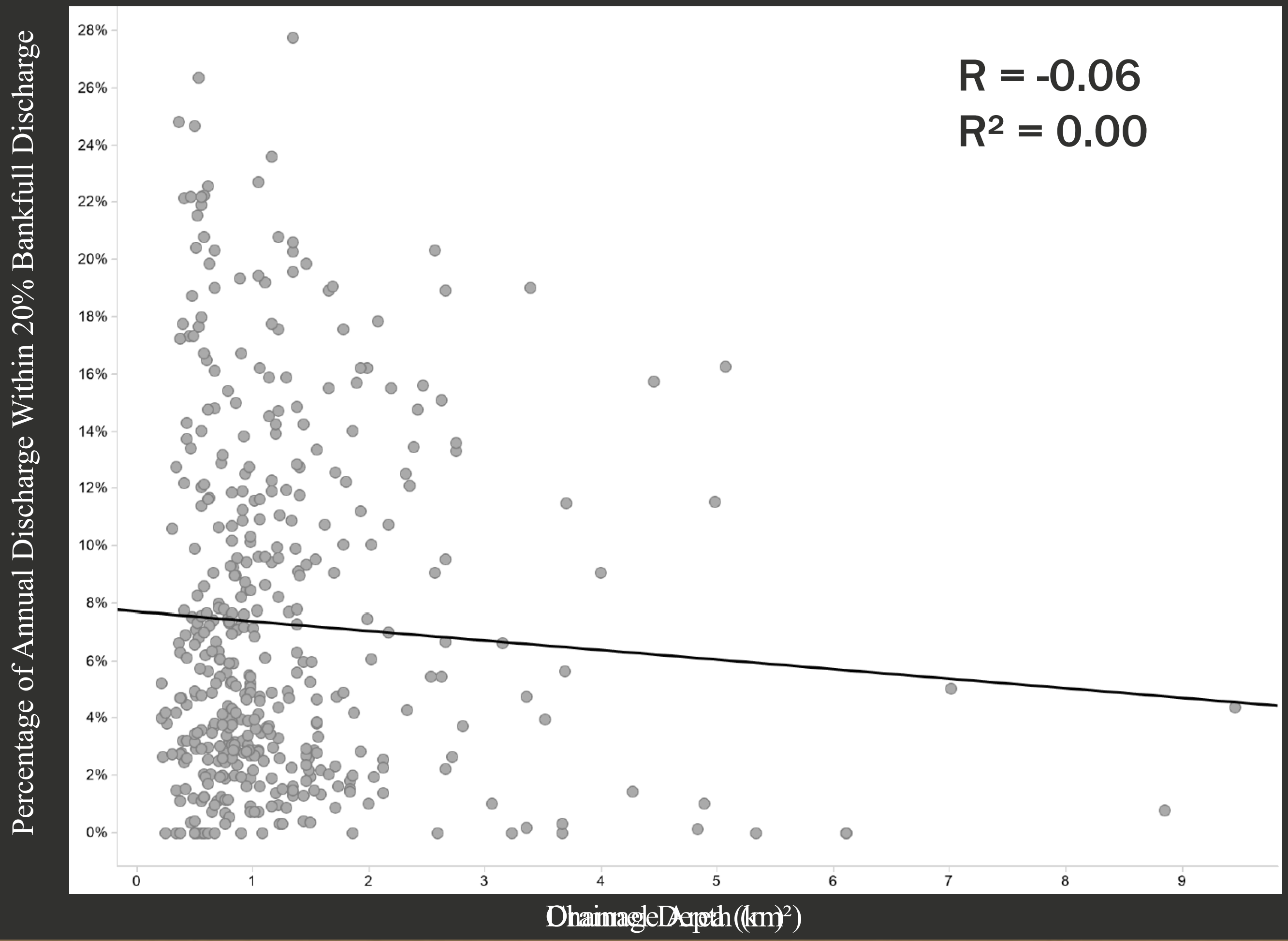
Proportion of Water Discharged During Bankfull vs. Spatial Attributes (Drainage Area & Channel Dimensions)



Proportion of Water Discharged During Bankfull vs. Spatial Attributes (Drainage Area & Channel Dimensions)



Proportion of Water Discharged During Bankfull vs. Spatial Attributes (Drainage Area & Channel Dimensions)



No Correlation ❌

Between Proportion of Water Discharged During Bankfull & Spatial Attributes (Drainage Area & Channel Dimensions)

Proportion of Water Discharged During Bankfull Binned by Climate

Category	Dependent	p-value	FStat	Critical F	n
Major Climate	Percentage of Average Annual Water Volume Discharged During Bankfull Flow	1.86E-01	1.5524	2.39	518
Köppen Climate		2.29E-13	6.4857	1.66	518

Proportion of Water Discharged During Bankfull Binned by Climate

Category	Dependent	p-value	FStat	Critical F	n
Major Climate	Percentage of Average Annual Water Volume Discharged During Bankfull Flow	1.86E-01	1.5524	2.39	518
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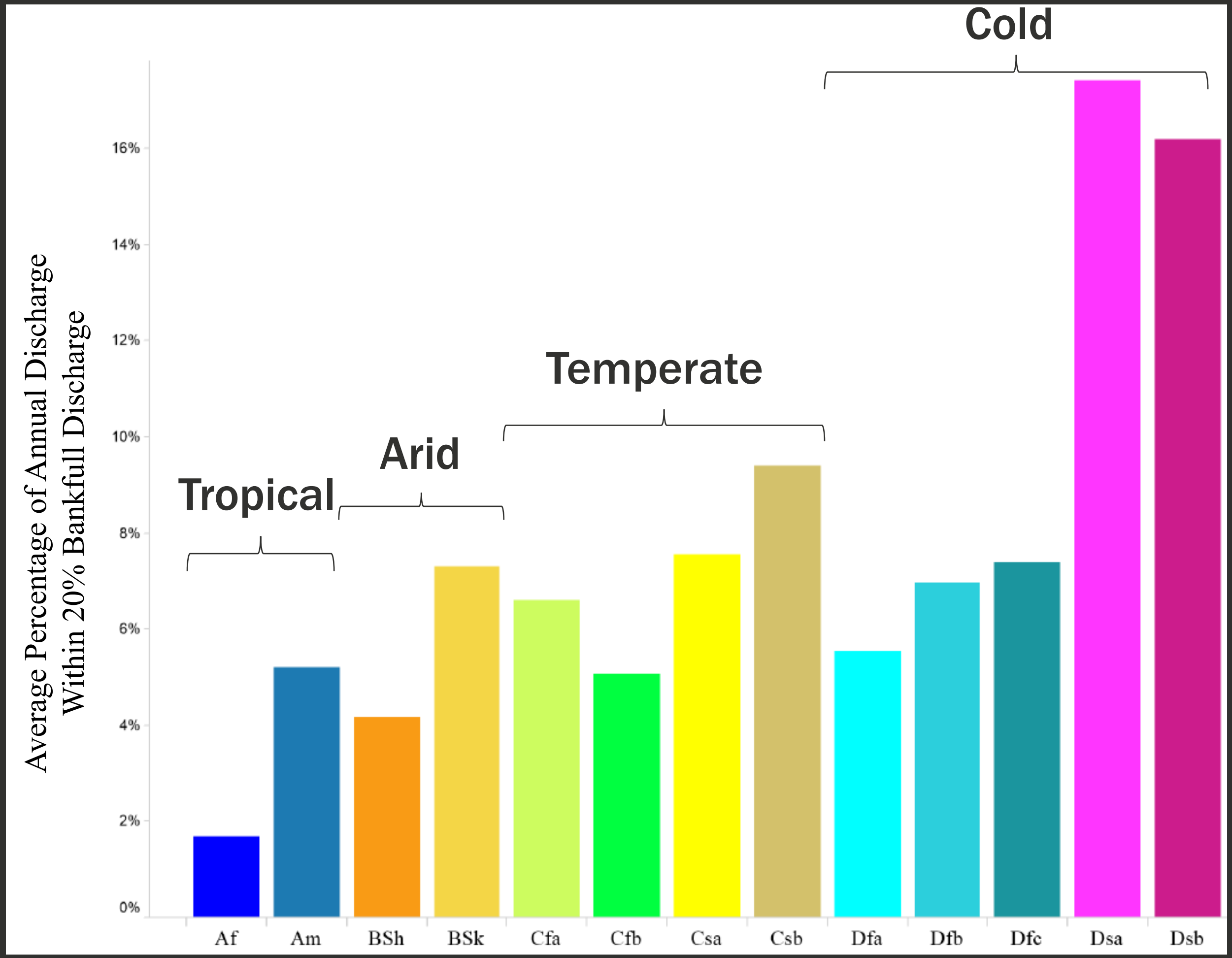
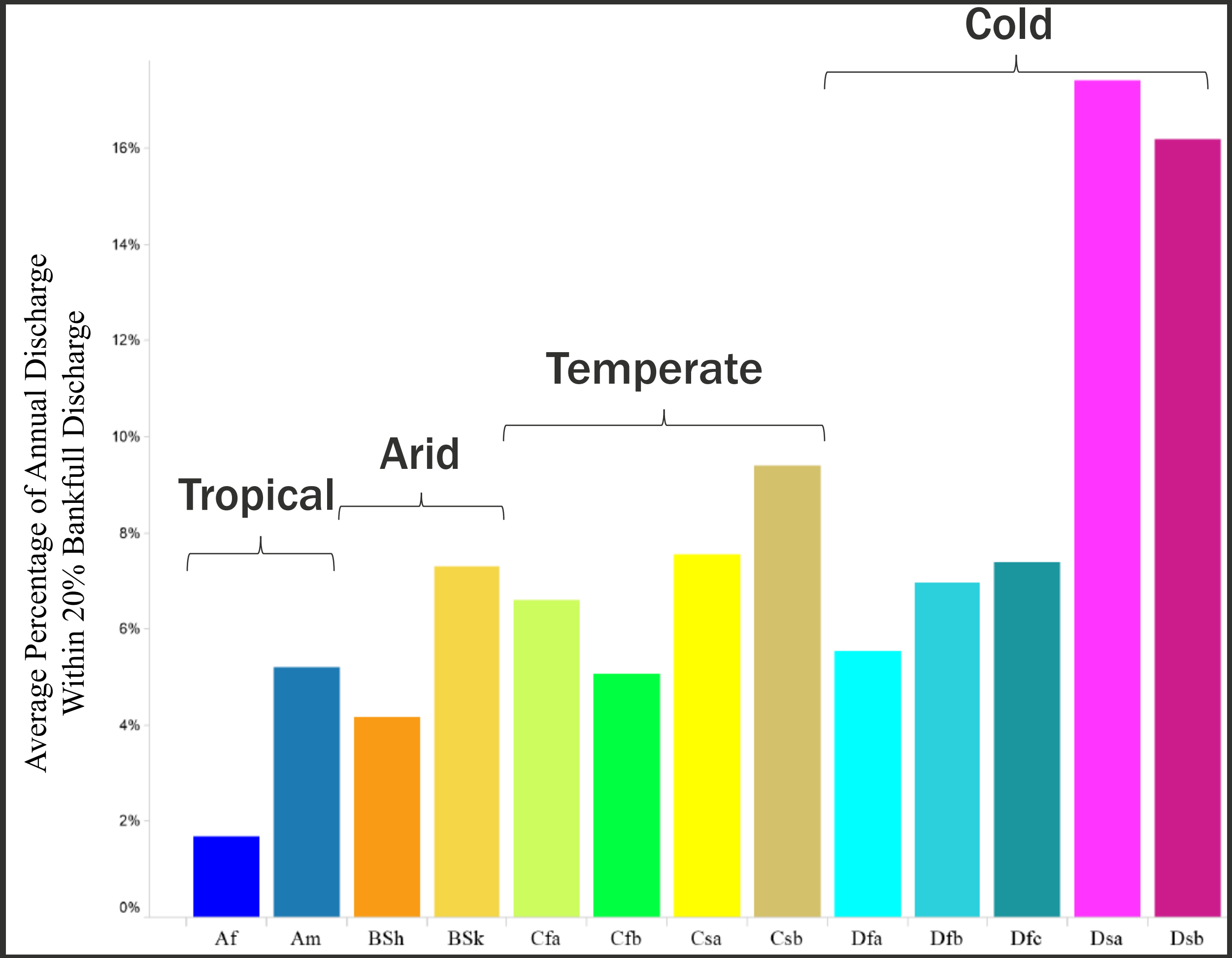
Proportion of Water Discharged During Bankfull Binned by Climate



Proportion of Water Discharged During Bankfull Binned by Climate



$$Q_{mas}=Q_{bts}(t_{bd})b$$

Q_{mas} = Mean annual water discharge

Q_{bts} = Bankfull water discharge

t_{bd} = Duration of time a stream runs at bankfull flow

b = Inverse of the proportion of the total annual water

Correlation ✓

Between Proportion of Water Discharged During Bankfull and Köppen Climate

When Does Bankfull Occur?

(http://www.michigan.gov/som/0,4669,7-192-45414-385043--,00.html)

When Does Bankfull Occur?

Site ID: 50063800			
Bankfull: 61.50 m³/sec			
Range Within 10% of Bankfull Discharge: 55.35-67.65 m³/sec			
Date	Mean Daily Discharge (m³/sec)	Date	Mean Daily Discharge (m³/sec)
9/19/1998	2.75	11/10/2003	3.68
9/20/1998	1.98	11/11/2003	9.54
9/21/1998	67.39	11/12/2003	64.56
9/22/1998	47.57	11/13/2003	22.71
9/23/1998	4.28	11/14/2003	5.15
9/24/1998	2.27	11/15/2003	3.40

Climate:
Tropical Rainforest (Af)

(http://www.michigan.gov/som/0,4669,7-192-45414-385043--,00.html)

When Does Bankfull Occur?

Site ID: 26017040			
Bankfull: 9.46 m³/sec			
Range Within 10% of Bankfull Discharge: 8.51-10.41 m³/sec			
Date	Mean Daily Discharge (m³/sec)	Date	Mean Daily Discharge (m³/sec)
11/12/2004	3.07	12/18/2013	2.128
11/13/2004	28.3	12/19/2013	2.057
11/14/2004	10.62	12/20/2013	1.845
11/15/2004	8.51	12/21/2013	27.05
11/16/2004	23.37	12/22/2013	12.2
11/17/2004	10.32	12/23/2013	12.93
11/18/2004	9.56	12/24/2013	11.96
11/19/2004	9.56	12/25/2013	11.72
11/20/2004	5.79	12/26/2013	7.844
11/21/2004	4.53	12/27/2013	6.438
11/22/2004	3.84	12/28/2013	5.188

Climate:
Tropical Monsoonal (Am)

(http://www.michigan.gov/som/0,4669,7-192-45414-385043--,00.html)

When Does Bankfull Occur?

Site ID: 09432000			
Bankfull: 49.21 m³/sec			
Range Within 10% of Bankfull Discharge: 44.29-54.1 m³/sec			
Date	Mean Daily Discharge (m³/sec)	Date	Mean Daily Discharge (m³/sec)
8/18/1996	6.06	9/14/2013	40.78
8/19/1996	6.06	9/15/2013	122.61
8/20/1996	10.76	9/16/2013	317.15
8/21/1996	317.15	9/17/2013	190.86
8/22/1996	32.56	9/18/2013	134.50
8/23/1996	20.22	9/19/2013	70.79
8/24/1996	17.70	9/20/2013	52.39
8/25/1996	62.58	9/21/2013	46.44
8/26/1996	17.84	9/22/2013	43.89
8/27/1996	14.02	9/23/2013	38.51
8/28/1996	15.43	9/24/2013	32.85

Climate:
Semi-Arid Cold (BSk)

(http://www.michigan.gov/som/0,4669,7-192-45414-385043--,00.html)

When Does Bankfull Occur?

Site ID: 02105900			
Bankfull: 2.76 m^3/sec			
Range Within 10% of Bankfull Discharge: 2.48- 3.04 m^3/sec			
Date	Mean Daily Discharge (m^3/sec)	Date	Mean Daily Discharge (m^3/sec)
10/20/1971	0.96	8/30/2006	0.15
10/21/1971	0.96	8/31/2006	7.76
10/22/1971	2.07	9/1/2006	58.05
10/23/1971	10.39	9/2/2006	21.86
10/24/1971	7.48	9/3/2006	8.61
10/25/1971	6.20	9/4/2006	4.76
10/26/1971	5.58	9/5/2006	2.97
10/27/1971	3.88	9/6/2006	4.96
10/28/1971	2.89	9/7/2006	4.56
10/29/1971	2.24	9/8/2006	2.46
10/30/1971	1.76	9/9/2006	1.47
10/31/1971	1.44	9/10/2006	0.96
11/1/1971	1.25	9/11/2006	0.67

Climate:
Temperate Without dry season Hot Summer (Cfa)

(http://www.michigan.gov/som/0,4669,7-192-45414-385043--,00.html)

When Does Bankfull Occur?

Site ID: 01AD003	
Bankfull: 243.00 m^3/sec	
Range Within 10% of Bankfull Discharge: 218.70- 267.30 m^3/sec	
Date	Mean Daily Discharge (m^3/sec)
4/23/2009	105.00
4/24/2009	157.00
4/25/2009	215.00
4/26/2009	260.00
4/27/2009	295.00
4/28/2009	288.00
4/29/2009	253.00
4/30/2009	223.00
5/1/2009	192.00

Climate: Cold
Without dry season
Warm Summer (Dfb)

(http://www.michigan.gov/som/0,4669,7-192-45414-385043–,00.html)

What Did We Learn?

- What impacts Average Annual Days of Bankfull Duration (t_{bd}) ?
- What impacts the proportion of water discharge during bankfull flow?
- When does bankfull duration occur?

(https://fineartamerica.com/featured/shenandoah-river-south-fork–snow-on-the-mountains–virginia-brendan-reals.html)

Presenter's notes: Average annual days at bankfull flow (t_{bd}) is not significantly impacted by any tested spatial attribute but is significantly impacted by climate.

Average Annual Days of Bankfull Duration (t_{bd})

- Vs. Drainage Area & Channel Dimensions ✗
- Vs. Major Climate ✓
- Vs. Köppen Climate ✓

(https://fineartamerica.com/featured/shenandoah-river-south-fork--snow-on-the-mountains--virginia-brendan-reals.html)

Presenter's notes: Average annual days at bankfull flow (t_{bd}) is not significantly impacted by any tested spatial attribute but is significantly impacted by climate.

Presenter's notes: Proportion of water discharged during bankfull is not significantly impacted by any tested spatial attribute.
Seasonality of precipitation significantly impact the proportion of water discharged during bankfull flow.
To estimate the most accurate average proportion of water discharged during bankfull specific Köppen climate for the stream's drainage area is required.

When Does Bankfull Occur

- During the bankfull flood event ✓
- As a component of a larger flooding event ✓

(https://www.usgs.gov/atom/13010)

Presenter's notes: Proportion of water discharged during bankfull is not significantly impacted by any tested spatial attribute.
Seasonality of precipitation significantly impact the proportion of water discharged during bankfull flow.
To estimate the most accurate average proportion of water discharged during bankfull specific Köppen climate for the stream's drainage area is required.

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Thank You

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Questions?

(http://vogeltalksrving.com/2015/09/shenandoah-river-state-park-the-mountains-are-calling/)