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science for a changing world

Montana StreamStats

An overview of Montana StreamStats and methods for obtaining streamflow characteristics at gaged and ungaged locations in Montana

In cooperation with
Montana Department of Natural Resources and Conservation,
Montana Department of Transportation,
and Montana Department of Environmental Quality

U.S. Department of the Interior
U.S. Geological Survey

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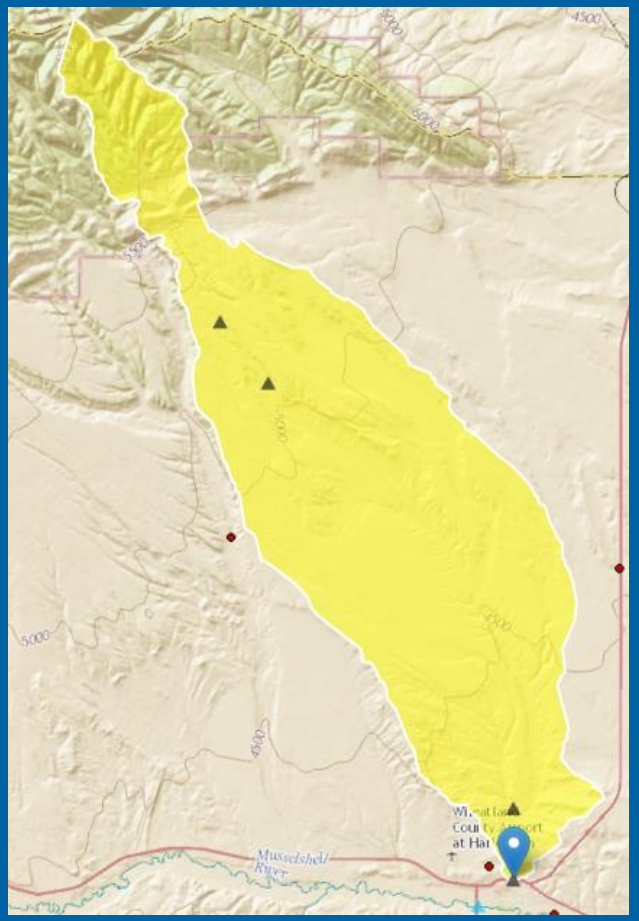
What is StreamStats?

- Web-based GIS system for retrieving basin and streamflow characteristics
- Delineates basins
- Computes basin characteristics
- Retrieves streamflow characteristics
- Solves regression equations for estimating streamflow characteristics



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Who developed StreamStats?

- StreamStats platform developed by USGS StreamStats Team
- Data developed locally in cooperation with
  - Montana Department of Natural Resources and Conservation
  - Montana Department of Transportation
  - Montana Department of Environmental Quality

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StreamStats Hydrography

- **NHDPlus Version 2: Application ready* geospatial datasets**

  http://www.horizon-systems.com/nhdplus/NHDPlusV2_home.php

  - **National Hydrography Dataset (NHD) 1:100K scale**
    - **Stream network represented by flowlines**
    - **Attributes of flow direction, length, name, and many others**
  - **Watershed Boundary Dataset (WBD)**
    - **Seamless national framework of drainage boundaries**
  - **30-meter Digital Elevation Model (DEM)**
    - **Developed from the National Elevation Dataset (NED)**
    - **Raster (grid) data for elevations used to create flow accumulation and flow direction grids (for delineating basins)**

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StreamStats Hydrography

- NHDPlus Version 2 also includes
  - USGS gaging stations
  - Dams from the National Inventory of Dams
  - Transboundary data harmonization between Canada and United States

Montana Basin Characteristics

- CONTDA-Contributing drainage area
- ELEV-Mean basin elevation
- TEMP-Mean annual temperature
- ELEVMAX-Maximum basin elevation
- MINBELEV-Minimum basin elevation
- Relief-Maximum minus minimum elevation
- EL5000, EL6000-Percent of basin above listed elevation
- IRRIGAT_MT-Percent of basin that is irrigated
- LAKESNHDH-Percent of basin in lakes, pons, and reservoirs
- LC01CRPHAY-Percent of basin with cultivated crops
- LC01DEV-Percent of basin with urban land
- LC01WTLND-Percent of basin with wetlands

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Montana Basin Characteristics

- BSLDEM30M-Mean basin slope
- SLOP30_30M-Percent of basin with slopes greater than 30%
- NFSL30_30M-Percent of basin with north-facing slopes >30%
- SLOP50_30M-Percent of basin with slopes greater than 50%
- PRECIP-Mean annual precipitation for basin (PRISM & Natural Resources Canada; 1971-2000)
- LC01Forest-Percent of basin with forest cover
- ET0306MOD-Mean monthly evapotranspiration for March-June
- ET0710MOD-Mean monthly evapotranspiration for July-October

Due to server processing capabilities and speeds we are limited to 20 basin characteristics

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Montana Streamflow Characteristics

- **One Scientific Investigations Report (SIR) with multiple chapters**
  - Chapter A: Montana StreamStats introduction

  Streamflow characteristics for USGS gages
  - Chapter B: Peak flow trends and stationarity
  - Chapter C: Peak-flow analyses
  - Chapter D: Methods for improving peak flow analyses
  - Chapter E: Streamflow characteristics (i.e. low flow, duration)

  Streamflow characteristics for ungaged sites
  - Chapter F: Peak-flow regional regression equations
  - Chapter G: Streamflow statistics regional regression equations

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Chapter A: StreamStats

- Description of hydrography and data used to develop StreamStats
- Regulation classification
  - Regulated: If the conjoined drainage area of all dams is greater than or equal to 20% of the basin
  - Major regulation: The drainage area of a single dam exceeds 20%
  - Minor regulation: The drainage are of no single dam exceeds 20%, however the conjoined drainage area exceeds 20%.

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Chapter B: Peak flow trends

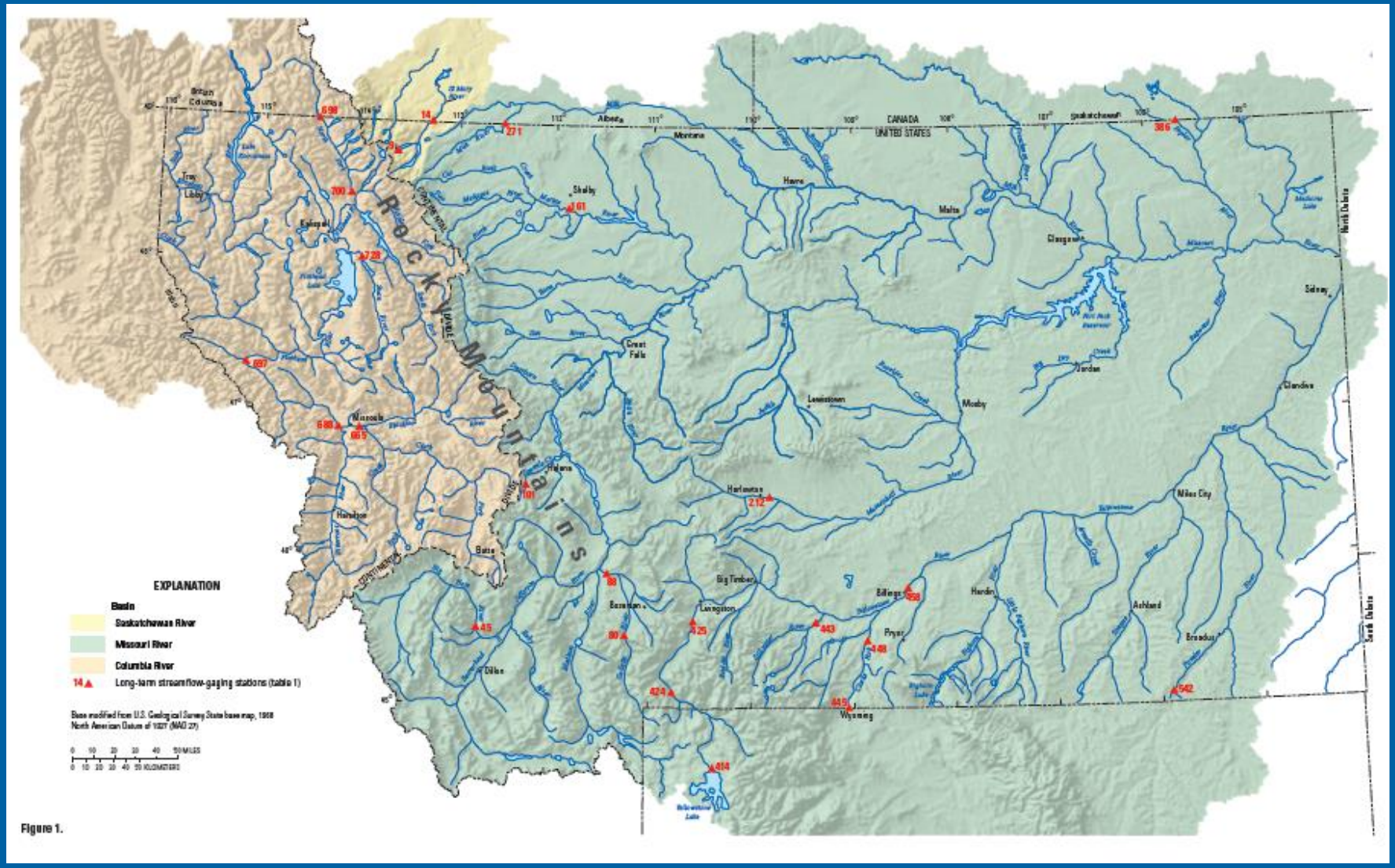
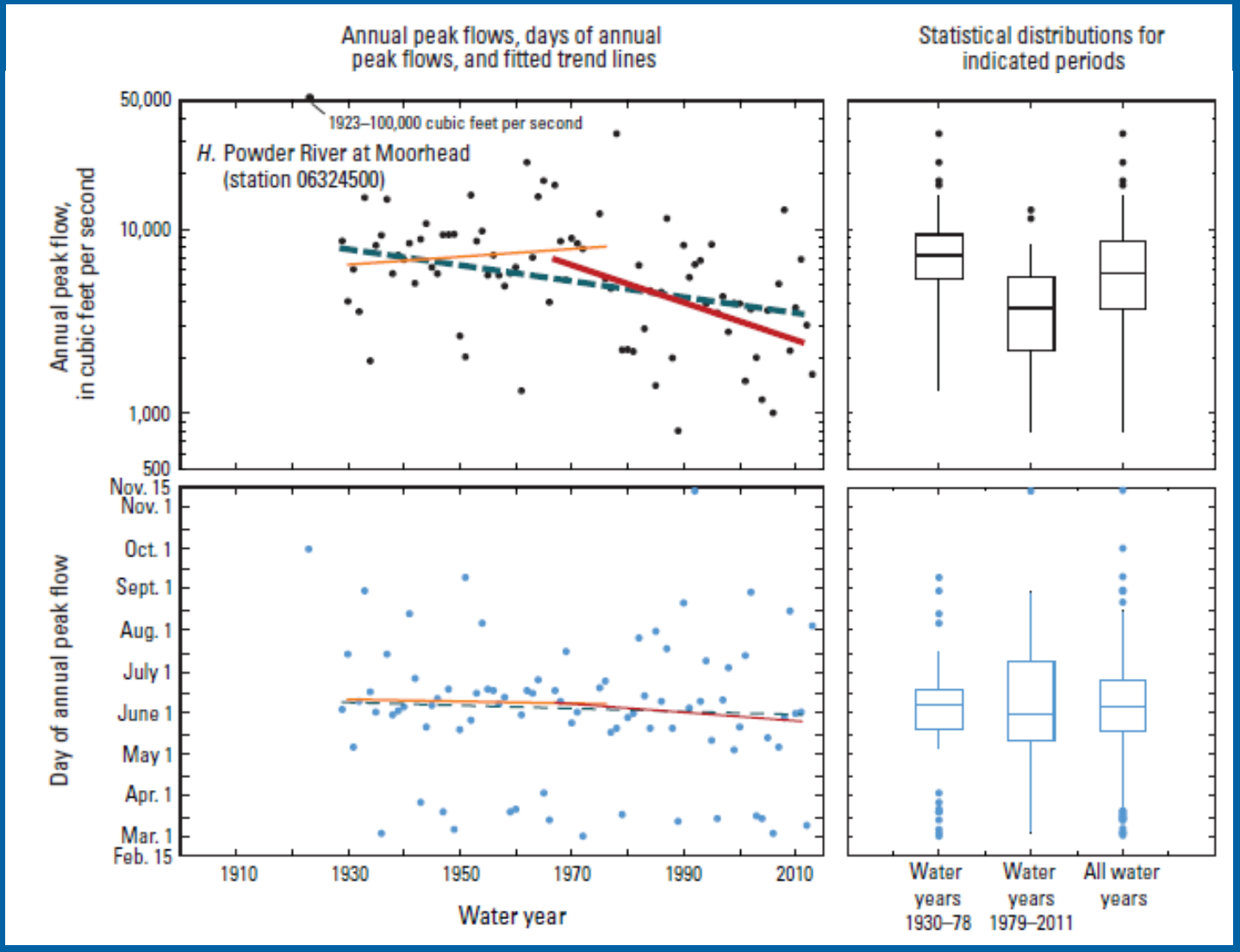


Figure 1.

Chapter B: Peak flow trends



EXPLANATION

[Water year is defined as the 12-month period from October 1 through September 30 and is designated by the year in which it ends]

Annual peak flows and days of annual peak flows

- Annual peak flow
- Day of annual peak flow

Fitted trend lines

- Start of systematic data collection through 1940
- 1930 through 1976
- 1967 through 2011
- Start of systematic data collection through 2011

Bold lines indicate statistical significance (*p*-value less than 0.05)

Boxplots

- Data value greater than 1.5 times the interquartile range outside the quartile

Data value less than or equal to 1.5 times the interquartile range outside the quartile

75th percentile

median

25th percentile

Inter-quartile range

Chapter B: Peak flow trends

- **06324500-Powder River at Moorhead**

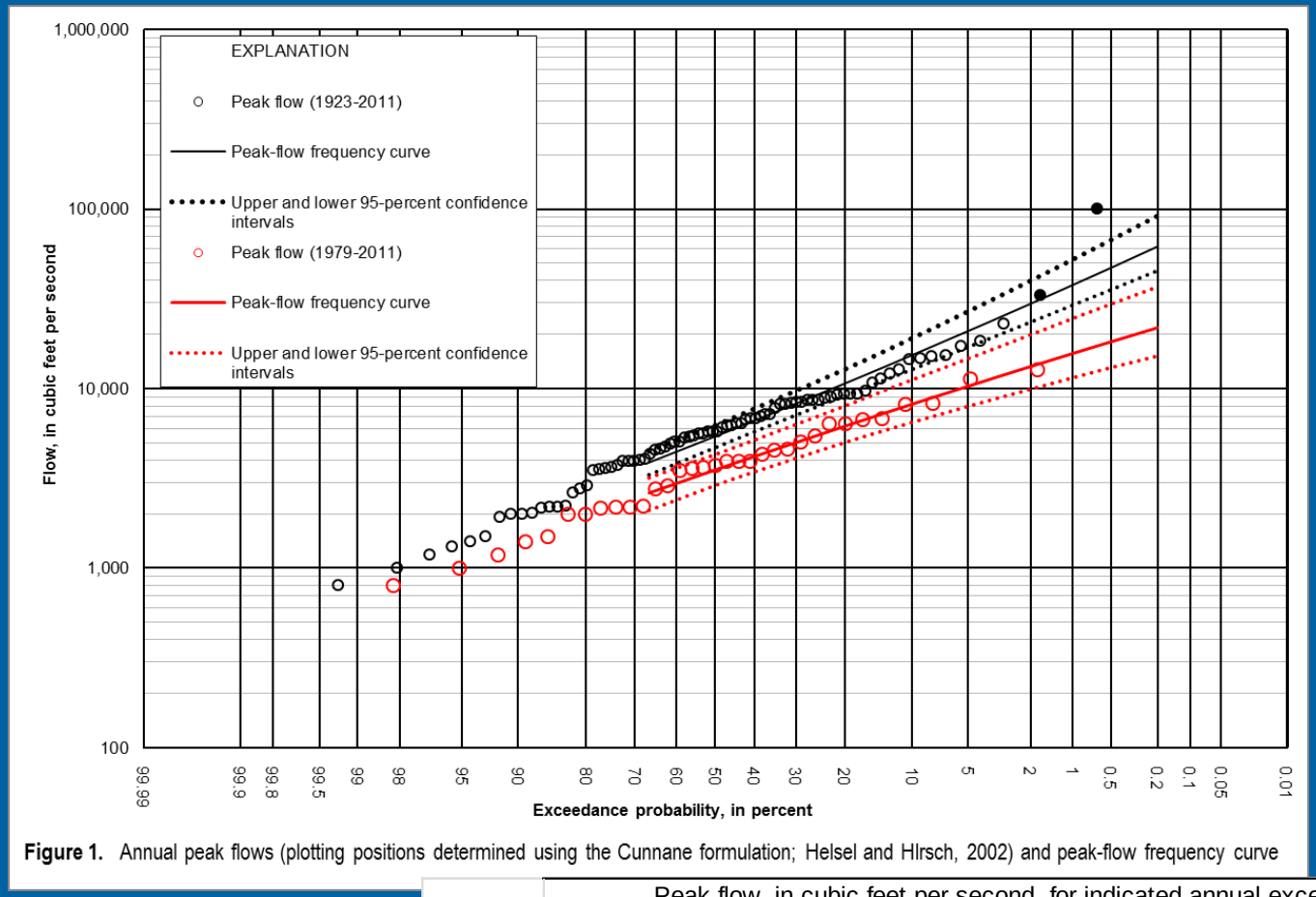
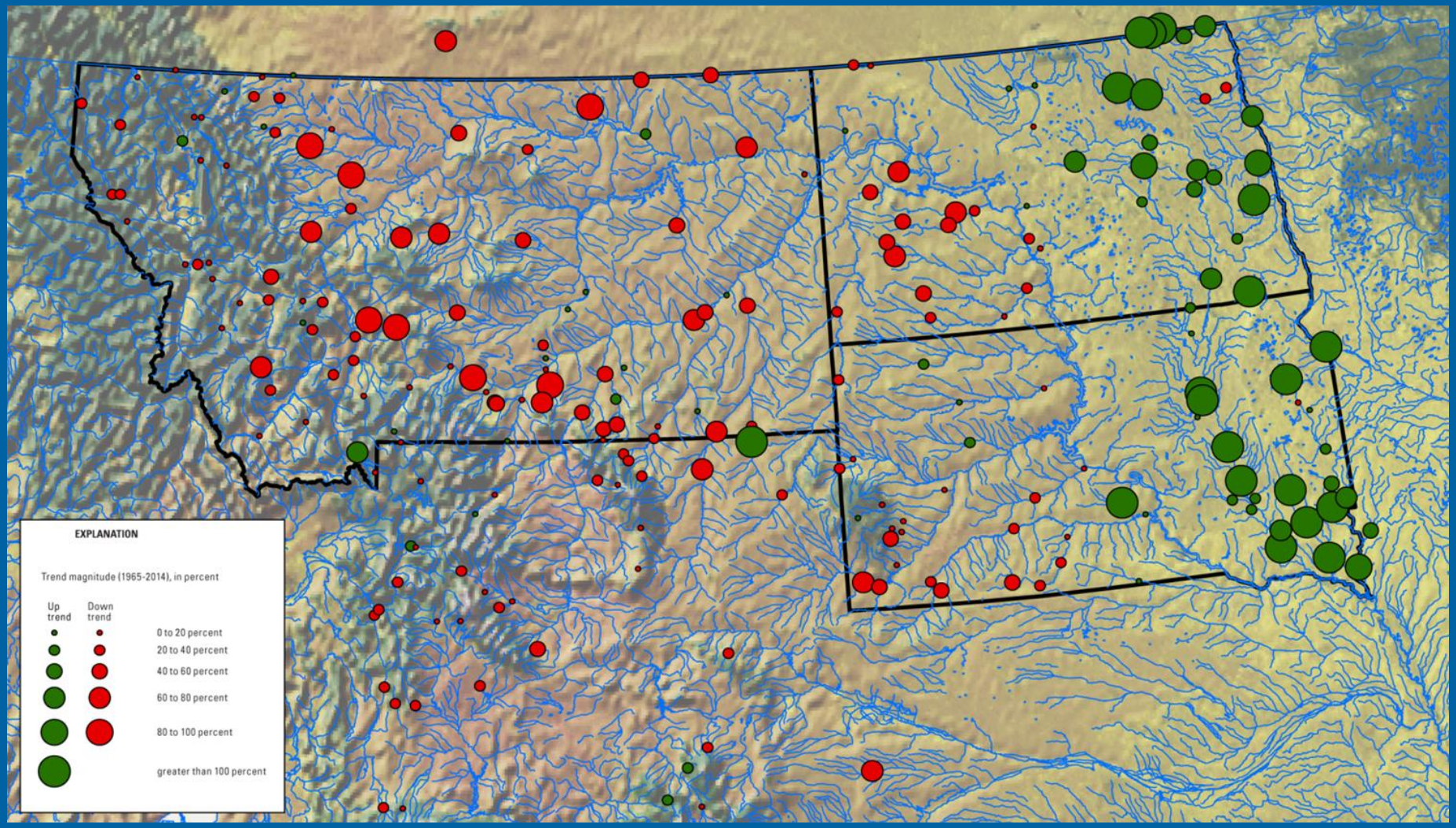


Figure 1. Annual peak flows (plotting positions determined using the Cunnane formulation; Helsel and Hirsch, 2002) and peak-flow frequency curve

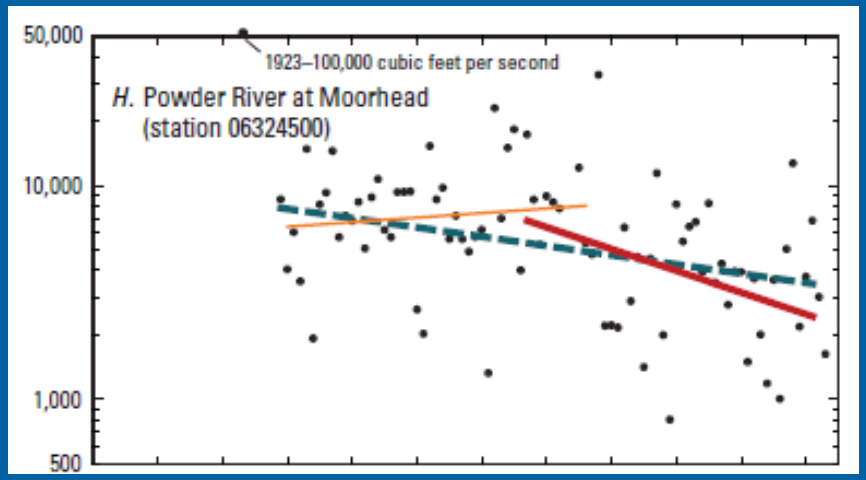
	Peak flow, in cubic feet per second, for indicated annual exceedance probability, in percent									
Period	**66.7**	**50**	**42.9**	**20**	**10**	**4**	**2**	**1.0**	**0.5**	**0.2**
1923-2011	3,879	5,424	6,238	10,680	15,390	22,920	29,780	37,820	47,190	61,930
1979-2011	2,625	3,526	3,981	6,172	8,198	11,020	13,300	15,710	18,250	21,850
Percent difference in flood frequency estimates for 1923-2011 versus 1979-2011										
	-32	-35	-36	-42	-47	-52	-55	-58	-61	-65

Chapter B: Peak flow trends



Chapter B: Peak flow trends

- More research and analyses are needed to better understand downward trends of peak flow magnitudes and timing in Eastern Montana
  - Effects of smaller dams and land use practices
  - Effects of climate changes
- Be conservative!



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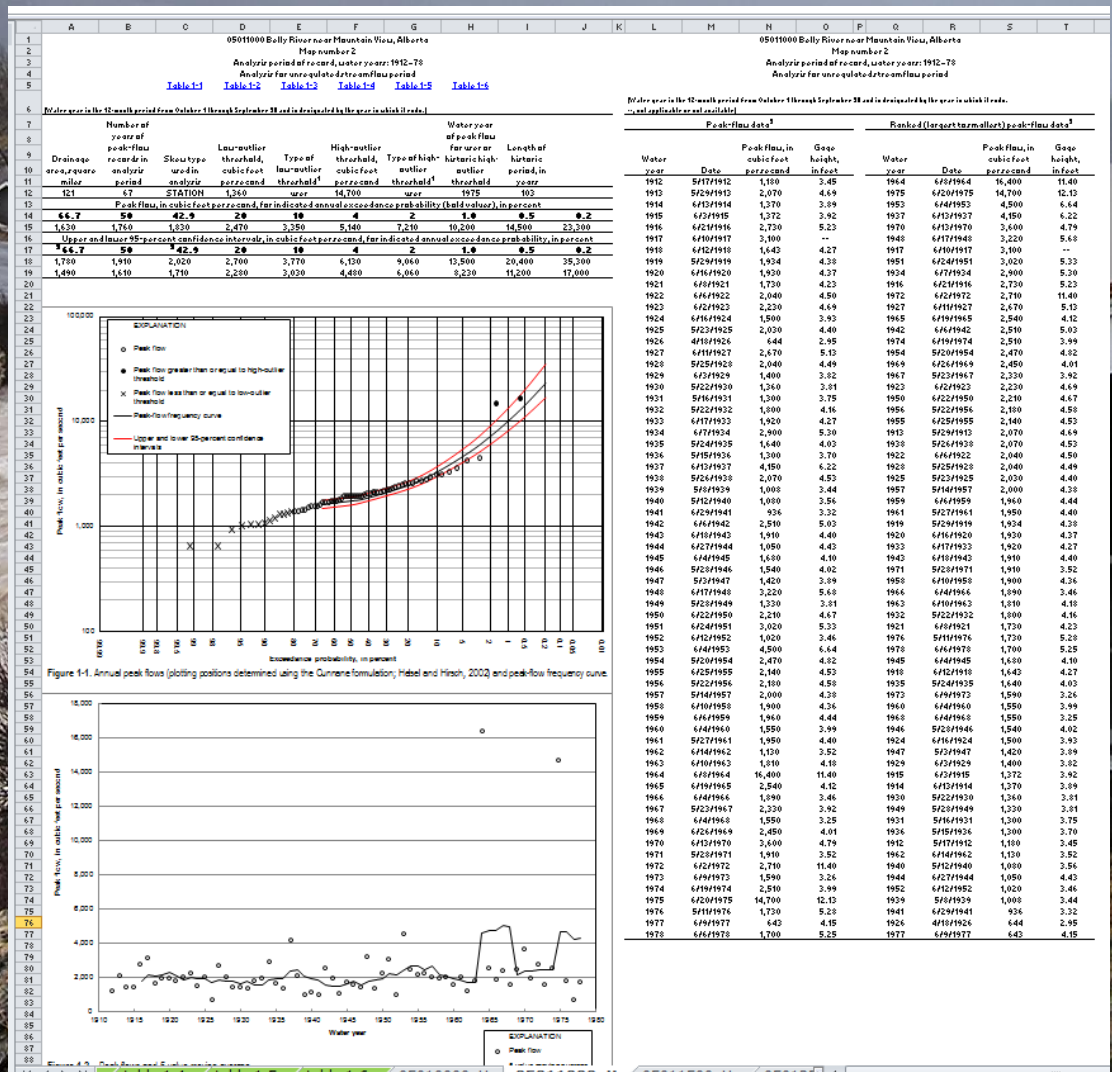
Chapter C: Peak flow analyses

- Performed analyses using Bulletin 17B
- 725 streamflow gaging stations in and near Montana
  - 579 unregulated streamflow stations
  - 146 regulated streamflow stations
    - 100 analyzed for post-regulation period only
    - 17 analyzed for pre-regulation period only
    - 29 analyzed for both pre- and post-regulation
  - Pre-regulation analyses used for regression equations

Chapter C: Peak flow analyses

- Analyses in downloadable file
- Tables 1-1 through 1-6 provide analyses info
- Tables provide NECESSARY background information

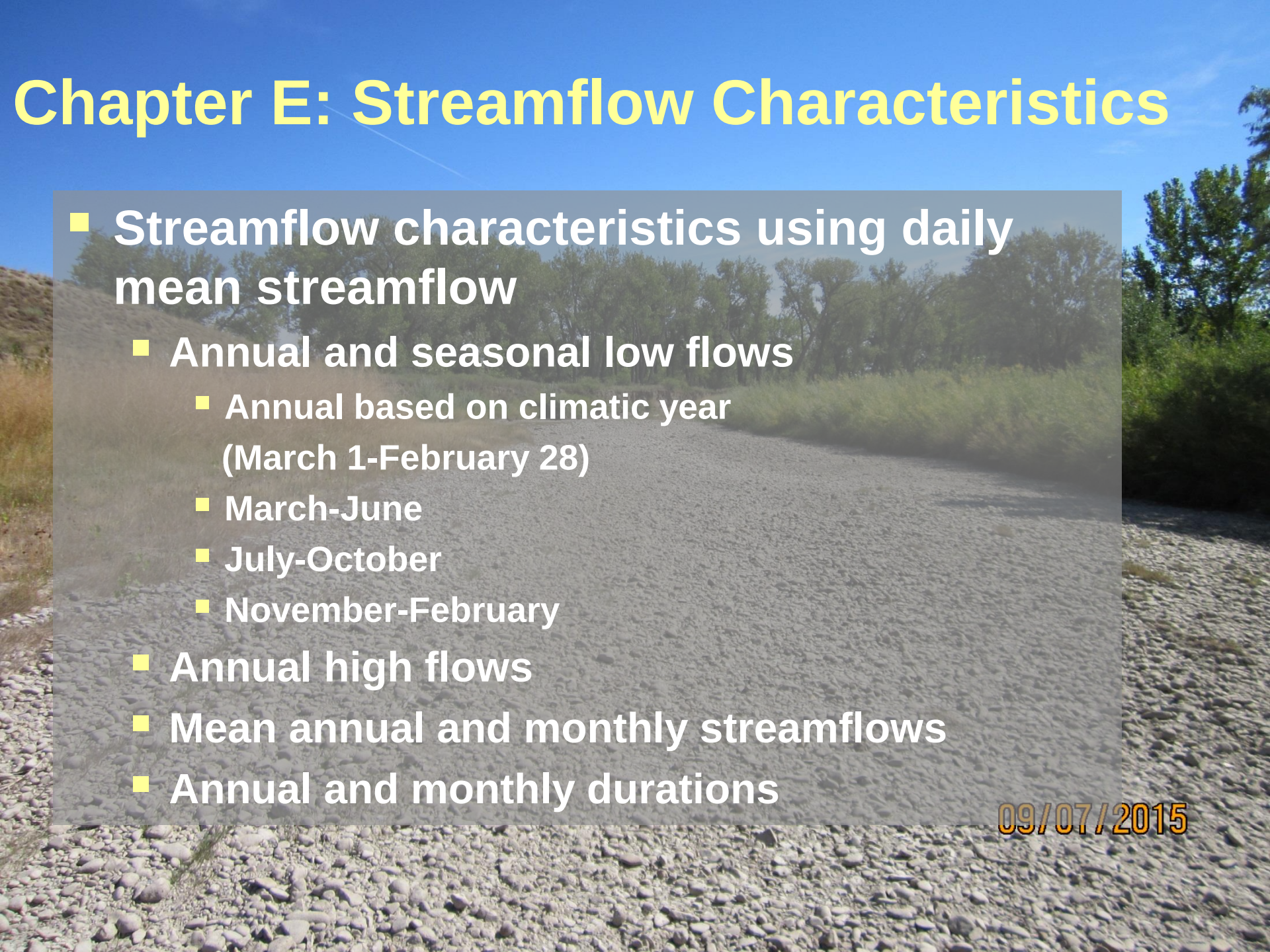


Chapter D: Improving peak flow analyses

- Why do peak flow analyses need to be improved?
  - Period of record (dry or wet period)
  - Length of record (short period of record)
  - Multiple stations along same stream with different periods of record and results
- How are peak flow analyses improved?
  - MOVE.1 Record extension methods (66 gaging stations)
  - Weighting station analyses with regression equations (438 gaging stations)

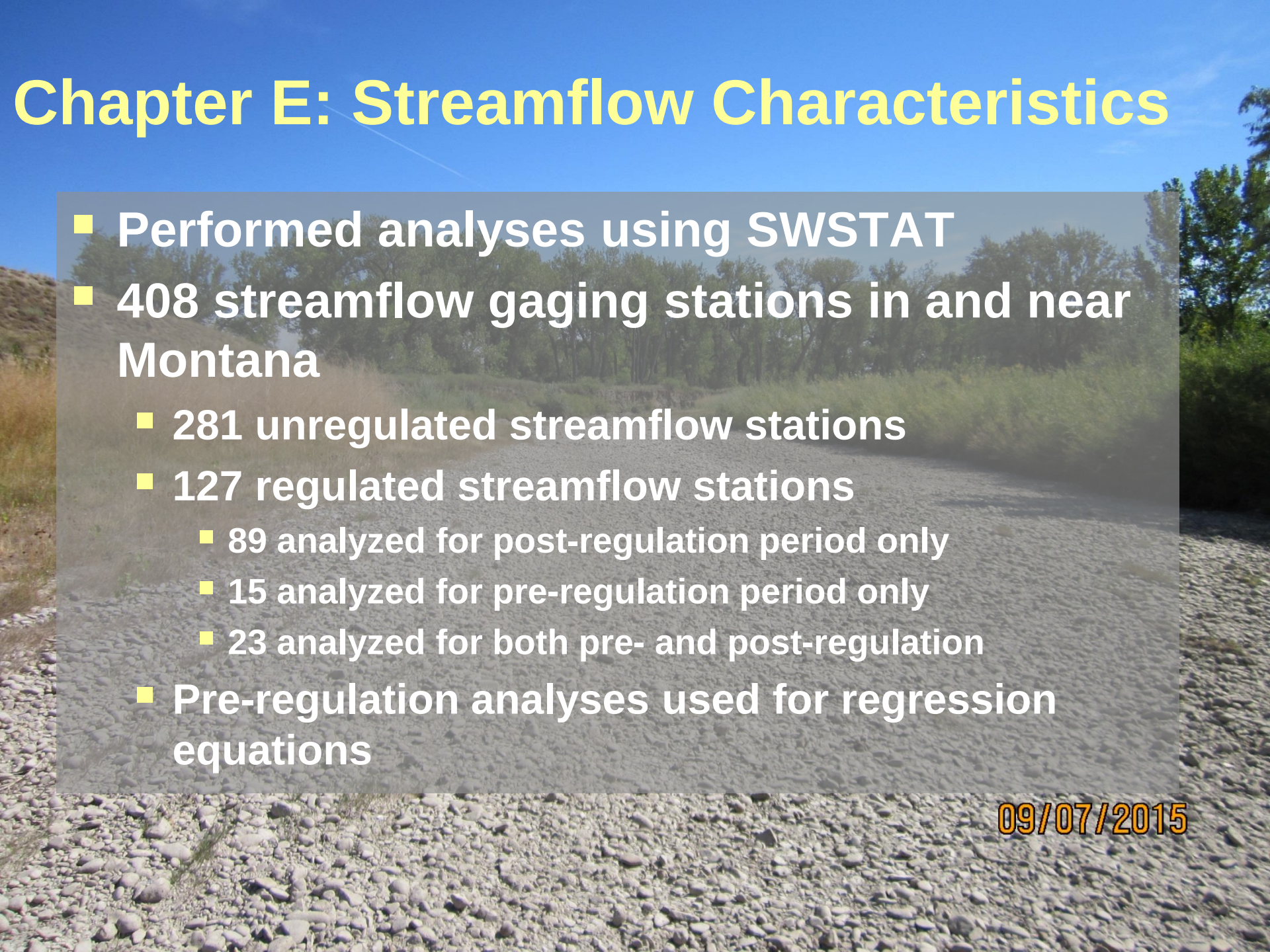
Chapter E: Streamflow Characteristics

- Streamflow characteristics using daily mean streamflow
  - Annual and seasonal low flows
    - Annual based on climatic year (March 1-February 28)
    - March-June
    - July-October
    - November-February
  - Annual high flows
  - Mean annual and monthly streamflows
  - Annual and monthly durations



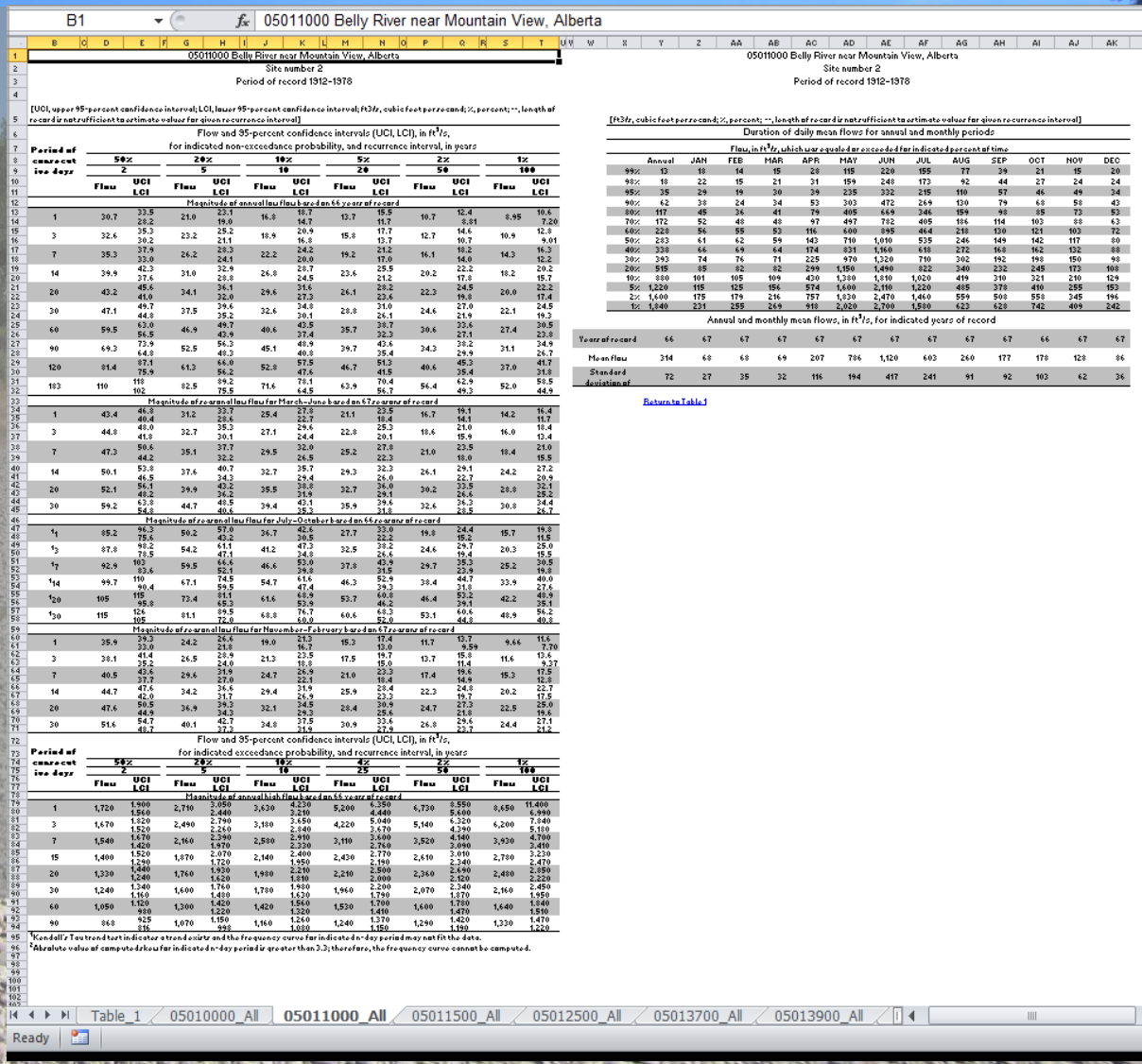
Chapter E: Streamflow Characteristics

- Performed analyses using SWSTAT
- 408 streamflow gaging stations in and near Montana
  - 281 unregulated streamflow stations
  - 127 regulated streamflow stations
    - 89 analyzed for post-regulation period only
    - 15 analyzed for pre-regulation period only
    - 23 analyzed for both pre- and post-regulation
  - Pre-regulation analyses used for regression equations



Chapter E: Streamflow Characteristics

- Analyses served in downloadable file
- Table_1 provides station information
- Excel tab for each station



B1 — 05011000 Belly River near Mountain View, Alberta

05011000 Belly River near Mountain View, Alberta
Site number 2
Period of record 1912–1978

[UCI, upper 95-percent confidence interval; LCI, lower 95-percent confidence interval; ft³/s, cubic foot per second; %, percent; --, length of record is not sufficient to estimate value for given recurrence interval]

Flow and 95-percent confidence intervals (UCI, LCI), in ft³/s, for indicated non-exceedance probability, and recurrence interval, in years

Period of consecutive days	50% 2		20% 5		10% 10		5% 20		2% 50		1% 100	
	Flow	UCI LCI	Flow	UCI LCI	Flow	UCI LCI	Flow	UCI LCI	Flow	UCI LCI	Flow	UCI LCI
Magnitude of annual low flow based on 66 years of record												
1	30.7	33.5 28.2	21.0	23.1 19.0	16.8	18.7 14.7	13.7	15.5 11.7	10.7	12.4 8.81	8.95	10.6 7.20
3	32.6	35.3 30.2	23.2	25.2 21.1	18.9	20.9 16.8	15.8	17.7 13.7	12.7	14.6 10.7	10.9	12.8 9.01
7	35.3	37.9 33.0	26.2	28.3 24.1	22.2	24.2 20.0	19.2	21.2 17.0	16.1	18.2 14.0	14.3	16.3 12.2
14	39.9	42.3 37.6	31.0	32.9 28.8	26.8	28.7 24.5	23.6	25.5 21.2	20.2	22.2 17.8	18.2	20.2 15.7
20	43.2	45.6 41.0	34.1	36.1 32.0	29.6	31.6 27.3	26.1	28.2 23.6	22.3	24.5 19.8	20.0	22.2 17.4
30	47.1	49.7 44.8	37.5	39.6 35.2	32.6	34.8 30.1	28.8	31.0 26.1	24.6	27.0 21.9	22.1	24.5 19.3
60	59.5	62.0 56.5	46.9	49.7 43.9	40.6	43.5 37.4	35.7	38.7 32.3	30.6	33.6 27.1	27.4	30.5 22.8
90	69.3	73.9 64.8	52.5	56.3 48.3	45.1	48.9 40.8	39.7	43.6 35.4	34.3	38.2 29.9	31.1	34.9 26.7
120	81.4	87.1 75.9	61.3	66.0 56.2	52.8	57.5 47.6	46.7	51.3 41.5	40.6	45.3 35.4	37.0	41.7 31.8
183	110	118 102	82.5	89.2 75.5	71.6	78.1 64.5	63.9	70.4 56.7	56.4	62.9 49.3	52.0	58.5 44.9
Magnitude of seasonal low flow for March–June based on 67 seasons of record												
1	43.4	46.8 40.4	31.2	33.7 28.6	25.4	27.8 22.7	21.1	23.5 18.4	16.7	19.1 14.1	14.2	16.4 11.7
3	44.8	48.0 41.6	32.7	35.3 30.1	27.1	29.6 24.4	22.8	25.3 20.1	18.6	21.0 15.9	16.0	18.4 13.4
7	47.3	50.6 44.2	35.1	37.7 32.2	29.5	32.0 26.5	25.2	27.8 22.3	21.0	23.5 18.0	18.4	21.0 15.5
14	50.1	53.8 46.5	37.6	40.7 34.3	32.7	35.7 29.4	29.3	32.3 26.0	26.1	29.1 22.7	24.2	27.2 20.9
20	52.1	56.1 48.2	39.9	43.2 36.2	35.5	38.8 31.9	32.7	36.0 29.1	30.2	33.5 26.6	28.8	32.1 25.2
30	59.2	63.8 54.8	44.7	48.5 40.6	39.4	43.1 35.3	35.9	39.6 31.8	32.6	36.3 28.5	30.8	34.4 26.7
Magnitude of seasonal low flow for July–October based on 66 seasons of record												
$^{1}_{1}$	85.2	96.3 75.6	50.2	57.0 43.2	36.7	42.6 30.5	27.7	33.0 22.2	19.8	24.4 15.2	15.7	19.8 11.5
$^{1}_{3}$	87.8	98.2 78.5	54.2	61.1 47.1	41.2	47.3 34.8	32.5	38.2 26.6	24.6	29.7 19.4	20.3	25.0 15.5
$^{1}_{7}$	92.9	103 83.6	59.5	66.6 52.1	46.6	53.0 39.8	37.8	43.9 31.5	29.7	35.3 23.9	25.2	30.5 19.8
$^{1}_{14}$	99.7	110 90.4	67.1	74.5 59.5	54.7	61.6 47.4	46.3	52.9 39.3	38.4	44.7 31.8	33.9	40.0 27.6
$^{1}_{20}$	105	115 95.8	73.4	81.1 65.3	61.6	68.9 54.2	53.7	60.8 46.2	46.4	53.2 39.1	42.2	48.9 35.1
$^{1}_{30}$	115	126 105	81.1	89.5 72.0	68.8	76.7 60.6	60.6	68.3 52.0	53.1	60.6 44.8	48.9	56.2 40.8
Magnitude of seasonal low flow for November–February based on 67 seasons of record												
1	35.9	39.3 33.0	24.2	26.6 21.8	19.0	21.3 16.7	15.3	17.4 13.0	11.7	13.7 9.59	9.66	11.6 7.70
3	38.1	41.4 35.2	26.5	28.9 24.0	21.3	23.5 19.1	17.5	19.7 15.0	13.7	15.8 11.4	11.6	13.6 9.37
7	40.5	43.6 37.7	29.6	31.9 27.0	24.7	26.9 22.1	21.0	23.2 18.4	17.4	19.6 14.9	15.3	17.5 12.8
14	44.7	47.6 42.0	34.2	36.6 31.7	29.4	31.9 26.9	25.9	28.4 22.5	22.3	24.8 19.7	20.2	22.7 17.5
20	47.6	50.5 44.9	36.9	39.3 34.3	32.1	34.5 29.3	28.4	30.9 25.6	24.7	27.3 21.8	22.5	25.0 19.6
30	51.6	54.7 48.7	40.1	42.7 37.2	34.8	37.5 31.9	30.9	33.6 27.9	26.8	29.6 23.7	24.4	27.1 21.2
Flow and 95-percent confidence intervals (UCI, LCI), in ft³/s, for indicated exceedance probability, and recurrence interval, in years												
Period of consecutive days	50% 2		20% 5		10% 10		4% 25		2% 50		1% 100	
	Flow	UCI LCI	Flow	UCI LCI	Flow	UCI LCI	Flow	UCI LCI	Flow	UCI LCI	Flow	UCI LCI
Magnitude of annual high flow based on 66 years of record												
1	1,720	1,900 1,560	2,710	3,050 2,440	3,630	4,230 3,210	5,200	6,350 4,440	6,730	8,550 5,600	8,650	11,400 6,990
3	1,670	1,820 1,520	2,490	2,760 2,260	3,180	3,650 2,840	4,220	5,040 3,670	5,140	6,320 4,390	6,200	7,840 5,180
7	1,540	1,670 1,420	2,160	2,390 1,970	2,580	2,910 2,330	3,110	3,600 2,760	3,520	4,140 3,090	3,920	4,700 3,410
15	1,400	1,520 1,290	1,870	2,070 1,720	2,140	2,400 1,950	2,430	2,770 2,190	2,610	3,010 2,340	2,780	3,220 2,470
20	1,320	1,440 1,240	1,760	1,930 1,620	1,980	2,210 1,810	2,210	2,500 2,000	2,360	2,690 2,120	2,480	2,850 2,220
30	1,240	1,340 1,160	1,600	1,760 1,480	1,780	1,980 1,620	1,960	2,200 1,790	2,070	2,340 1,870	2,160	2,450 1,950
60	1,050	1,120 980	1,300	1,420 1,220	1,420	1,560 1,320	1,530	1,700 1,410	1,600	1,720 1,470	1,640	1,840 1,510
90	868	925 816	1,070	1,150 998	1,160	1,260 1,080	1,240	1,370 1,150	1,290	1,420 1,190	1,330	1,470 1,220

[1]Kendall's Tau trend test indicates a trend exists and the frequency curve for indicated n-day period may not fit the data.
[2]Absolute value of computed skew for indicated n-day period is greater than 3.3; therefore, the frequency curve cannot be computed.

05011000 Belly River near Mountain View, Alberta
Site number 2
Period of record 1912–1978

[ft³/s, cubic foot per second; %, percent; --, length of record is not sufficient to estimate value for given recurrence interval]

Duration of daily mean flows for annual and monthly periods

Flow, in ft³/s, which was equaled or exceeded for indicated percent of time

	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	13	18	14	15	28	115	220	155	77	39	21	15	20
98%	18	22	15	21	31	159	248	173	92	44	27	24	24
95%	35	29	19	30	39	235	332	215	110	57	46	49	34
90%	62	38	24	34	53	303	472	269	130	79	68	58	43
80%	117	45	36	41	79	405	649	346	156	93	85	73	53
70%	172	52	48	48	97	497	782	405	186	114	103	88	63
60%	228	56	58	53	116	600	895	464	218	130	121	103	72
50%	283	61	62	59	143	710	1,010	535	246	149	142	117	80
40%	338	66	69	64	174	831	1,160	618	272	168	162	132	88
30%	393	74	76	71	225	970	1,320	710	302	192	198	150	98
20%	515	85	92	92	299	1,150	1,490	822	340	232	245	173	108
10%	880	101	105	109	430	1,380	1,810	1,020	419	310	321	210	129
5%	1,220	115	125	156	574	1,600	2,110	1,220	485	378	410	255	153
2%	1,600	175	179	216	757	1,830	2,470	1,460	559	508	558	345	196
1%	1,840	231	255	269	918	2,020	2,700	1,590	623	628	742	409	242

Annual and monthly mean flows, in ft³/s, for indicated years of record

Years of record	66	67	67	67	67	67	67	67	67	67	66	67	67
Mean flow	314	68	68	69	207	786	1,120	603	260	177	178	128	86
Standard deviation of	72	27	25	32	116	194	417	241	91	92	103	62	36

Return to Table 1

Table_1 | 05010000_All | 05011000_All | 05011500_All | 05012500_All | 05013700_All | 05013900_All

Ready

Chapter F: Peak-Flow Regional Regression Equations

- Regional Regression Equations for unregulated annual exceedance probabilities
  - 8 hydrologic regions
  - 537 gaging stations
    - Drainage area less than ~2,500 sq. mi.
    - Systematic record unaffected by major regulation
    - No redundancy with nearby stations
    - Representation of peak-flow characteristics in MT
  - 28 candidate basin characteristics

    A, EL_{5000}, EL_{6000}, ET_{SPR}, F, P, SLP_{30}

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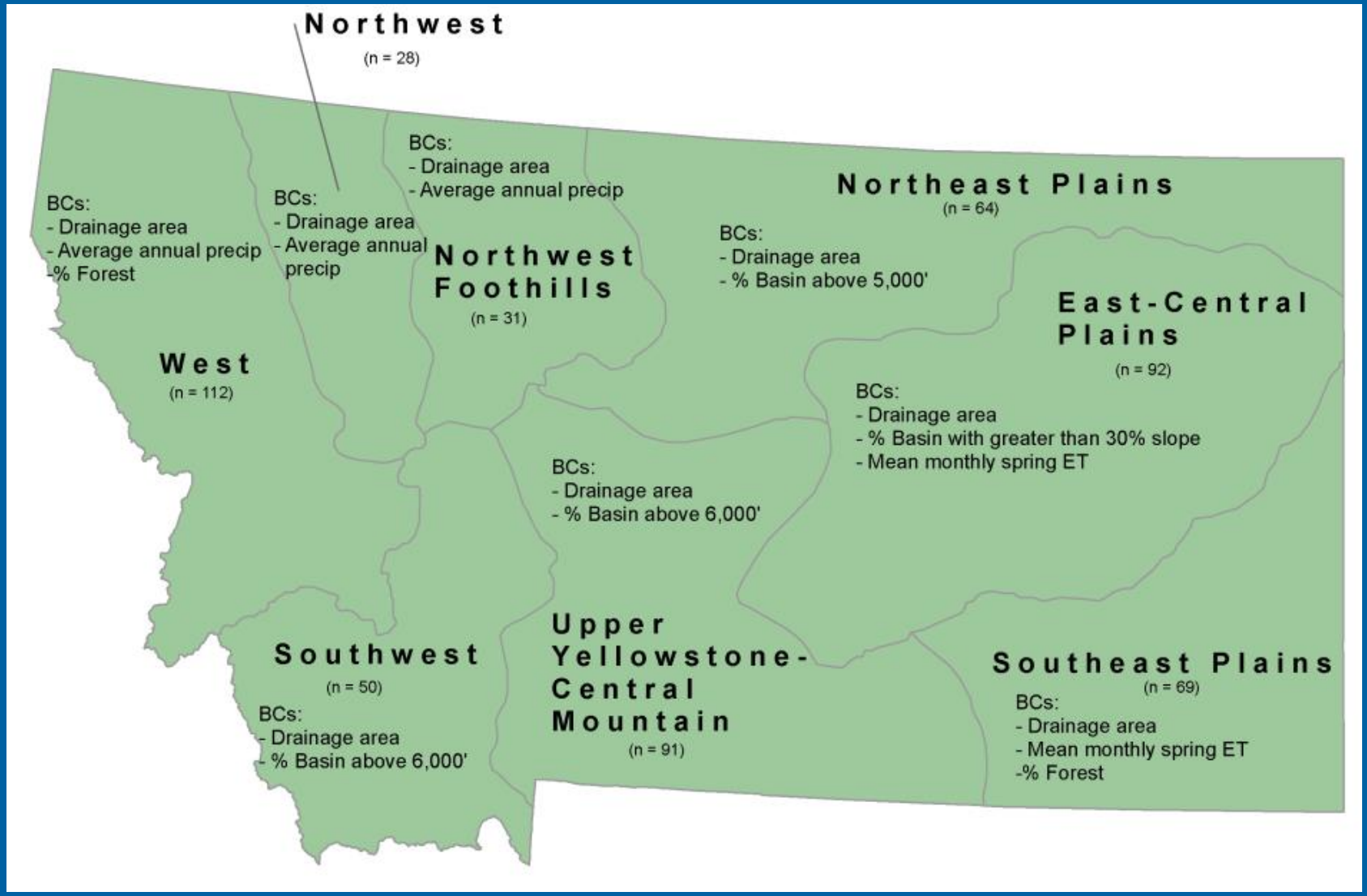
Chapter F: Peak-Flow Regional Regression Equations



Chapter G: Regional Regression Equations for Streamflow Characteristics

- Annual and seasonal low-flow
  - 7Q10
  - 14Q5
- Annual and monthly
  - Mean
  - Duration values for
    - Q20%
    - Q50%
    - Q80%
- Explanatory Variables
  - Drainage area
  - Mean annual precip.
  - Percent of basin with slopes greater than 50 percent.

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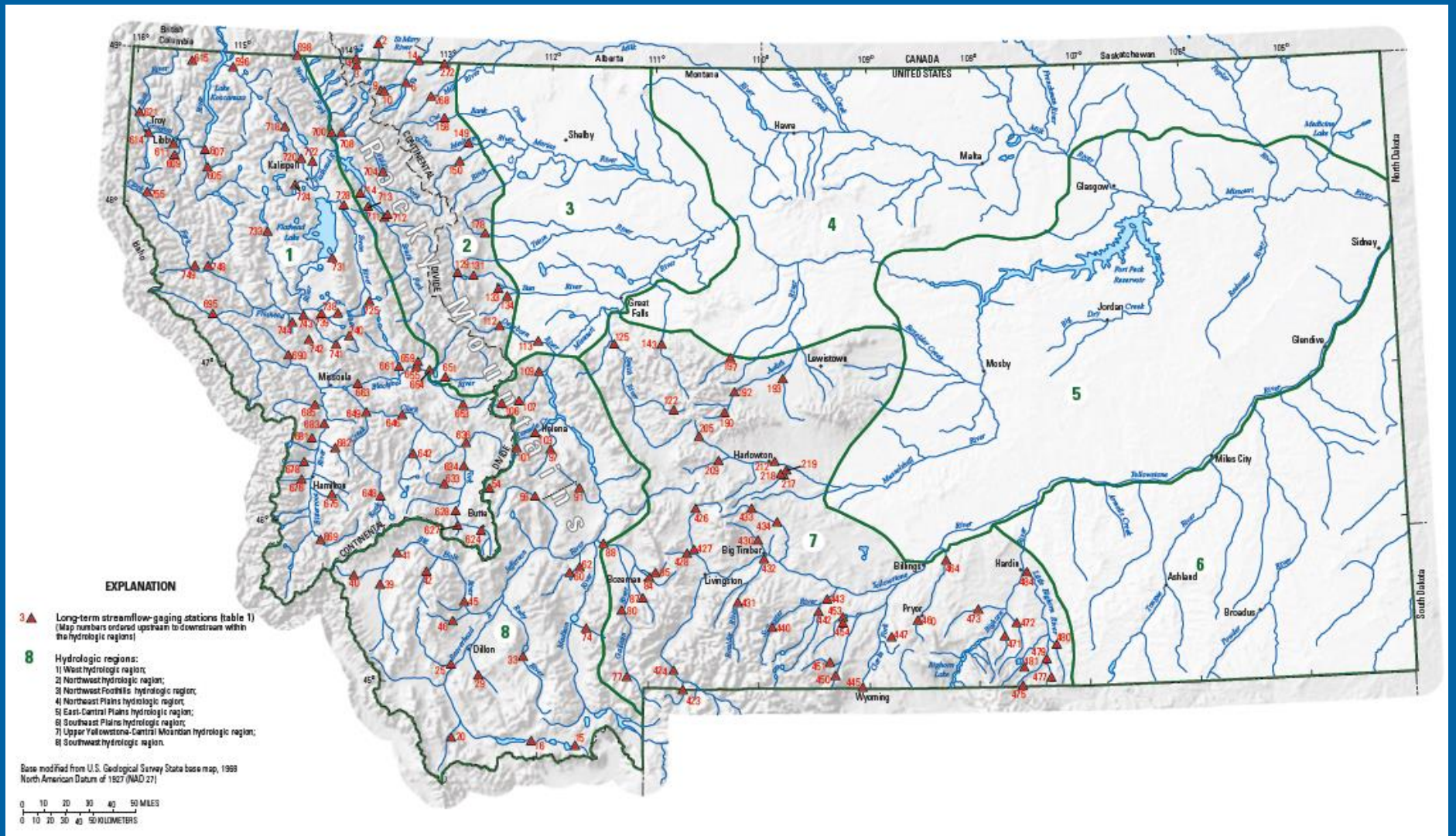
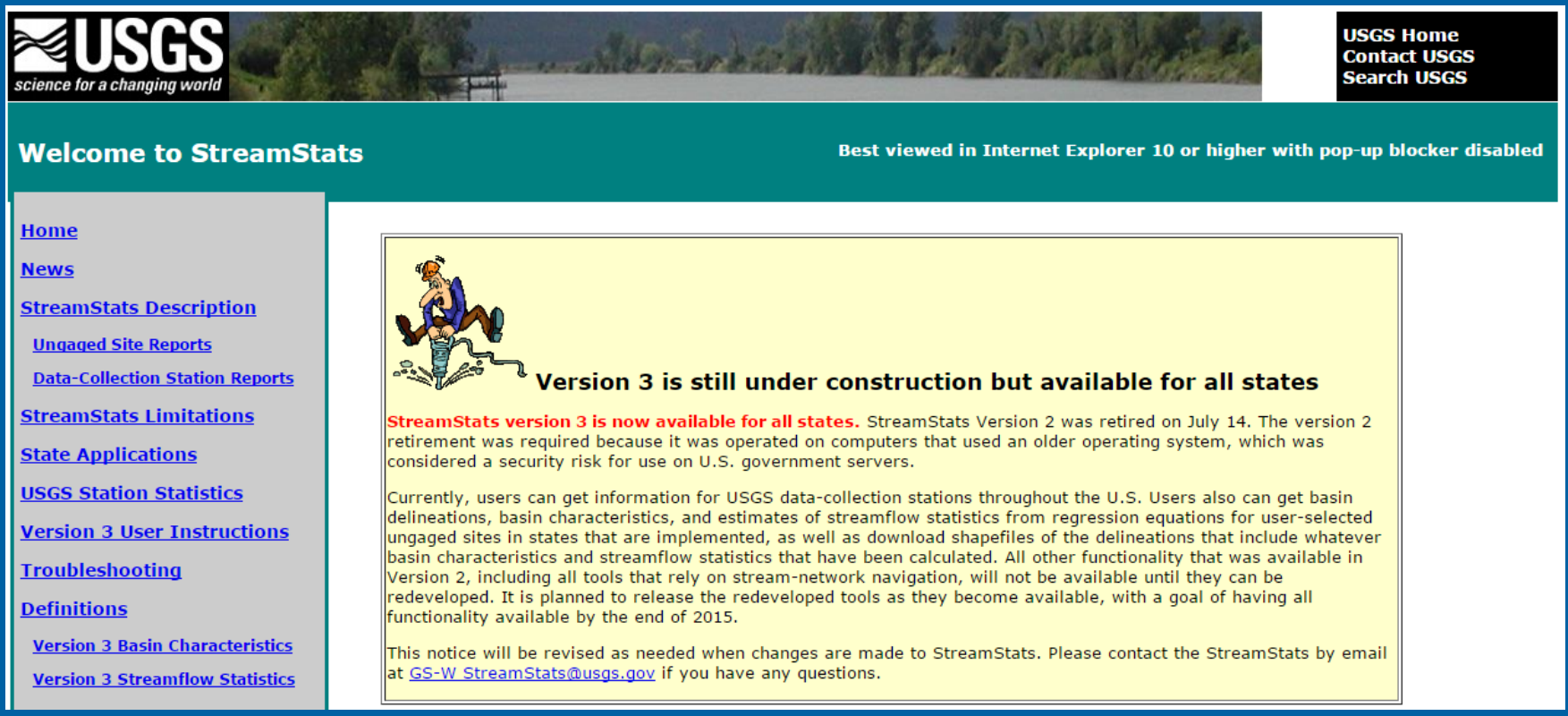
Chapter G: Regional Regression Equations for Streamflow Characteristics



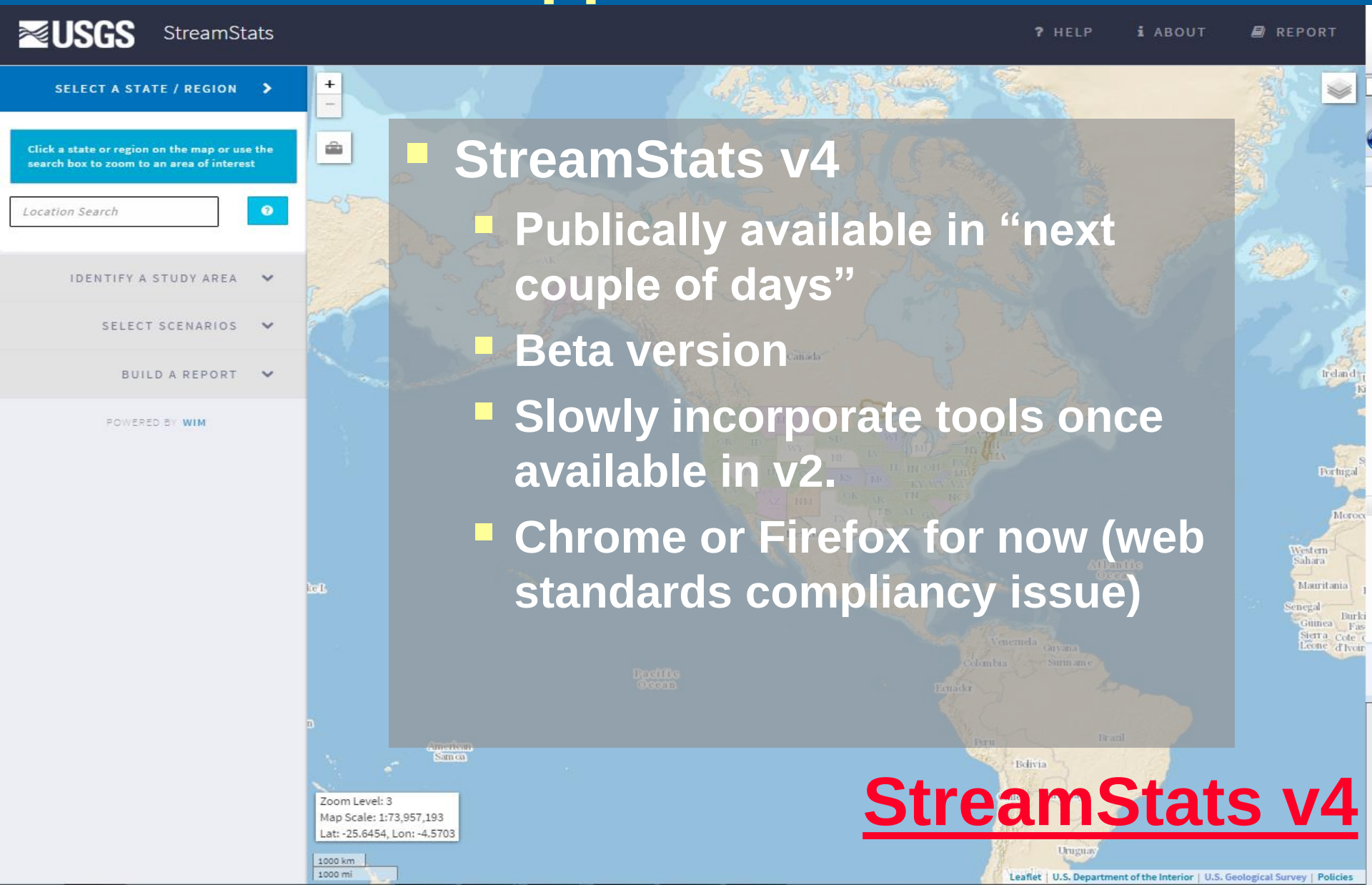
StreamStats Application

http://water.usgs.gov/osw/streamstats/



USGS

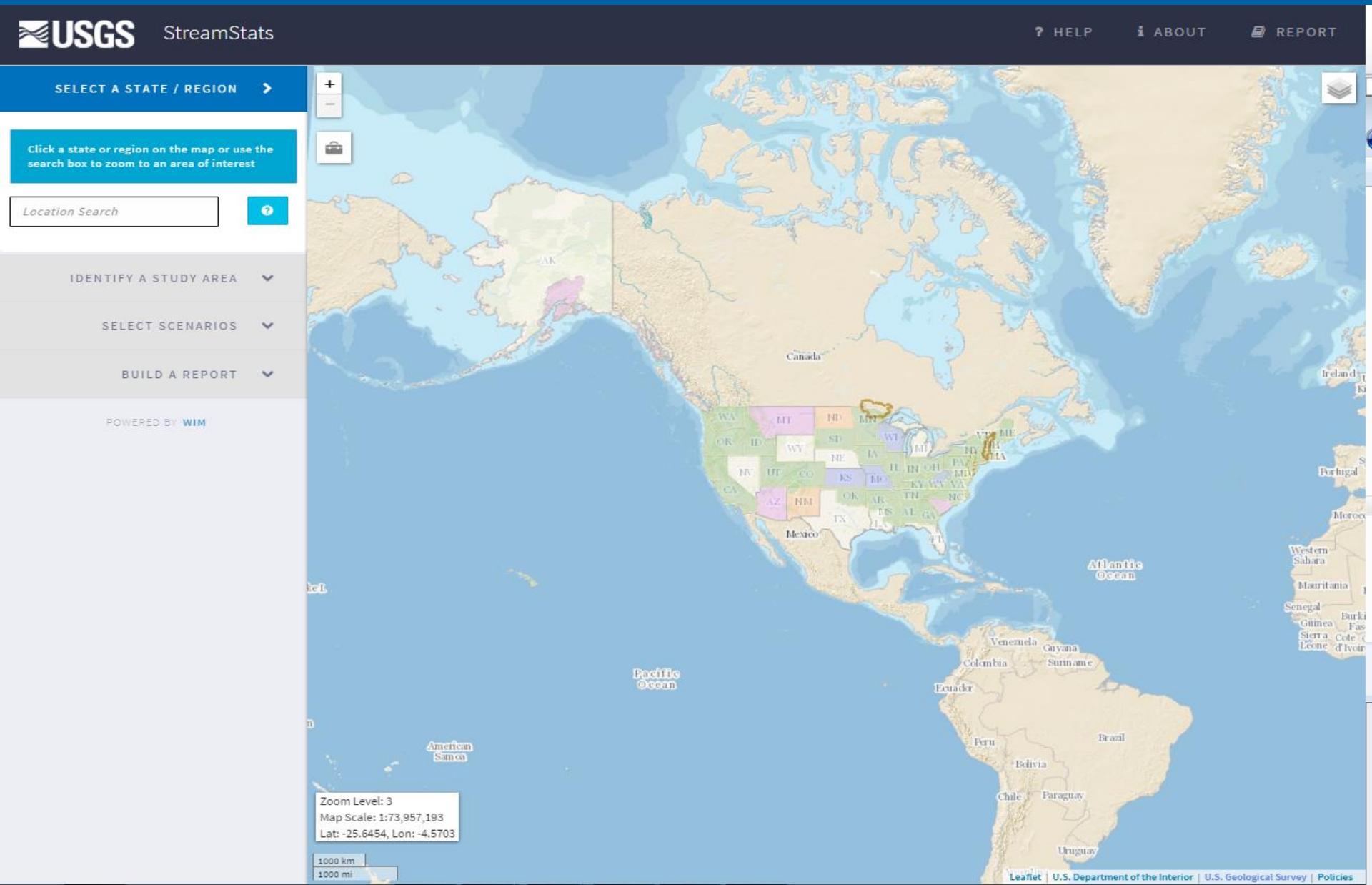
StreamStats Application



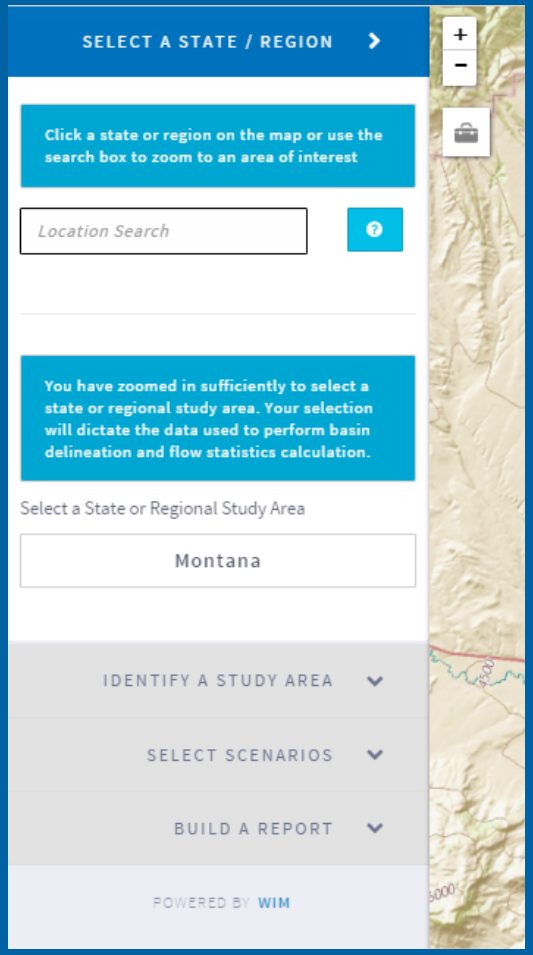
- StreamStats v4
  - Publically available in “next couple of days”
  - Beta version
  - Slowly incorporate tools once available in v2.
  - Chrome or Firefox for now (web standards compliancy issue)

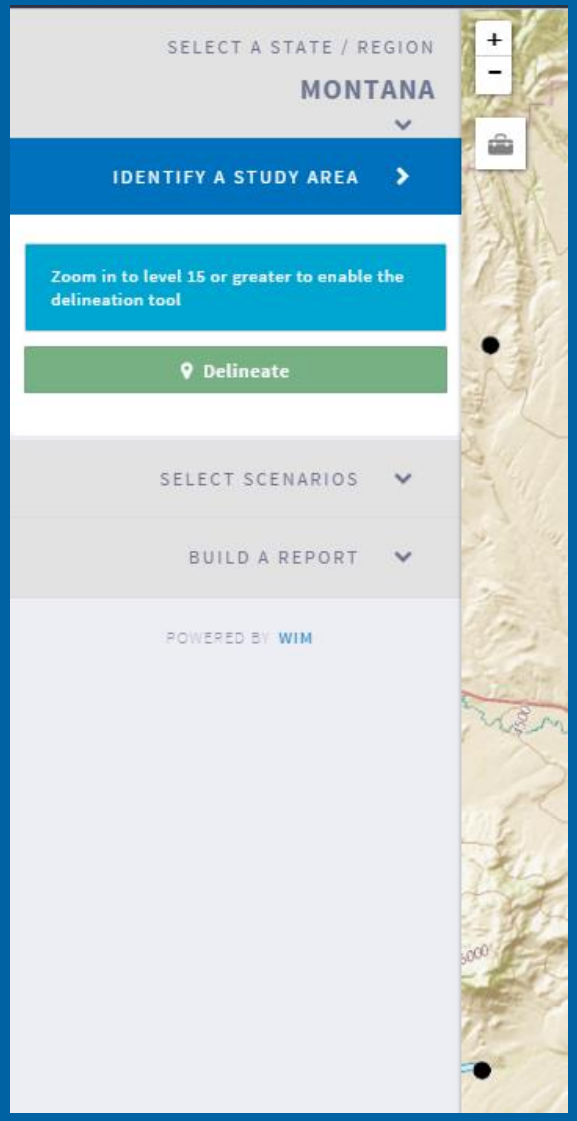
StreamStats v4

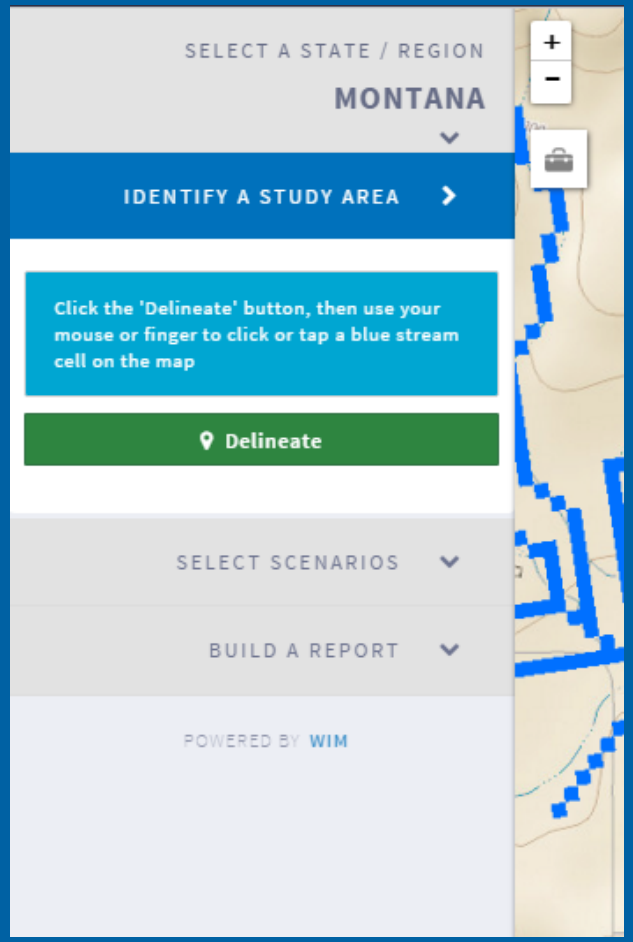
StreamStats v4



StreamStats v4

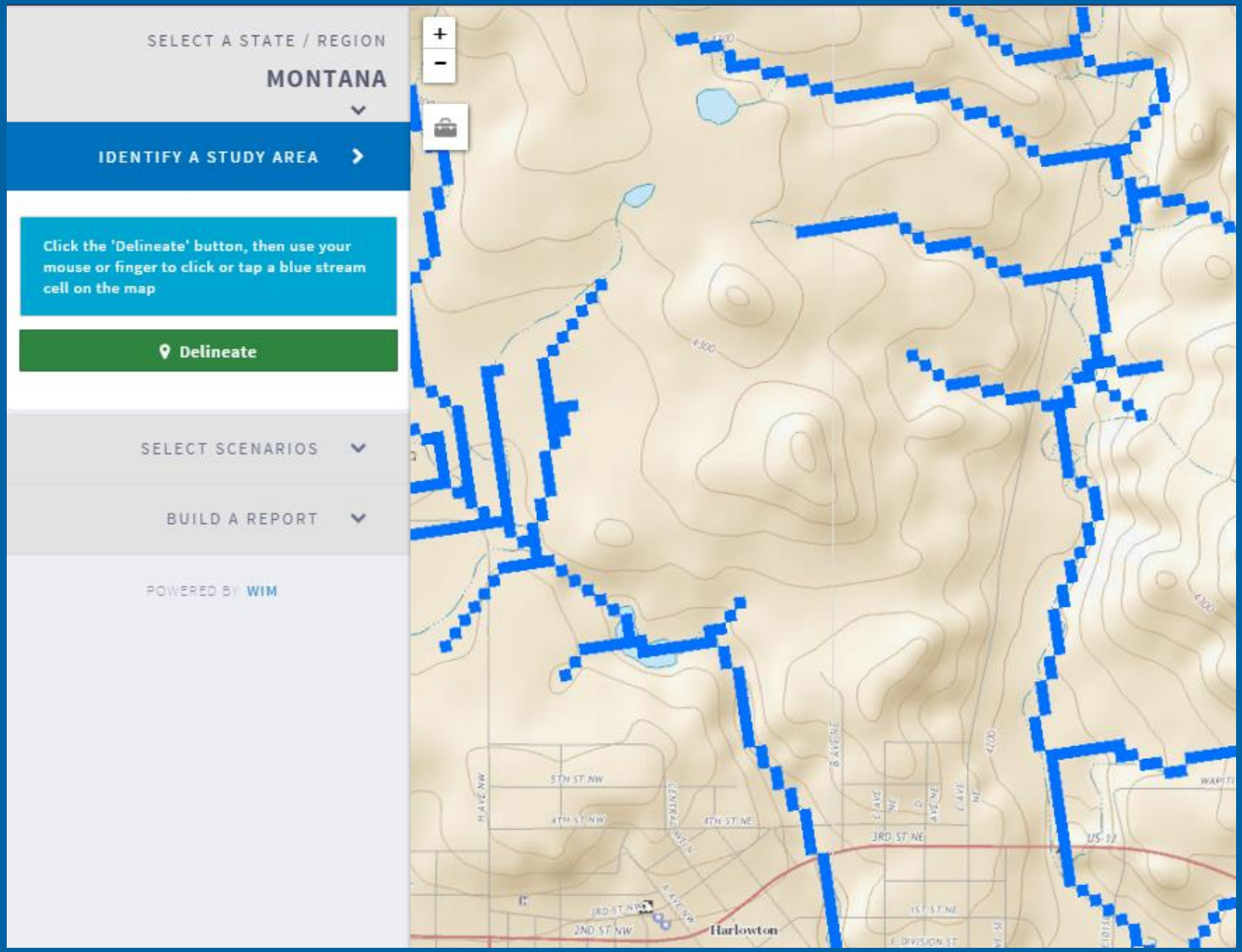




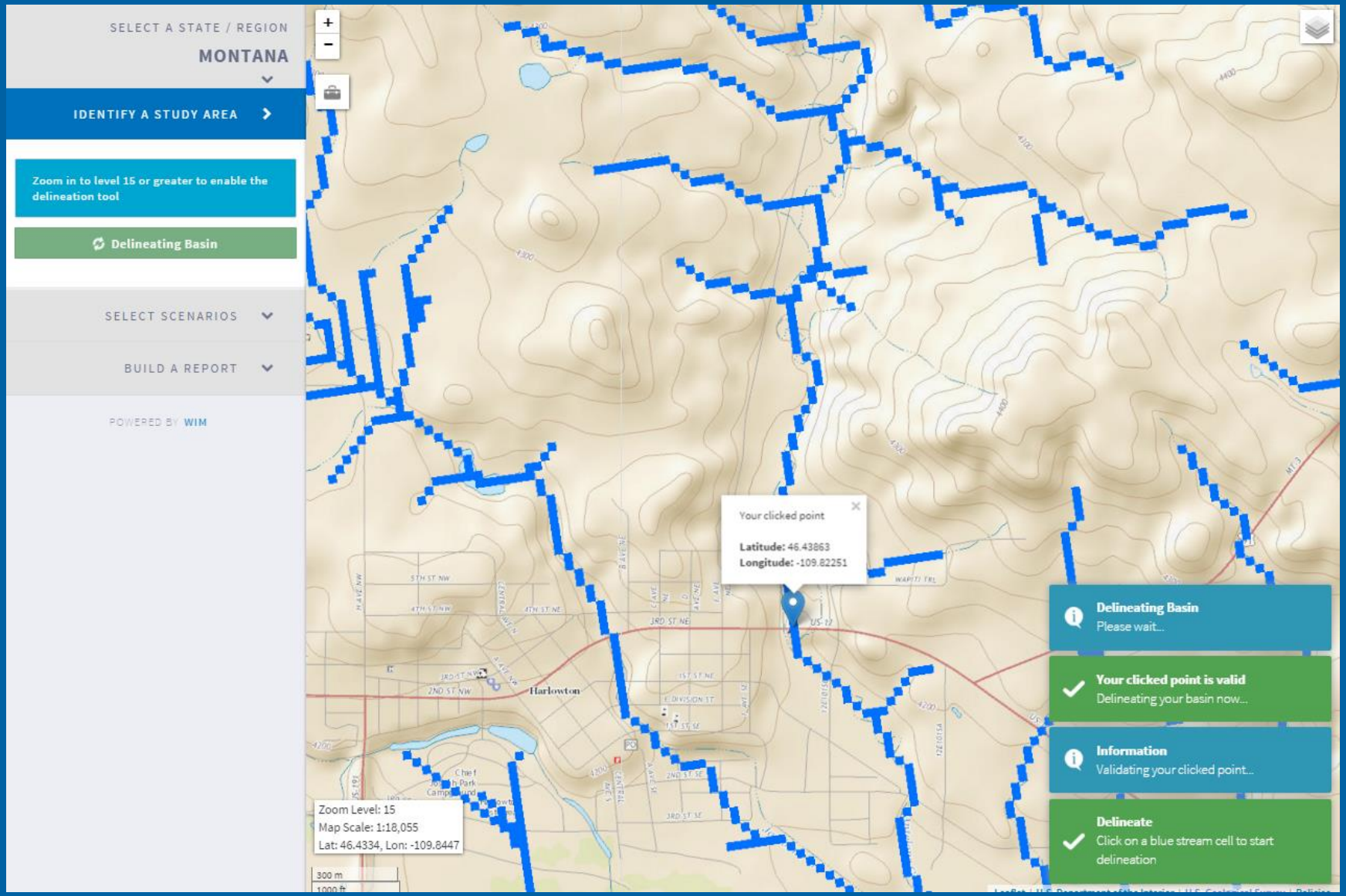


USGS

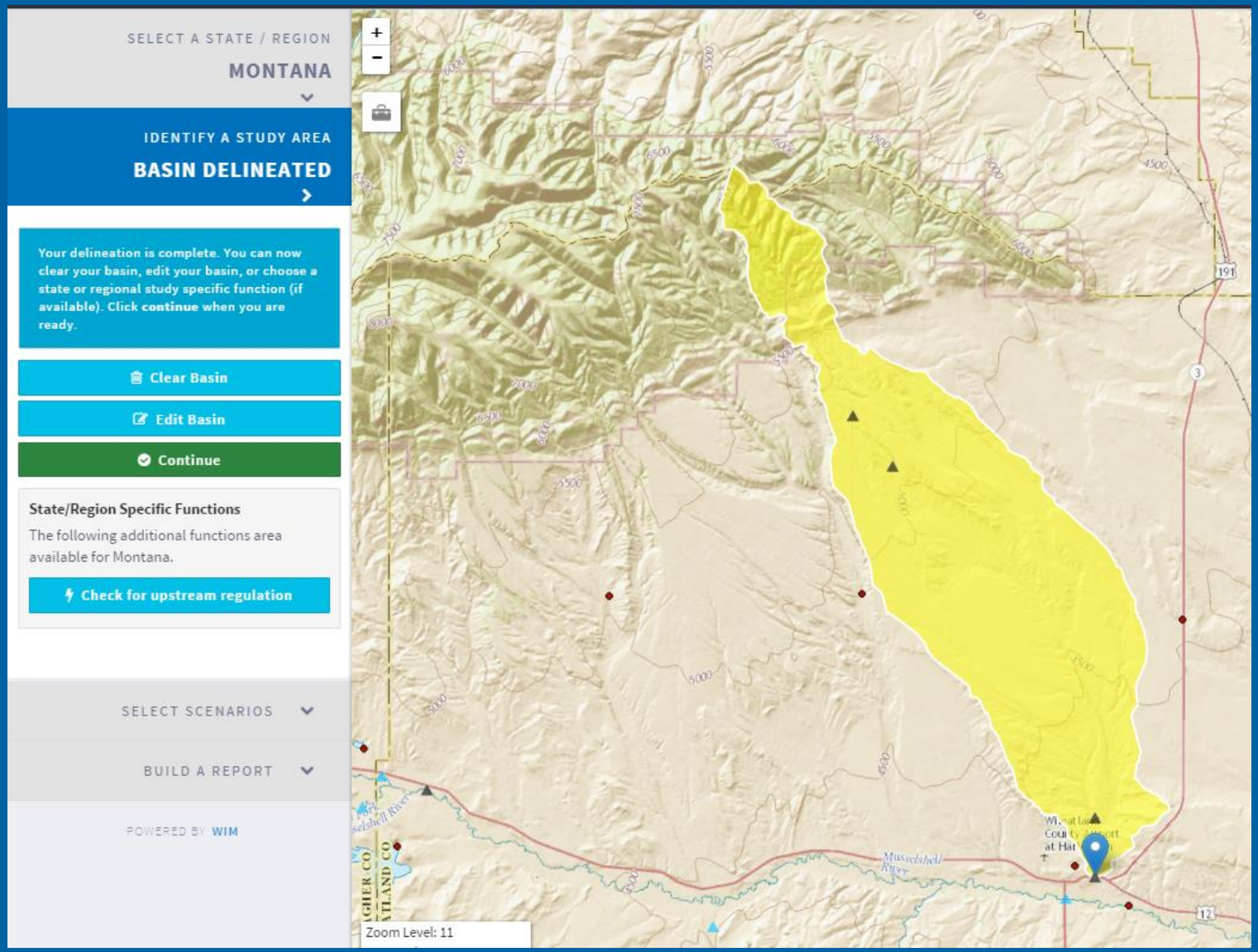
StreamStats v4

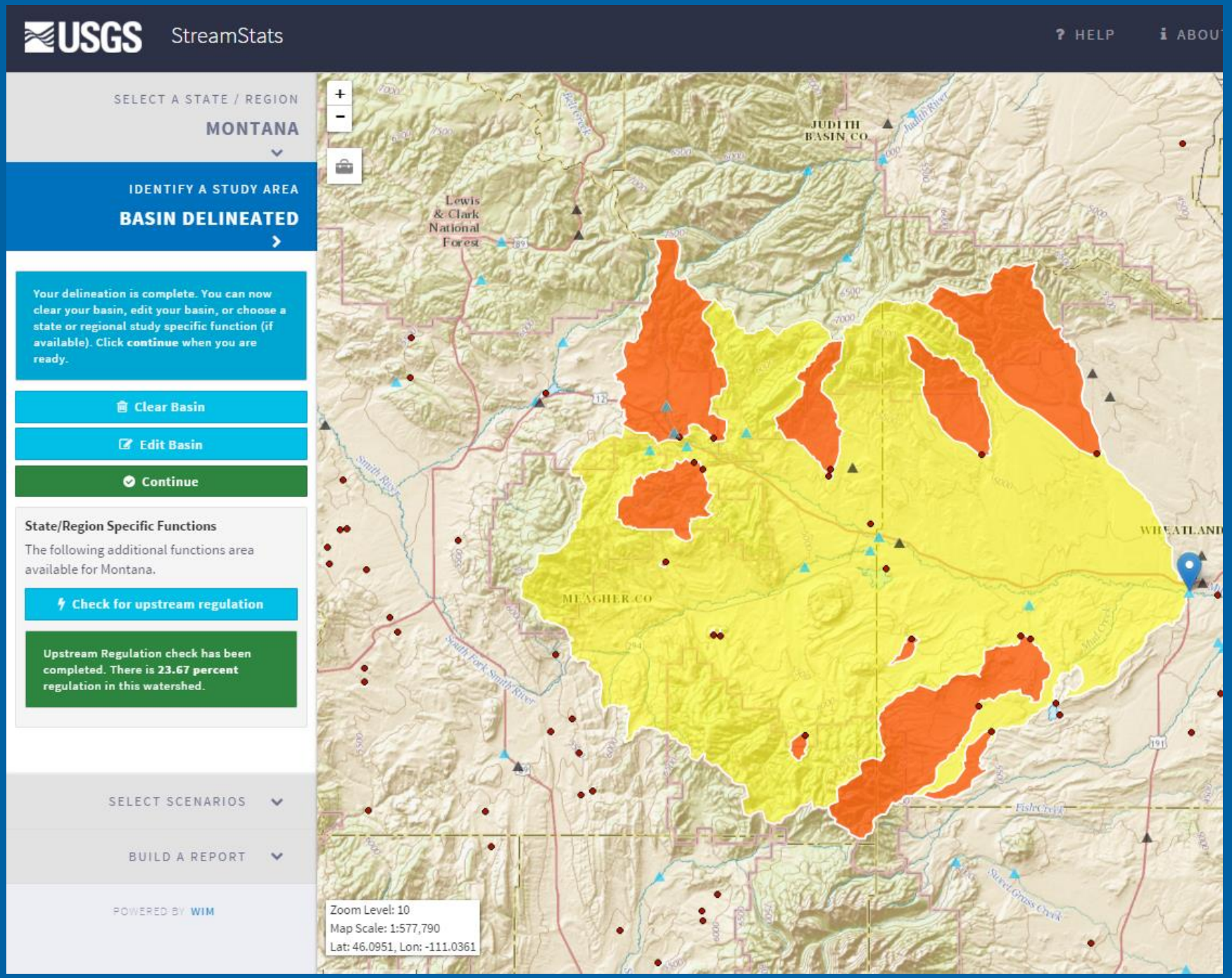


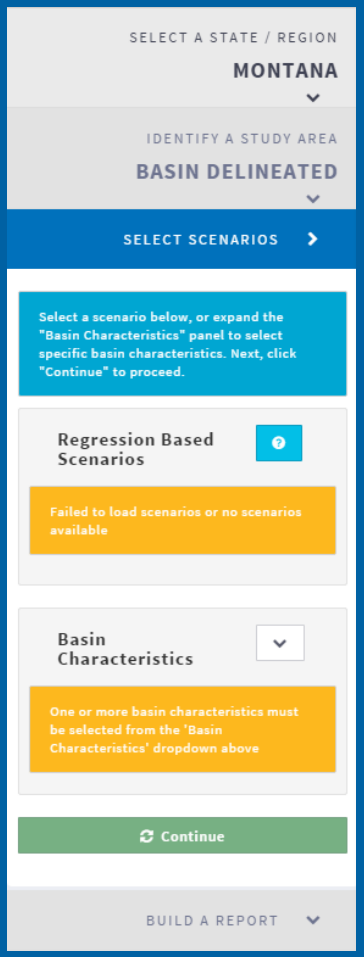
StreamStats v4



StreamStats v4

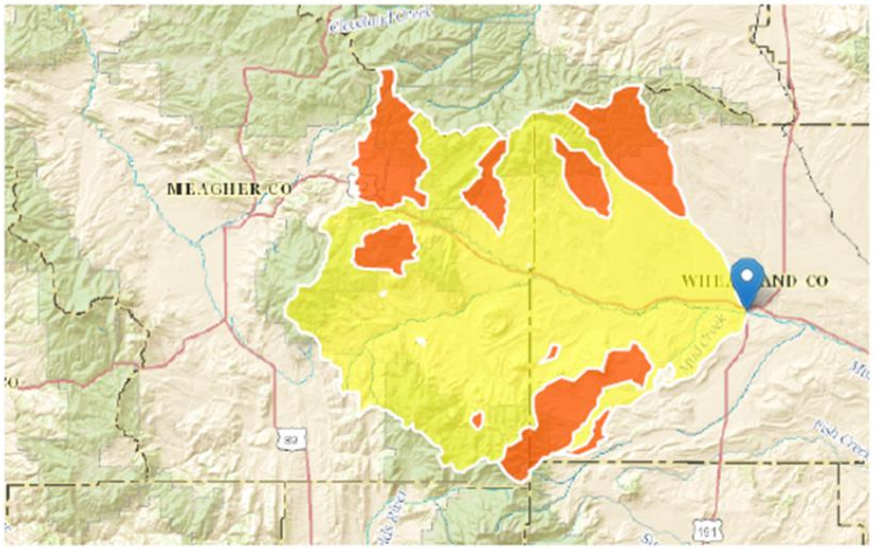



USGS StreamStats
? HELP
i ABOU
SELECT A STATE / REGION
MONTANA
IDENTIFY A STUDY AREA
BASIN DELINEATED
Your delineation is complete. You can now clear your basin, edit your basin, or choose a state or regional study specific function (if available). Click continue when you are ready.
Clear Basin
Edit Basin
Continue
State/Region Specific Functions
The following additional functions area available for Montana.
Check for upstream regulation
Upstream Regulation check has been completed. There is 23.67 percent regulation in this watershed.
SELECT SCENARIOS
BUILD A REPORT
POWERED BY WIM
Lewis & Clark National Forest
JUDITH BASIN CO
MEAGHER CO
Zoom Level: 10
Map Scale: 1:577,790
Lat: 46.0951, Lon: -111.0361



StreamStats Report

Region ID:
MT
Workspace ID:
MT20160314161050037000
Clicked Point (Latitude, Longitude):
46.42898,-109.84151
Time:
2016-03-14 16:10:59 -0600



Basin Characteristics

Parameter Code	Parameter Description	Value	Unregulated Value	Regulated Value	Unit
CONTDA	Area that contributes flow to a point on a stream (total drainage area minus non-contributing areas within basin)	1108.2			square miles

When?

- National StreamStats Version 4
  - Internally testing
  - Expected public release soon (days to weeks)
- Montana StreamStats Application
  - Currently able to compute basin characteristics
  - Fully Implemented (~6 weeks)

USGS

StreamStats Developments

- National development of NHDPlus High Res.
  - 2-3 years out
  - Will include value attributes for high resolution hydrography (1:24K NHD, 10-meter DEM)
- Updated basin and streamflow characteristics
  - Regulation (better methods, more inclusive)
  - Trends (land use/climate, etc)
- Spinoff applications
  - Time of travel
  - Real-time streamflow estimation for ungaged sites
- USGS WY-MT WSC – Wyoming StreamStats

USGS

StreamStats Training

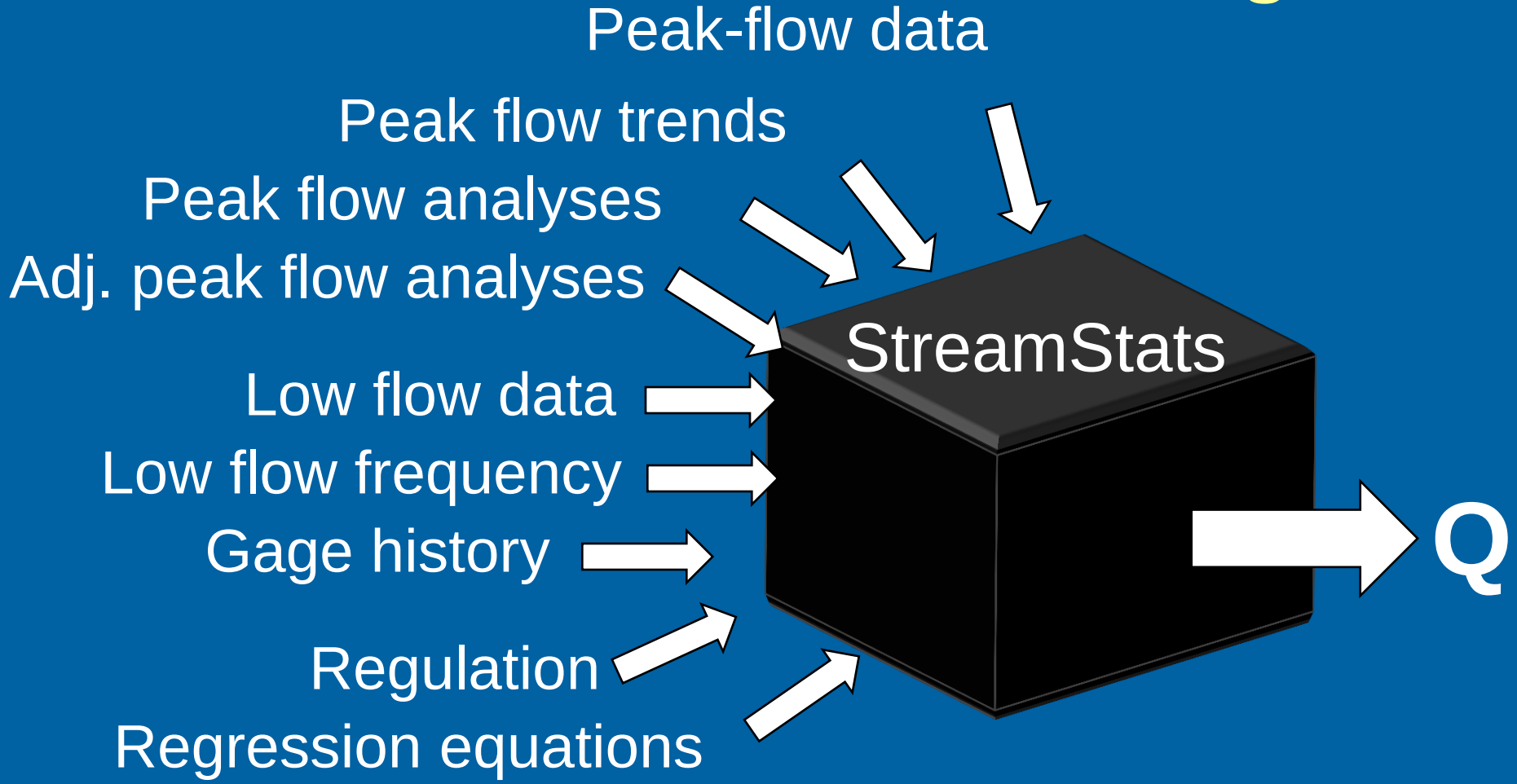
- Sign up for training notifications at

http://wy-mt.water.usgs.gov/mtwy-notices.html

- Association of Montana Floodplain Managers meeting-March 15-17, 2016
- AWRA
- Others?

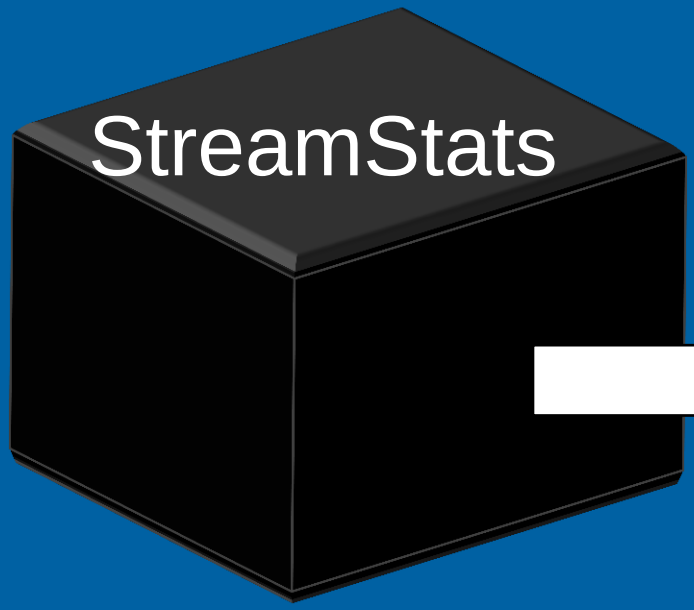
USGS

Data qualifications, and limitations of a StreamStats determined discharge…



USGS

….are described in USGS Reports



Q

SIR20155019A
SIR20155019B
SIR20155019C
SIR20155019D
SIR20155019E
SIR20155019F
SIR20155019G

USGS

Questions?

USGS

Clark Fork River at Milltown Dam, June 1908
http://www.floodsafety.noaa.gov/states/mt-flood.shtml
Q_{peak}=48,000cfs