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Flood Frequency Discharge Analysis of the Big Hole River

A Case Study

Ben Fennelly, P.E., CFM

Matt Johnson, E.I., CFM

Overview

- Purpose
- Flow Change Locations
- Explore Hydrologic Methods
- Review/Interpret Results

Project Background

- Purpose: Understand flood hazards and refine floodplain boundaries
- Stakeholders
  - MT DNRC
  - MT DEQ
  - Big Hole River Watershed Committee
  - Future West
  - Anaconda – Deer Lodge County
  - Beaverhead County
  - Butte – Silver Bow County
  - Madison County

Watershed Description

- Big Hole River Extents: Pioneer Creek to Twin Bridges
  - 116 river miles
- Drainage Area of 2,792 mi^2
- Watershed separated into 3 distinct areas
  - Upper Watershed: Broad, low sloping valley
    - Sinuous, multi-threaded channel
  - Middle Watershed: Relatively steep confined canyon
    - Primarily bedrock channel with large boulders
  - Lower Watershed; Broad, low sloping valley
    - Broad floodplains, split channels

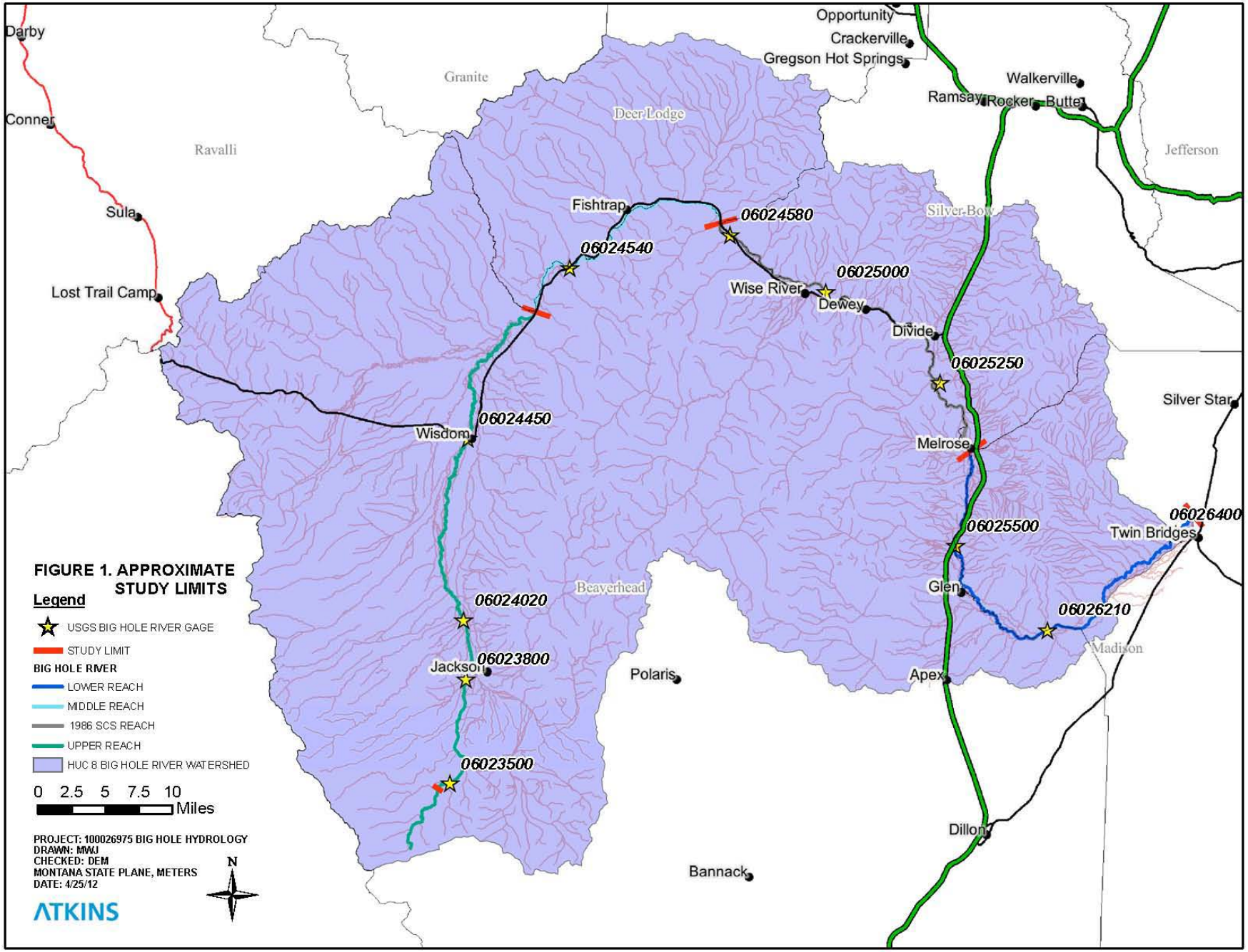
FIGURE 1. APPROXIMATE STUDY LIMITS
Legend
USGS BIG HOLE RIVER GAGE
STUDY LIMIT
BIG HOLE RIVER
LOWER REACH
MIDDLE REACH
1986 SCS REACH
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HUC 8 BIG HOLE RIVER WATERSHED
0 2.5 5 7.5 10 Miles
PROJECT: 100026975 BIG HOLE HYDROLOGY
DRAWN: MWJ
CHECKED: DEM
MONTANA STATE PLANE, METERS
DATE: 4/25/12
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ATKINS
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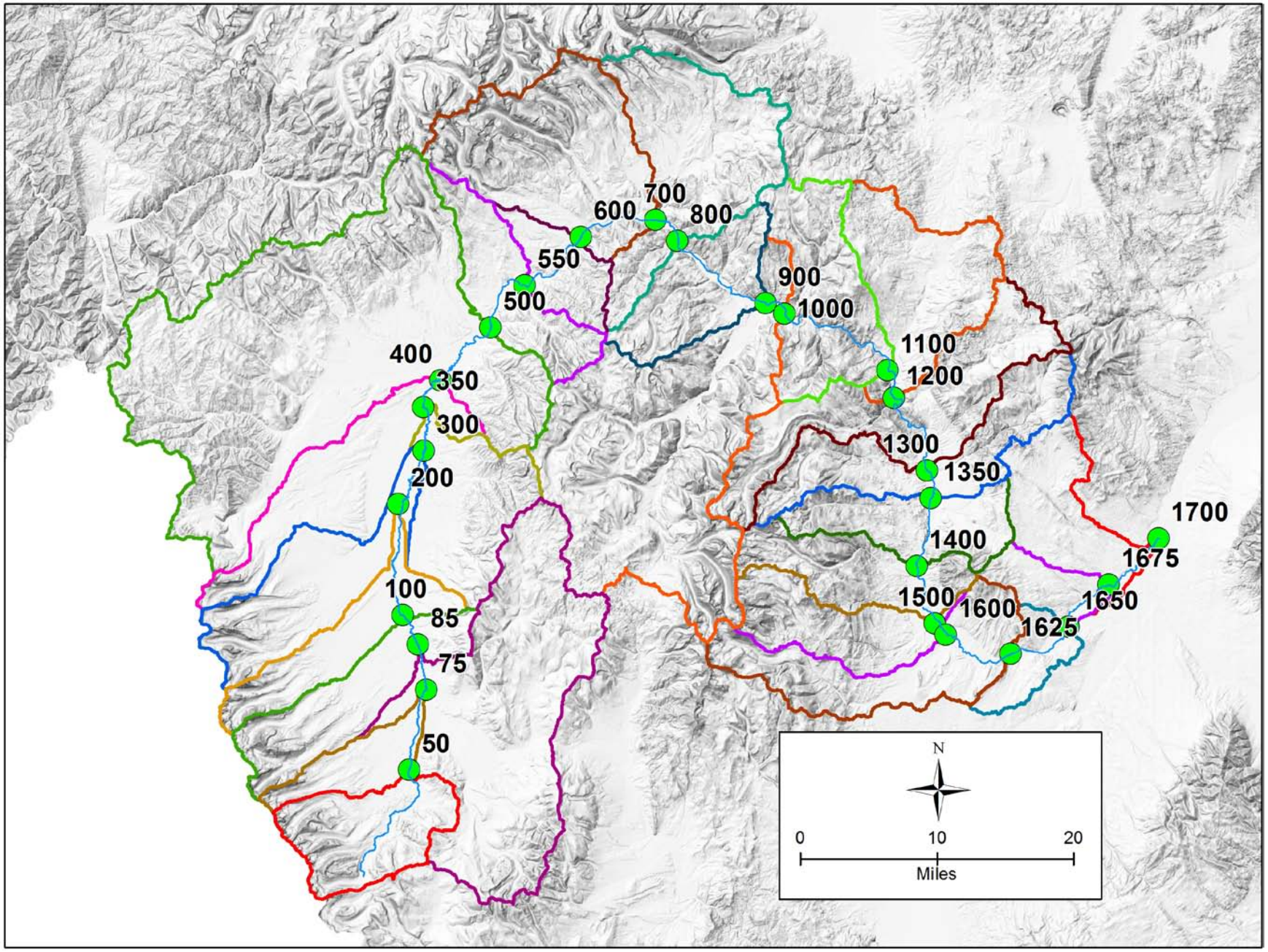
Polaris
Apex
06023500
Dillon
Bannack

Flow Change Locations

- **Considerations:**
  - **Contributing Drainage Area of Tributaries**
  - **Reach Length**
    - **Limit distance between flow nodes**

- **Resulted in 26 flow change locations**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1650
1600
85
1625
75
50
N
0
10
20
Miles

Hydrologic Methods

- USGS Regression Analysis
  - Generally used when gage data is not available or for comparison purposes
  - Based on correlation of regional gage data to measureable basin and river characteristics
- Stream Gage Analysis
  - 12 gages
    - Range of record – 2 to 87 years

USGS Regression Analysis

USGS WRIR 03-4308, “Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998” (2004)

- Four different methods:
  - Basin Characteristics
  - Active Channel Width
  - Bankfull Channel Width
  - Weighted Combinations
- Specific equations depend upon location of project

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
BUREAU OF INDIAN AFFAIRS, BUREAU OF LAND MANAGEMENT, CONFEDERATED SALISH AND KOOTENAI TRIBES, MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION, MONTANA DEPARTMENT OF TRANSPORTATION, and the U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE

WATER-RESOURCES INVESTIGATIONS REPORT 03-4308
(Figures 1 and 6) Plate 1

Parrett, Charles, and Johnson, D.R., 2003, Methods for estimating flood frequency in Montana based on data through water year 1998

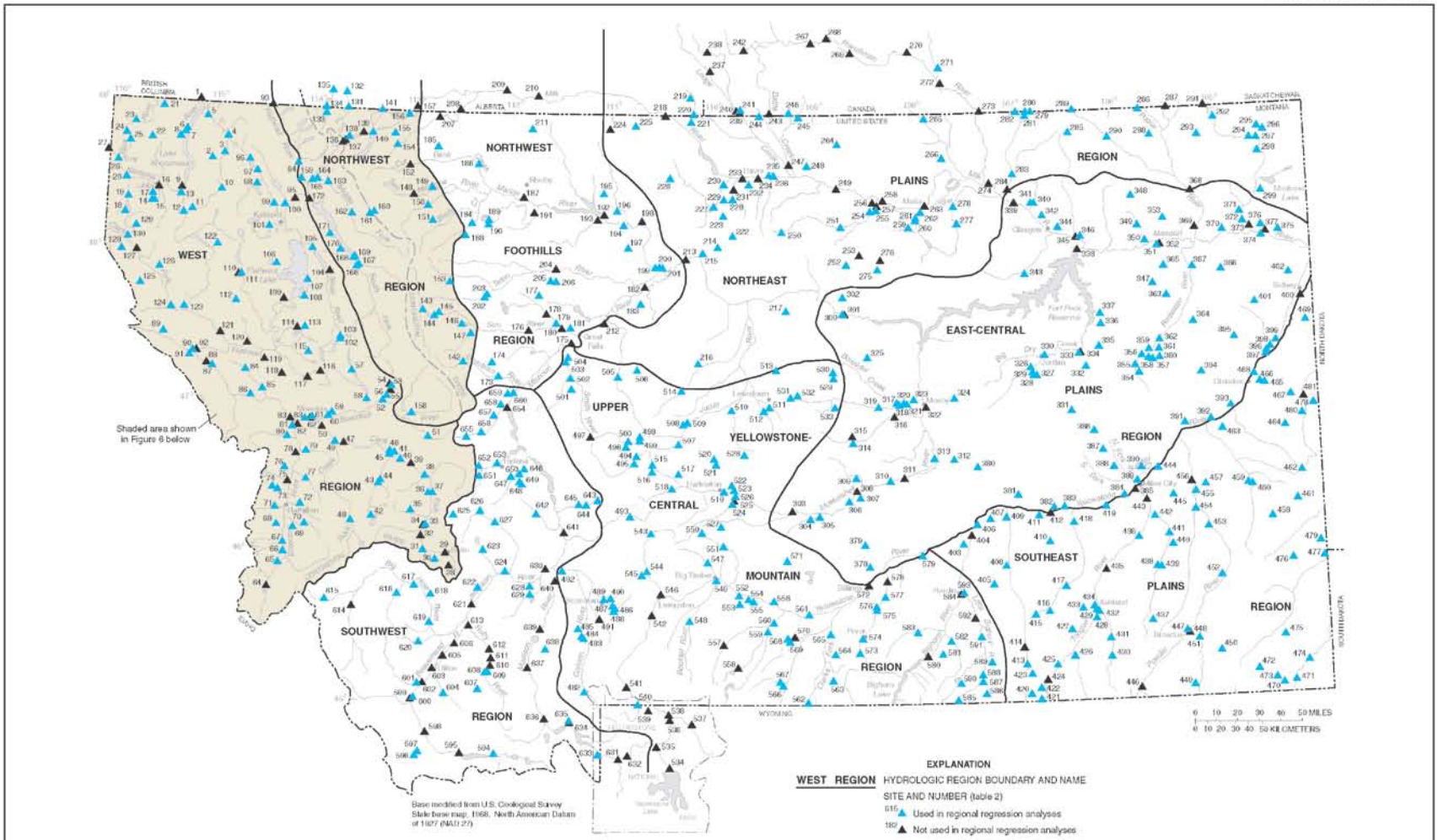
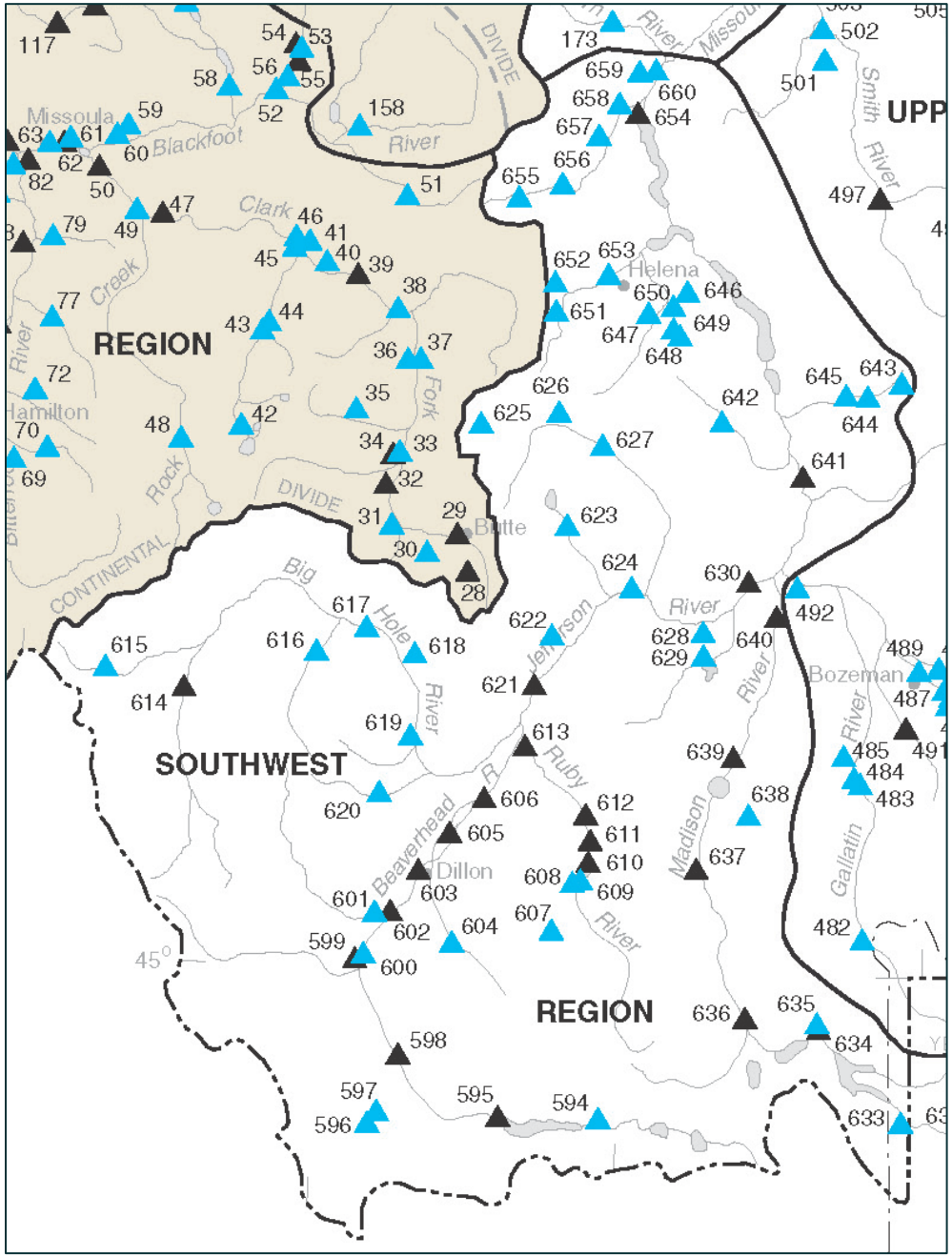


Figure 1. Hydrologic regions and streamflow-gaging stations having compiled flood-frequency characteristics, Montana and adjacent areas in Idaho, Wyoming, and Canada.


REGION
SOUTHWEST
REGION
UPP
Missoula
Hamilton
Butte
Helena
Bozeman
Dillon
Blackfoot
Clark
Creek
Rock
Fork
Big
Hole
River
Jefferson
Ruby
Beaverhead
Madison
Gallatin
Smith
River
CONTINENTAL
DIVIDE
45°

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Regression Analysis

- Strengths of Regression Method
  - Analysis of multiple gages
    - Large sample size
  - Wide range of applicability
  - Simple and time efficient

Regression Analysis

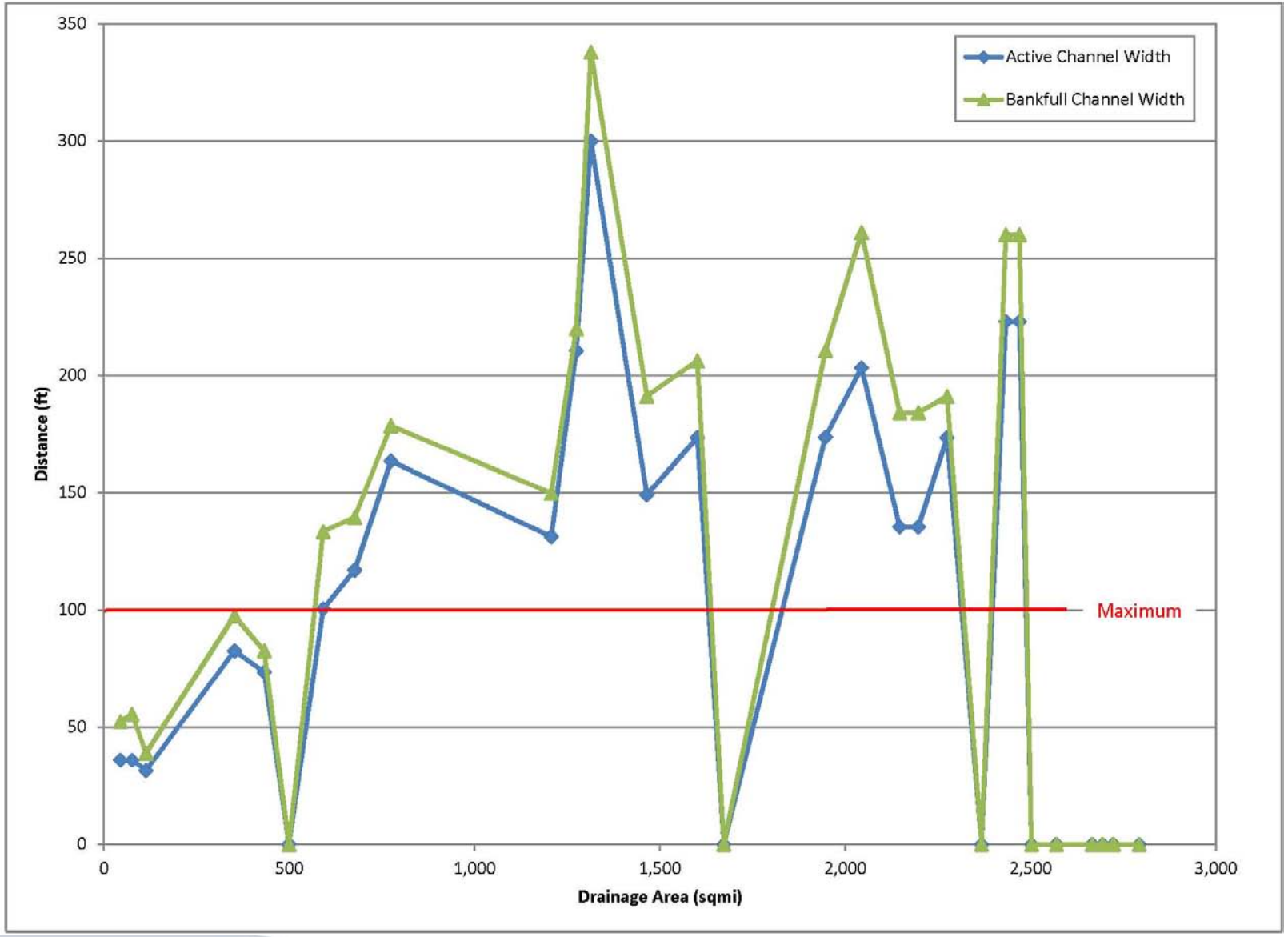
- Weaknesses of Regression Method
  - Generalized Approach (i.e. Regional)
  - Multiple Stream Types
  - Split Channel Locations
  - Inconsistent Widths
  - High Error Values
  - Specific Range of Applicability

Southwest Region Regression

- Basin Characteristics: $Q_{100} = 351A^{0.682}(E_{6000}+1)^{-0.476}$
  - Drainage Area (A): 0.39 mi^2 – 2,476 mi^2
  - Drainage Area Above 6,000' (E_{6000}): 15% – 100%
- Active Channel: $Q_{100} = 41.8W_{ac}^{1.02}$
  - 1.8' to 100'
- Bankfull Channel: $Q_{100} = 19.3W_{bf}^{1.15}$
  - 3.5' to 100'
- Weighted Combinations

Regression Analysis

Regression Analysis



Regression Analysis

Gage/Basin ID	Drainage Area (mi^2)	Drainage Area Above 6000' (%)	Active Channel Width (ft)	Bankfull Channel Width (ft)
USGS 06023500	43.9	100	36	53
50	75.2	100	36	56
75	113	100	32	39
85	352	100	83	98
100	432	100	74	83
200	499	100	N/A	N/A
300	591	100	101	134
350	676	99.9	117	140
400	774	99.5	164	179
500	1,206	98.5	131	150
550	1,274	97.9	211	220
600	1,313	97.6	300	338
700	1,464	97.3	149	191
800	1,601	97.2	173	206
900	1,672	96.8	N/A	N/A
1000	1,946	96.7	174	211
1100	2,043	96.3	203	261
1200	2,146	94.8	135	184
USGS 06025250	2,196	94.8	135	184
1300	2,274	94.1	173	191
1350	2,367	93.5	N/A	N/A
1400	2,433	92.2	223	260
USGS 06025500	2,469	92.1	223	260
1500	2,502	91.5	N/A	N/A
1600	2,569	90.9	N/A	N/A
1625	2,665	89.4	N/A	N/A
1650	2,693	88.4	N/A	N/A
1675	2,722	87.8	N/A	N/A
1700	2,792	86.7	N/A	N/A

Regression Results

Gage/Basin ID	Drainage Area (mi^2)	Percent Basin Above 6000' (%)	Discharge (cfs)				
			10-year	25-year	50-year	100-year	500-year
USGS 06023500	43.9	100	282	369	438	514	700
50	75.2	100	425	547	640	743	986
75	113	100	582	737	854	982	1,280
85	352	100	1,380	1,680	1,900	2,130	2,630
100	432	100	1,620	1,950	2,190	2,450	3,000
200	499	100	1,810	2,170	2,430	2,700	3,290
300	591	100	2,060	2,450	2,730	3,030	3,660
350	676	99.9	2,280	2,710	3,010	3,320	3,990
400	774	99.5	2,530	2,990	3,310	3,650	4,360
500	1,206	98.5	3,560	4,150	4,540	4,970	5,820
550	1,274	97.9	3,720	4,320	4,730	5,170	6,040
600	1,313	97.6	3,810	4,420	4,840	5,290	6,170
700	1,464	97.3	4,140	4,790	5,230	5,700	6,620
800	1,601	97.2	4,440	5,110	5,570	6,060	7,010
900	1,672	96.8	4,590	5,290	5,760	6,250	7,230
1000	1,946	96.7	5,160	5,910	6,410	6,940	7,970
1100	2,043	96.3	5,360	6,130	6,640	7,190	8,240
1200	2,146	94.8	5,580	6,380	6,920	7,490	8,580
USGS 06025250	2,196	94.8	5,680	6,490	7,040	7,610	8,710
1300	2,274	94.1	5,850	6,670	7,230	7,820	8,940
1350	2,367	93.5	6,040	6,890	7,460	8,060	9,210
1400	2,433	92.2	6,180	7,060	7,650	8,270	9,450
USGS 06025500	2,469	92.1	6,250	7,140	7,730	8,350	9,550
1500	2,502	91.5	N/A	N/A	N/A	N/A	N/A
1600	2,569	90.9	N/A	N/A	N/A	N/A	N/A
1625	2,665	89.4	N/A	N/A	N/A	N/A	N/A
1650	2,693	88.4	N/A	N/A	N/A	N/A	N/A
1675	2,722	87.8	N/A	N/A	N/A	N/A	N/A
1700	2,792	86.7	N/A	N/A	N/A	N/A	N/A

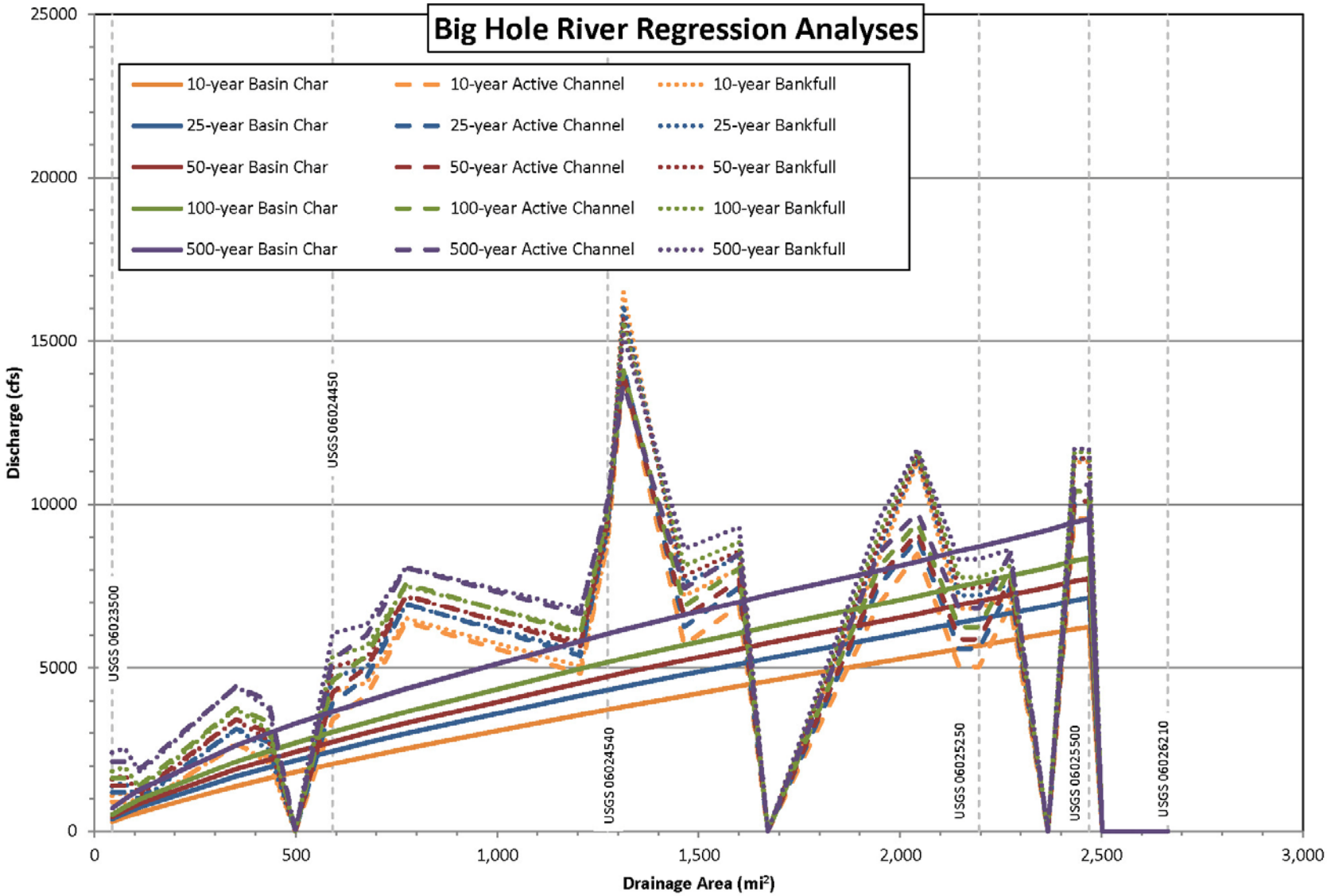
Regional Regression Results

Location	Active Channel Width (ft)	Discharge (cfs)				
		10-year	25-year	50-year	100-year	500-year
USGS 06023500	36.0	910	1,190	1,390	1,620	2,140
50	36.0	910	1,190	1,390	1,620	2,140
75	31.5	766	1,010	1,200	1,410	1,910
85	82.5	2,650	3,130	3,420	3,770	4,430
100	73.5	2,280	2,730	3,020	3,350	4,000
200	N/A	N/A	N/A	N/A	N/A	N/A
300	101	3,420	3,940	4,250	4,610	5,260
350	117	4,160	4,710	5,010	5,380	6,010
400	164	6,410	6,960	7,220	7,570	8,060
500	131	4,830	5,380	5,680	6,050	6,650
550	211	8,880	9,360	9,510	9,800	10,100
600	300	14,000	14,200	14,000	14,100	13,700
700	149	5,690	6,250	6,530	6,890	7,430
800	173	6,910	7,460	7,690	8,040	8,480
900	N/A	N/A	N/A	N/A	N/A	N/A
1000	174	6,930	7,470	7,710	8,050	8,500
1100	203	8,490	8,980	9,150	9,450	9,750
1200	135	5,030	5,590	5,880	6,250	6,830
USGS 06025250	135	5,030	5,590	5,880	6,250	6,830
1300	173	6,910	7,460	7,690	8,040	8,480
1350	N/A	N/A	N/A	N/A	N/A	N/A
1400	223	9,560	10,000	10,100	10,400	10,600
USGS 06025500	223	9,560	10,000	10,100	10,400	10,600
1500	N/A	N/A	N/A	N/A	N/A	N/A
1600	N/A	N/A	N/A	N/A	N/A	N/A
1625	N/A	N/A	N/A	N/A	N/A	N/A
1650	N/A	N/A	N/A	N/A	N/A	N/A
1675	N/A	N/A	N/A	N/A	N/A	N/A
1700	N/A	N/A	N/A	N/A	N/A	N/A

Regional Regression Results

Location	Bankfull Channel Width (ft)	Discharge (cfs)				
		10-year	25-year	50-year	100-year	500-year
USGS 06023500	52.5	1,090	1,380	1,590	1,840	2,410
50	55.5	1,180	1,480	1,710	1,960	2,540
75	39.0	707	931	1,110	1,300	1,800
85	97.5	2,690	3,120	3,410	3,740	4,440
100	82.5	2,110	2,500	2,780	3,090	3,760
200	N/A	N/A	N/A	N/A	N/A	N/A
300	134	4,260	4,720	5,020	5,370	6,060
350	140	4,540	5,010	5,300	5,650	6,320
400	179	6,510	6,930	7,180	7,500	8,070
500	150	5,040	5,500	5,790	6,130	6,790
550	220	8,830	9,130	9,270	9,530	9,910
600	338	16,500	16,100	15,700	15,600	15,200
700	191	7,200	7,590	7,810	8,120	8,640
800	206	8,040	8,390	8,570	8,850	9,310
900	N/A	N/A	N/A	N/A	N/A	N/A
1000	211	8,290	8,620	8,790	9,070	9,500
1100	261	11,300	11,400	11,500	11,600	11,700
1200	184	6,810	7,220	7,450	7,770	8,320
USGS 06025250	184	6,810	7,220	7,450	7,770	8,320
1300	191	7,190	7,580	7,800	8,110	8,630
1350	N/A	N/A	N/A	N/A	N/A	N/A
1400	260	11,300	11,400	11,400	11,600	11,700
USGS 06025500	260	11,300	11,400	11,400	11,600	11,700
1500	N/A	N/A	N/A	N/A	N/A	N/A
1600	N/A	N/A	N/A	N/A	N/A	N/A
1625	N/A	N/A	N/A	N/A	N/A	N/A
1650	N/A	N/A	N/A	N/A	N/A	N/A
1675	N/A	N/A	N/A	N/A	N/A	N/A
1700	N/A	N/A	N/A	N/A	N/A	N/A

Regional Regression Results



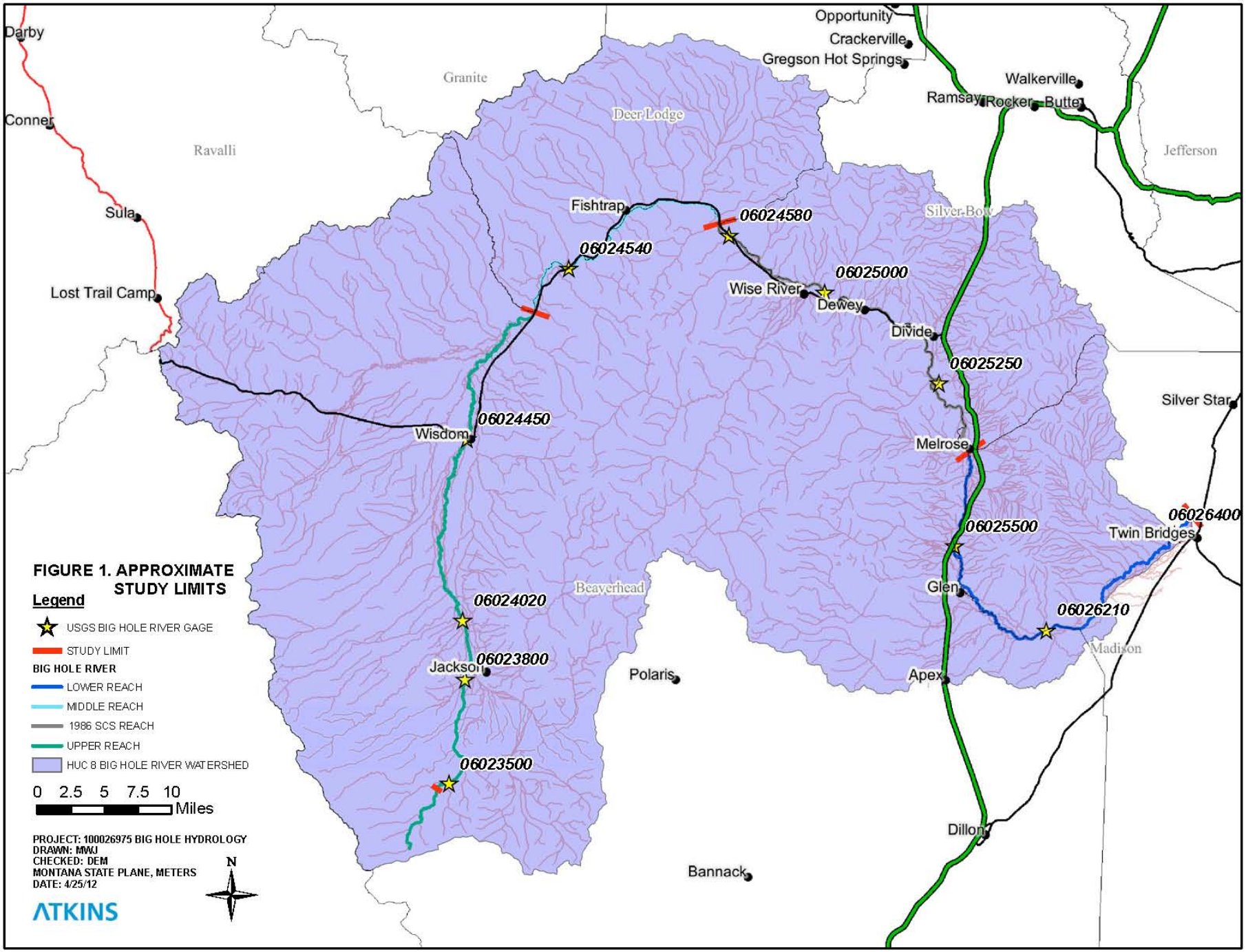
Regression Analysis

- Basin Characteristics
  - Logical increasing trend with drainage area
  - However, USGS suggested limits exceeded for approx. 12% of drainage area

- Active Channel/Bankfull Width
  - Widths highly variable throughout entire reach
  - USGS suggested limits exceeded for most of reach

Stream Gage Analyses

- Single Gage Method
- Two Station Gage Method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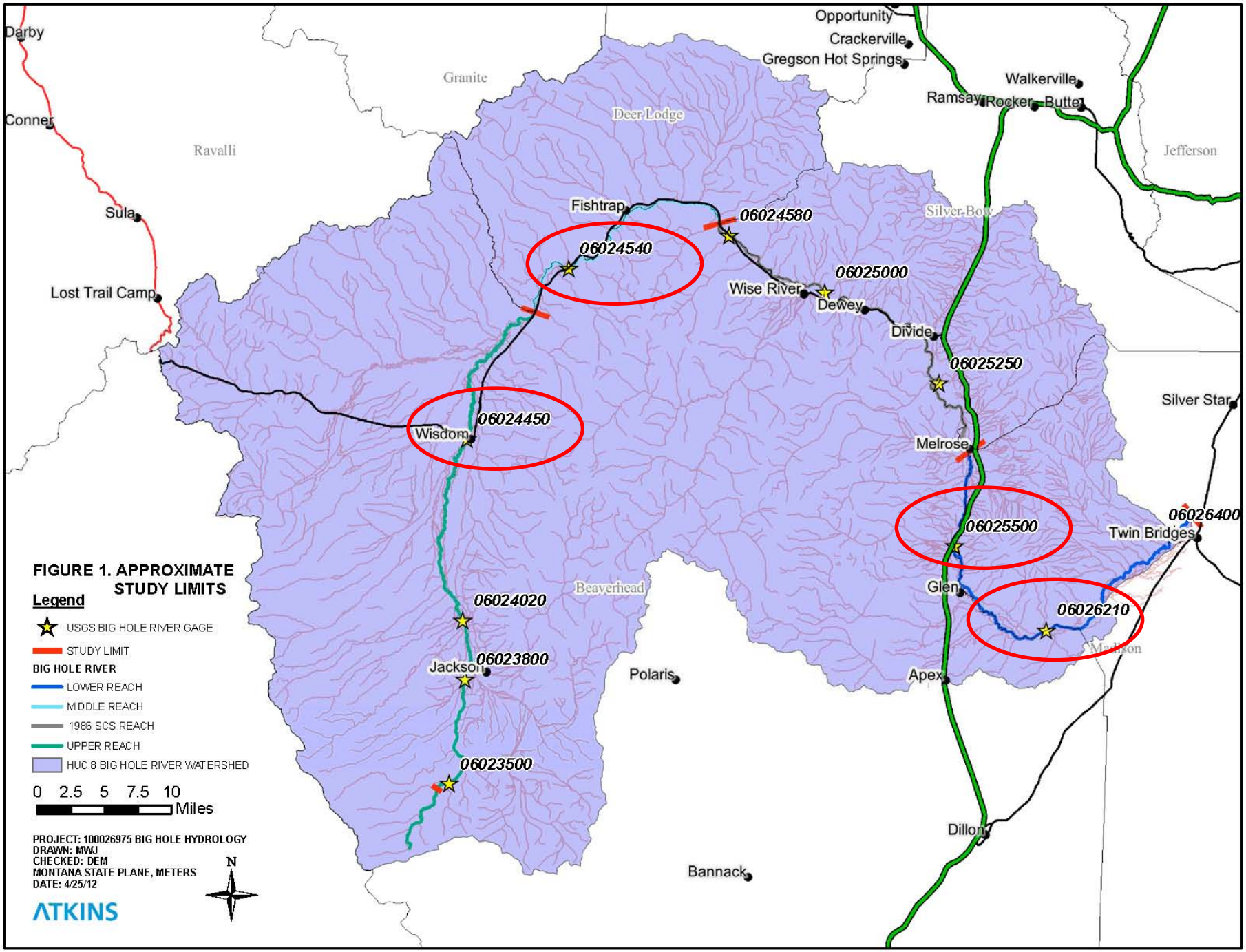
Stream Gage Analyses

- Single Gage Method
  - Bulletin 17B
  - 12 Gages
    - 4 Applicable Gages with record > 10 years
  - Baseline Analysis – requested by DNRC, duplicate USGS 03-4308
  - Updated Analysis – add additional record since USGS 03-4308

Station No.	Station Name	Period of Record	Number of Annual Peaks	Drainage Area (mi^2)
06023500	Big Hole River near Jackson, MT	1948 – Present*	8	44
06023800	Big Hole River above Spring Creek near Jackson, MT	2010 – Present	2	*N/A*
06024020	Big Hole River at Miner Creek near Jackson, MT	2010 – Present	2	352
06024450	Big Hole River below Big Lake Creek at Wisdom, MT.	1988 – Present	24	593
06024540	Big Hole River below Mudd Creek near Wisdom, MT	1998 – Present*	14	1,274
06024580	Big Hole River near Wise River, MT	1980 – Present	5	1,611
06025000	Big Hole River near Dewey, MT	1910 – 1913	0	1,946
06025250	Big Hole River at Maiden Rock near Divide, MT	1998 – Present*	9	2,146
06025500	Big Hole River near Melrose, MT.	1924 – Present	87	2,433
06026210	Big Hole River near Glen, MT	1998 – Present*	14	2,665
06026400	Big Hole River near mouth	1980 – 1981	2	2,762
06026420	Big Hole River below Hamilton Ditch near Twin Bridges, MT	2007 – Present	4	2,790

N/A denotes that this drainage area was not provided by USGS.

** denotes discontinuous record*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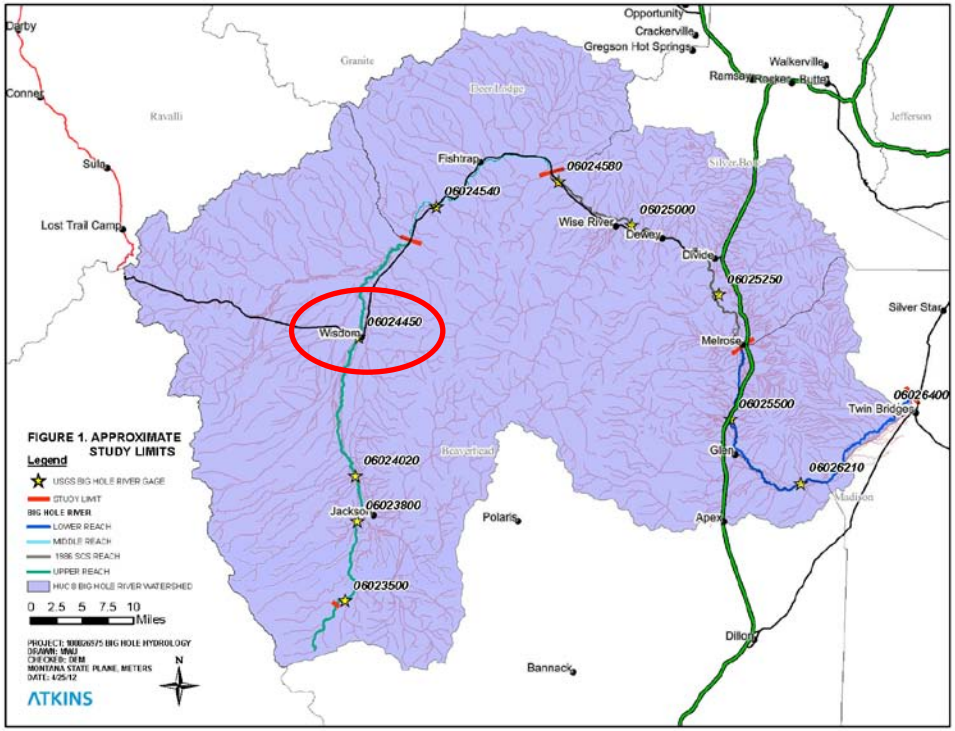
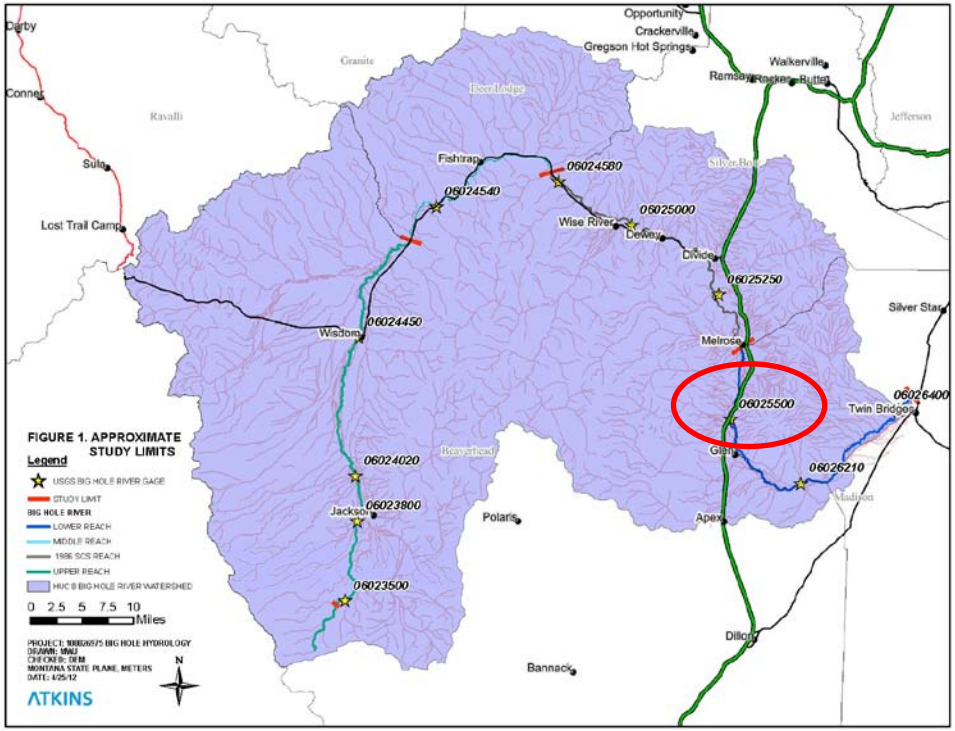
Stream Gage Analyses

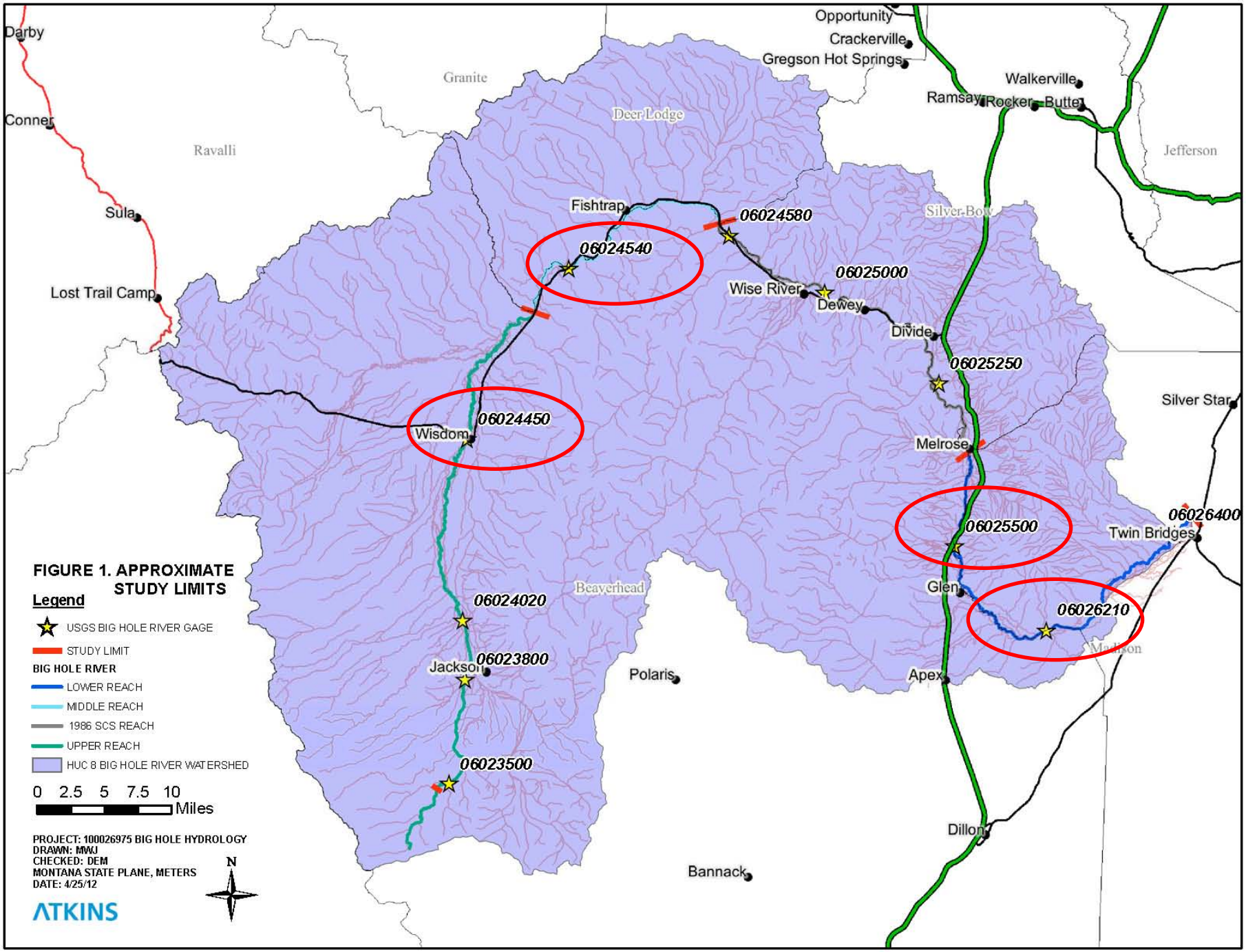
Frequency	WRIR 03-4308 Estimated Discharge (cfs)	Baseline Estimated Discharge (cfs)	Updated Estimated Discharge (cfs)
10-year	4,290	4,290	3,750
25-year	6,010	6,010	5,010
50-year	7,450	7,450	6,010
100-year	9,020	9,020	7,060
500-year	13,300	13,300	9,680



Stream Gage Analyses

Frequency	WRIR 03-4308 Estimated Discharge (cfs)	Baseline Estimated Discharge (cfs)	Updated Estimated Discharge (cfs)
10-year	12,300	12,300	12,200
25-year	14,500	14,500	14,400
50-year	15,900	15,900	15,900
100-year	17,200	17,200	17,300
500-year	19,900	19,900	20,200

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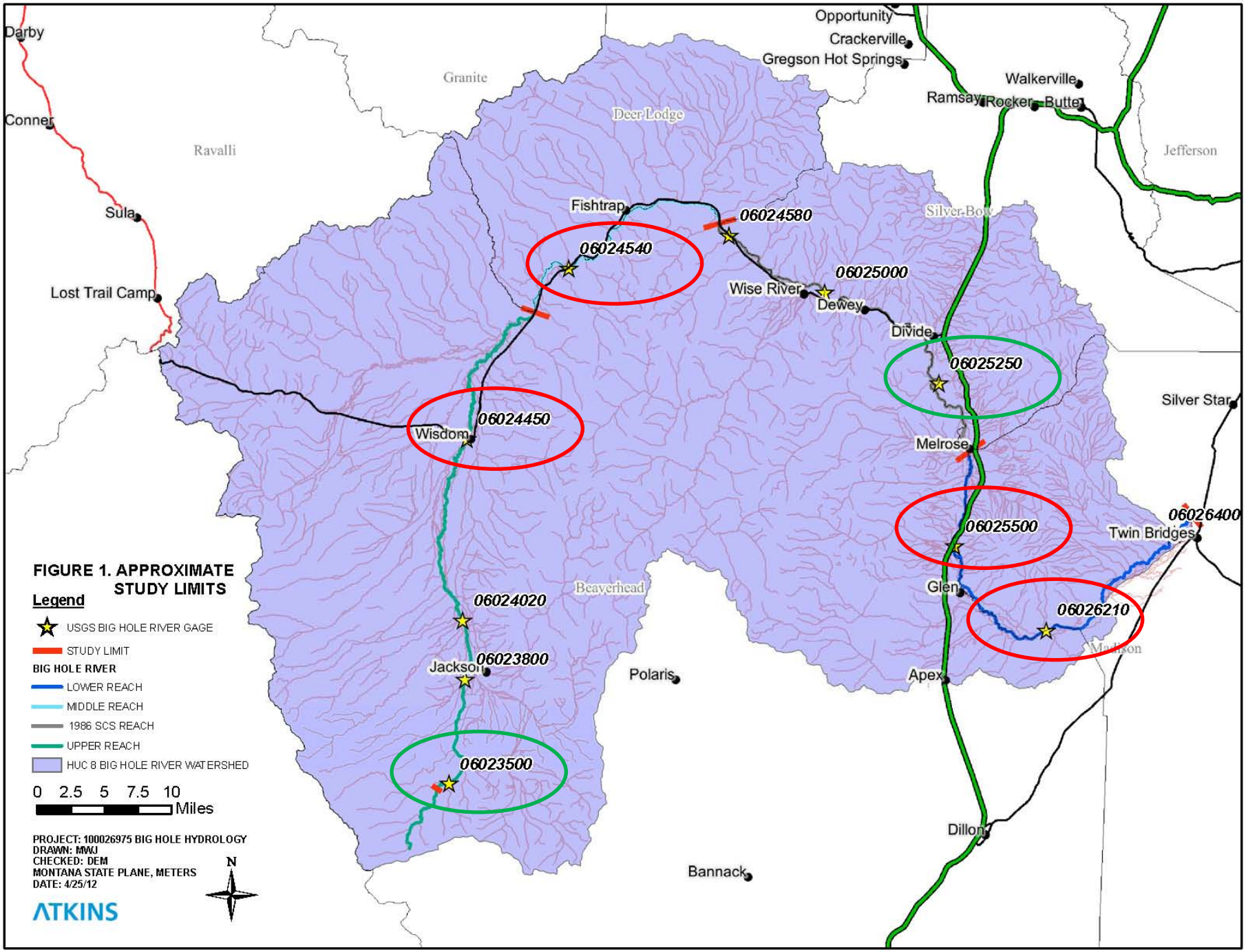
Stream Gage Analyses

- Two Station Gage Method
  - Bulletin 17B
  - 12 Gages
    - **6** Applicable Gages

Station No.	Station Name	Period of Record	Number of Annual Peaks	Drainage Area (mi^2)
06023500	**Big Hole River near Jackson, MT**	**1948 – Present***	**8**	**44**
06023800	Big Hole River above Spring Creek near Jackson, MT	2010 – Present	2	*N/A*
06024020	Big Hole River at Miner Creek near Jackson, MT	2010 – Present	2	352
06024450	**Big Hole River below Big Lake Creek at Wisdom, MT.**	**1988 – Present**	**24**	**593**
06024540	**Big Hole River below Mudd Creek near Wisdom, MT**	**1998 – Present***	**14**	**1,274**
06024580	Big Hole River near Wise River, MT	1980 – Present	5	1,611
06025000	Big Hole River near Dewey, MT	1910 – 1913	0	1,946
06025250	**Big Hole River at Maiden Rock near Divide, MT**	**1998 – Present***	**9**	**2,146**
06025500	**Big Hole River near Melrose, MT.**	**1924 – Present**	**87**	**2,433**
06026210	**Big Hole River near Glen, MT**	**1998 – Present***	**14**	**2,665**
06026400	Big Hole River near mouth	1980 – 1981	2	2,762
06026420	Big Hole River below Hamilton Ditch near Twin Bridges, MT	2007 – Present	4	2,790

N/A denotes that this drainage area was not provided by USGS.
** denotes discontinuous record*


Darby
Conner
Sula
Lost Trail Camp
Ravalli
Granite
Deer Lodge
Opportunity
Crackerville
Gregson Hot Springs
Walkerville
Ramsay
Rocker
Butte
Jefferson
Silver Bow
Fishtrap
06024580
06024540
06025000
Wise River
Dewey
Divide
06025250
Silver Star
Wisdom
06024450
Melrose
06025500
06026400
Twin Bridges
Glen
06026210
Madison
Beaverhead
06024020
Jackson
06023800
Polaris
Apex
06023500
Dillon
Bannack
FIGURE 1. APPROXIMATE STUDY LIMITS
Legend
USGS BIG HOLE RIVER GAGE
STUDY LIMIT
BIG HOLE RIVER
LOWER REACH
MIDDLE REACH
1986 SCS REACH
UPPER REACH
HUC 8 BIG HOLE RIVER WATERSHED
0 2.5 5 7.5 10
Miles
PROJECT: 100026975 BIG HOLE HYDROLOGY
DRAWN: MWJ
CHECKED: DEM
MONTANA STATE PLANE, METERS
DATE: 4/25/12
N
ATKINS

Stream Gage Analyses

- Test: perform regression on concurrent record fromlong term gage and short term gage:

Station No.	Number of Annual Peaks	Equivalent Years of Record, EYR	Correlation Coefficient, r
06025500	87	Base Gage	Base Gage
06023500	8	20	.845
06024450	24	66	.943
06024540	14	72	.982
06025250	9	78	.995
06026210	14	85	.999

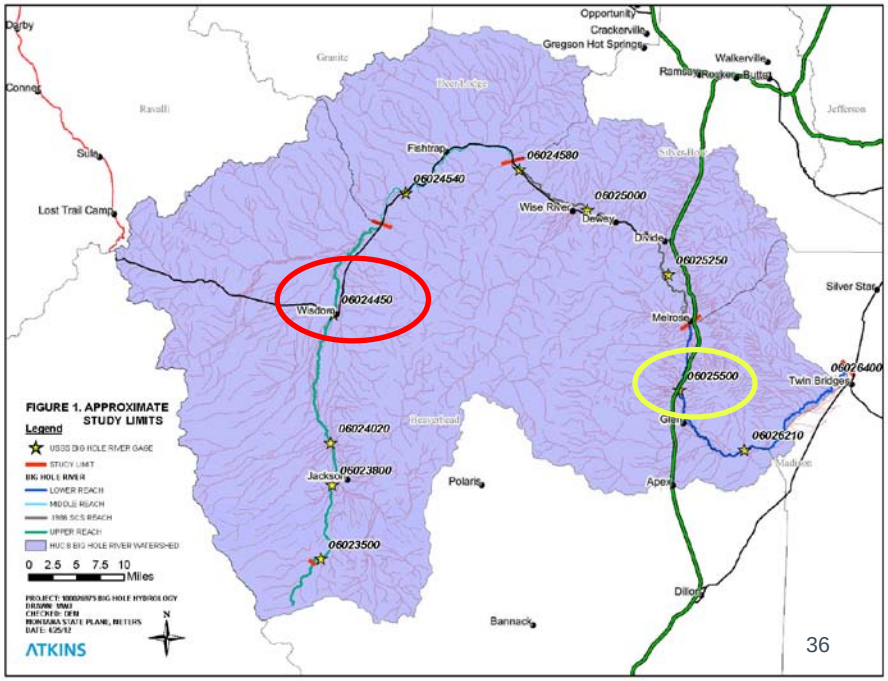
- If r > .xx, then improvements to the mean and std dev are worthwhile.
- Based on length of record and correlation, an EQY is calculated.

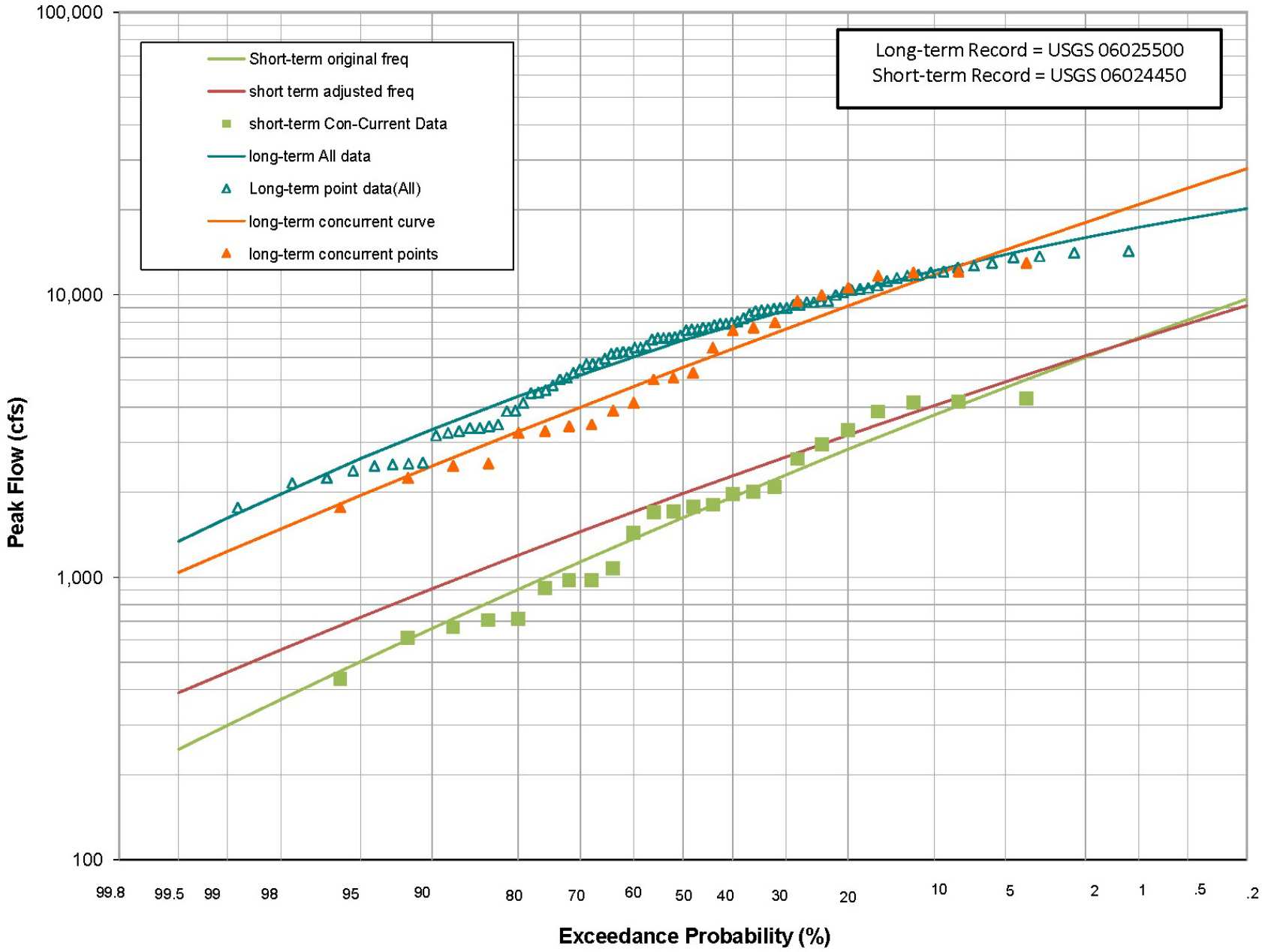
Stream Gage Analyses

- Two Station Gage Method Results

Stream Gage Analyses

Year Flood	Annual Exceedance Probability	Original Discharge Estimate (cfs)	Adjusted Discharge Estimate (cfs)
10	0.1	3,750	4,060
25	0.04	5,010	5,200
50	0.02	6,010	6,080
100	0.01	7,060	6,980
500	0.002	9,680	9,160




Long-term Record = USGS 06025500
Short-term Record = USGS 06024450
Short-term original freq
short term adjusted freq
short-term Con-Current Data
long-term All data
Long-term point data(All)
long-term concurrent curve
long-term concurrent points
Peak Flow (cfs)
100,000
10,000
1,000
100
99.8
99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
.5
.2
Exceedance Probability (%)

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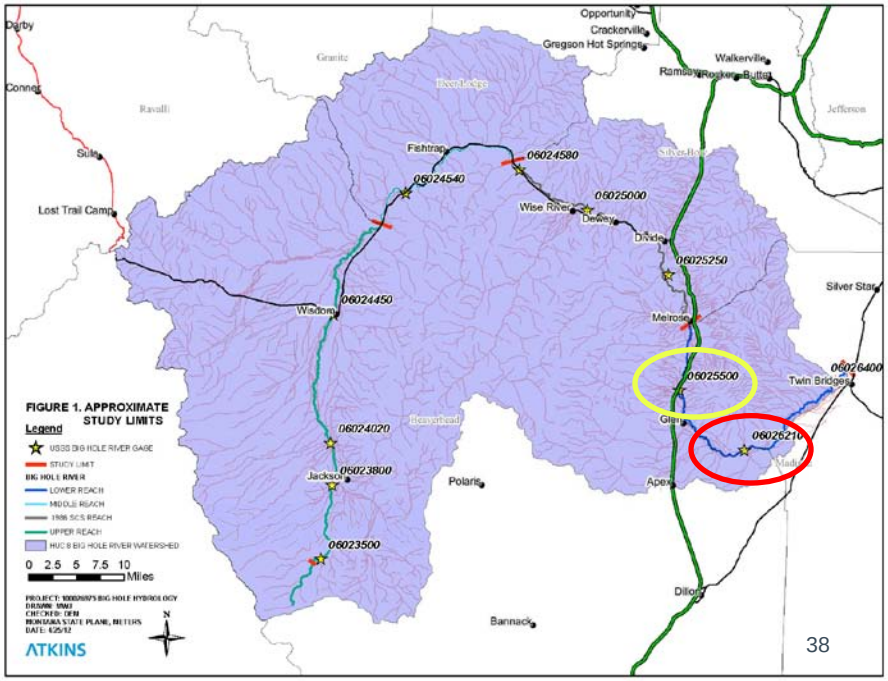
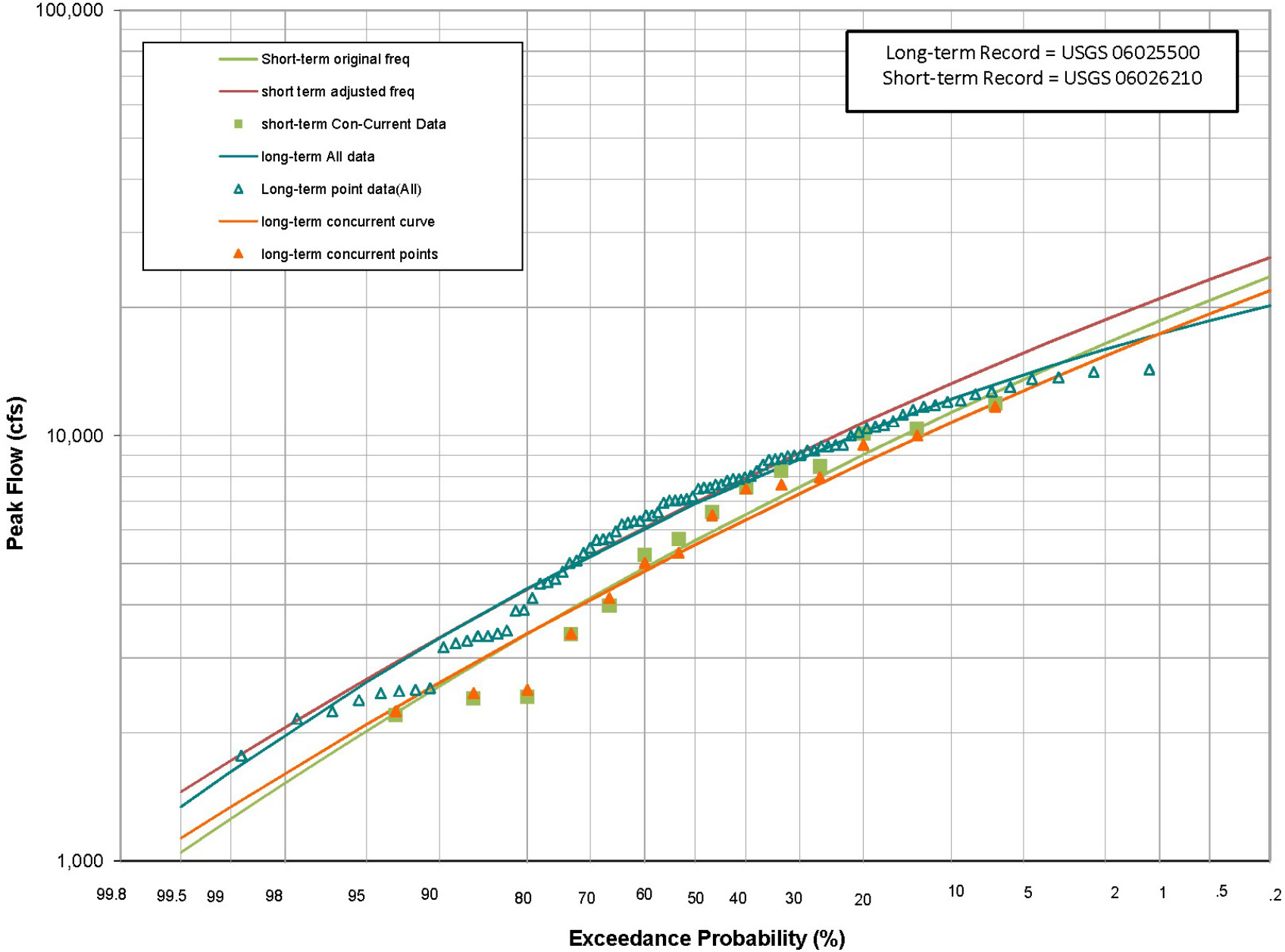
Stream Gage Analyses

Year Flood	Annual Exceedance Probability	Original Discharge Estimate (cfs)	Adjusted Discharge Estimate (cfs)
10	0.1	11,300	13,200
25	0.04	14,300	16,400
50	0.02	16,400	18,700
100	0.01	18,600	21,000
500	0.002	23,600	26,200




Short-term original freq
short term adjusted freq
short-term Con-Current Data
long-term All data
Long-term point data(All)
long-term concurrent curve
long-term concurrent points
Long-term Record = USGS 06025500
Short-term Record = USGS 06026210
100,000
10,000
1,000
Peak Flow (cfs)
99.8
99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
.5
.2
Exceedance Probability (%)

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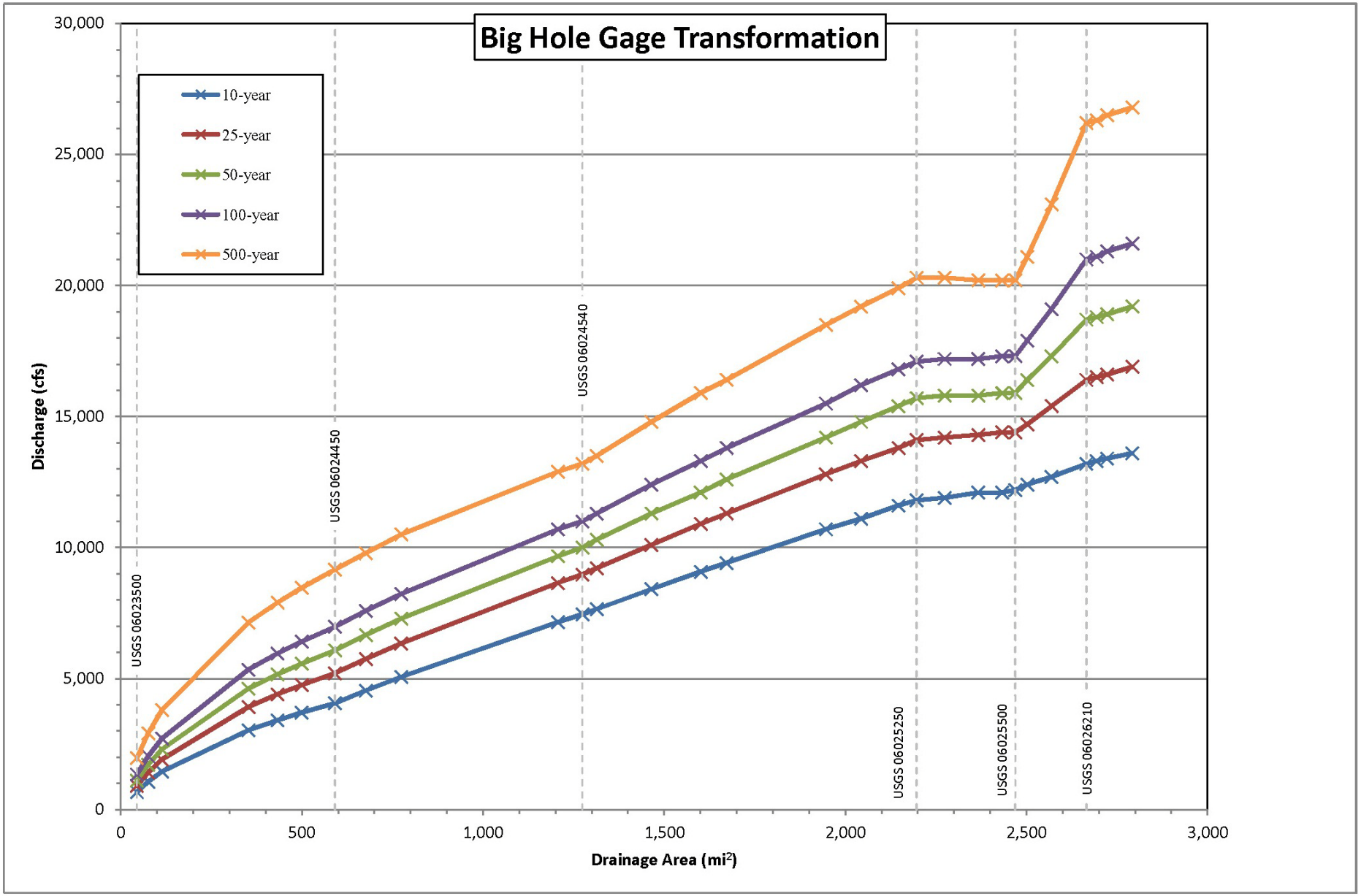
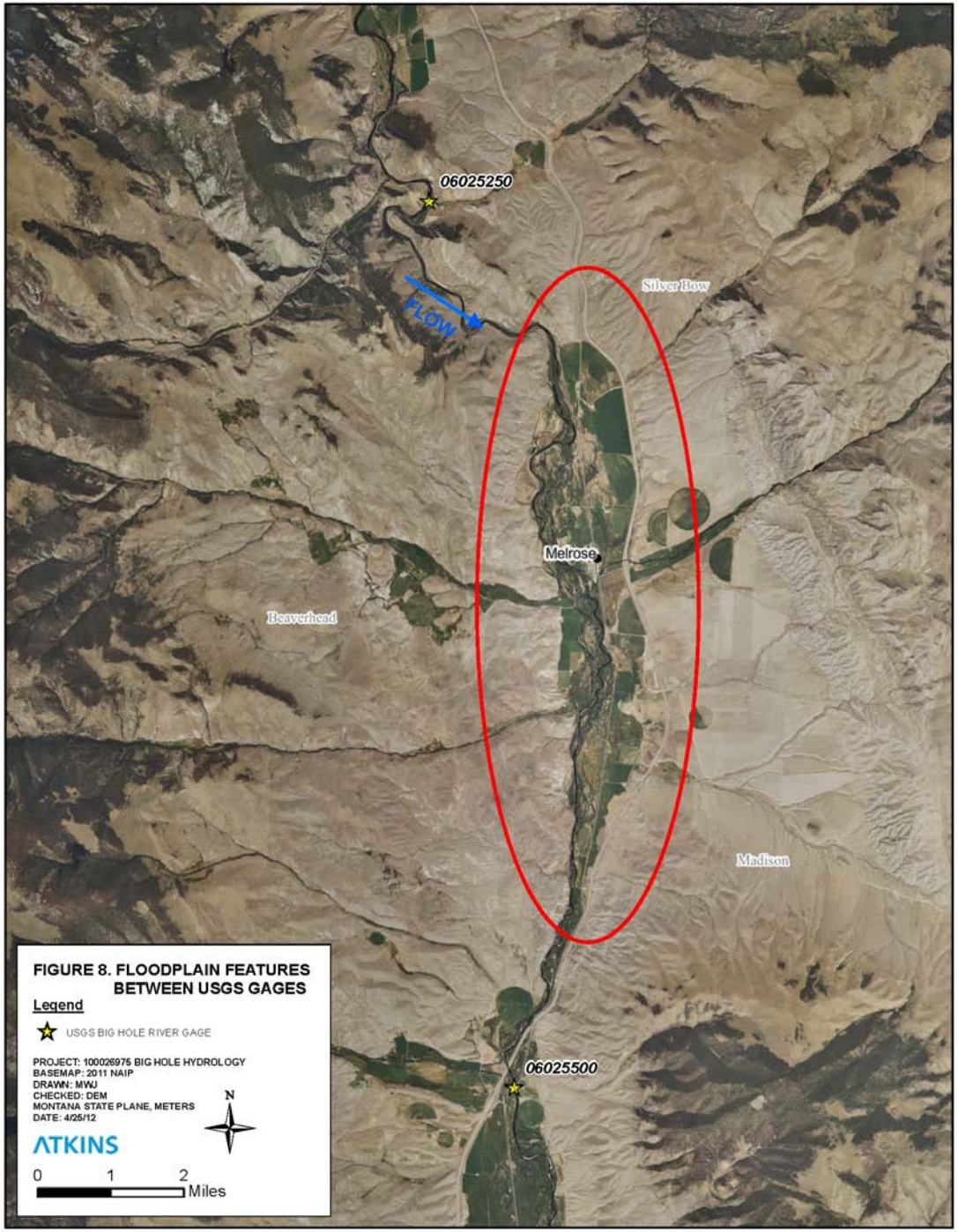
Gage Analysis

- Single gage vs. Two Station Comparison
  - Only 4 gages with adequate record for single gage analysis
  - Two Station Comparison allowed use of 6 gage records
    - Improves confidence in results

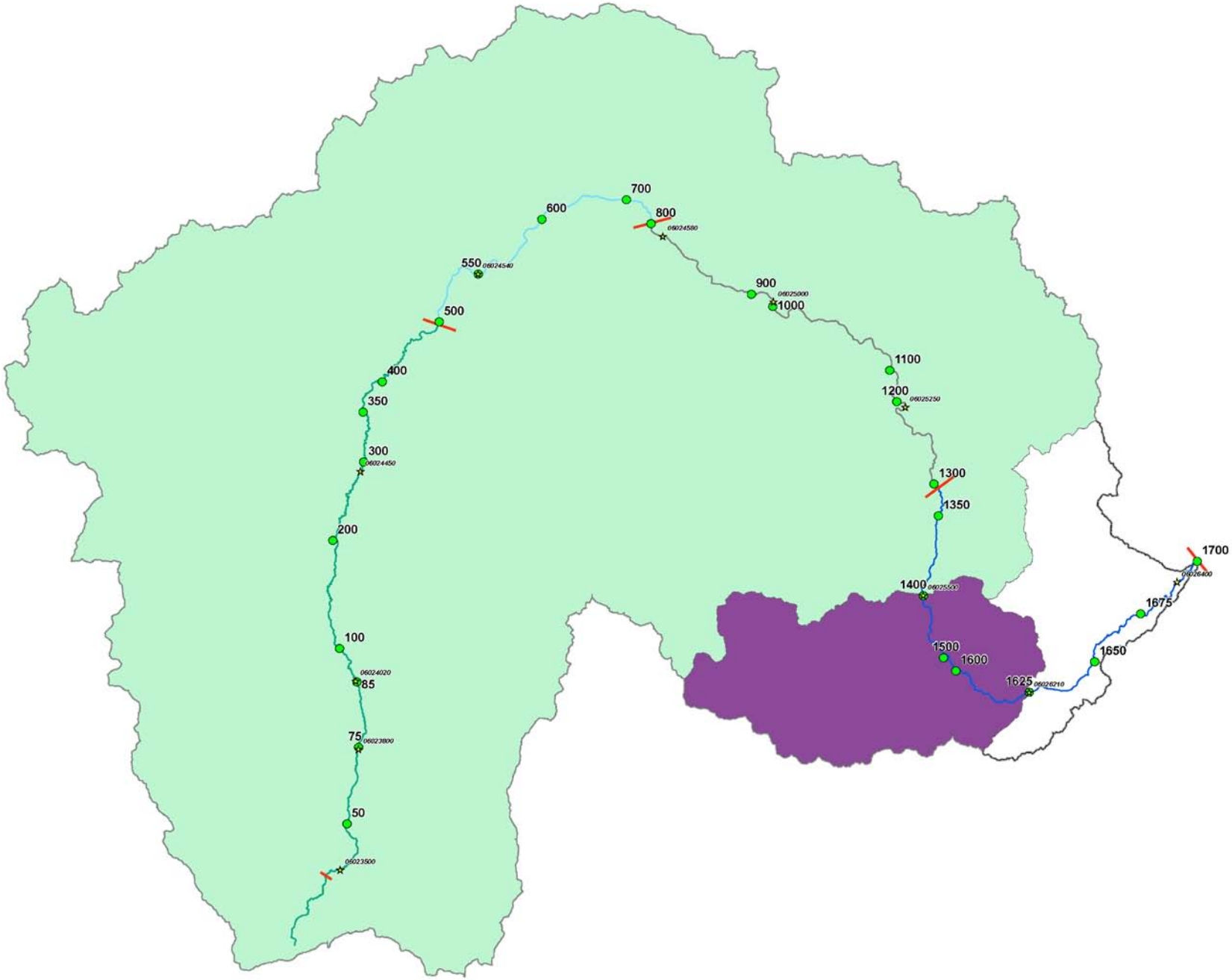
- Transfer to ungaged sites
  - Logarithmic interpolation between sequential gages

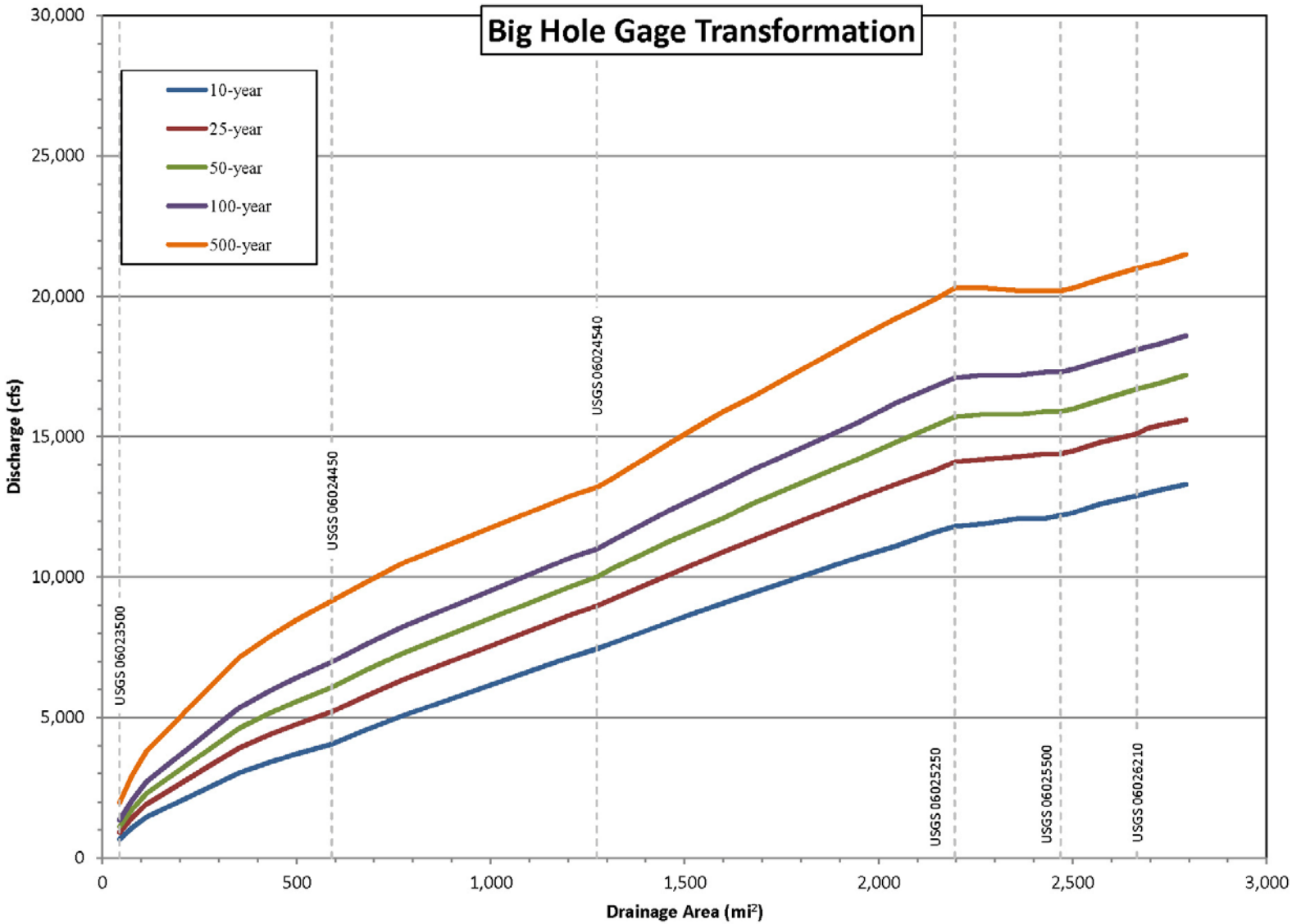
    OR
  - Transfer by drainage area ratio


Big Hole Gage Transformation
10-year
25-year
50-year
100-year
500-year
Discharge (cfs)
Drainage Area (mi²)
30,000
25,000
20,000
15,000
10,000
5,000
0
0
500
1,000
1,500
2,000
2,500
3,000
USGS 06023500
USGS 06024450
USGS 06024540
USGS 06025250
USGS 06025500
USGS 06026210


06025250
FLOW
Silver Bow
Melrose
Beaverhead
Madison
06025500
FIGURE 8. FLOODPLAIN FEATURES BETWEEN USGS GAGES
Legend
USGS BIG HOLE RIVER GAGE
PROJECT: 100026975 BIG HOLE HYDROLOGY
BASEMAP: 2011 NAIP
DRAWN: MWJ
CHECKED: DEM
MONTANA STATE PLANE, METERS
DATE: 4/25/12
ATKINS
N
0 1 2
Miles

ATKINS


700
600
800
06024580
550
06024540
900
06025000
1000
500
1100
400
1200
06025250
350
300
06024450
1300
1350
200
1700
06026400
1400
06025500
1675
100
1500
1600
1650
06024020
85
1625
06026210
75
06023800
50
06023500

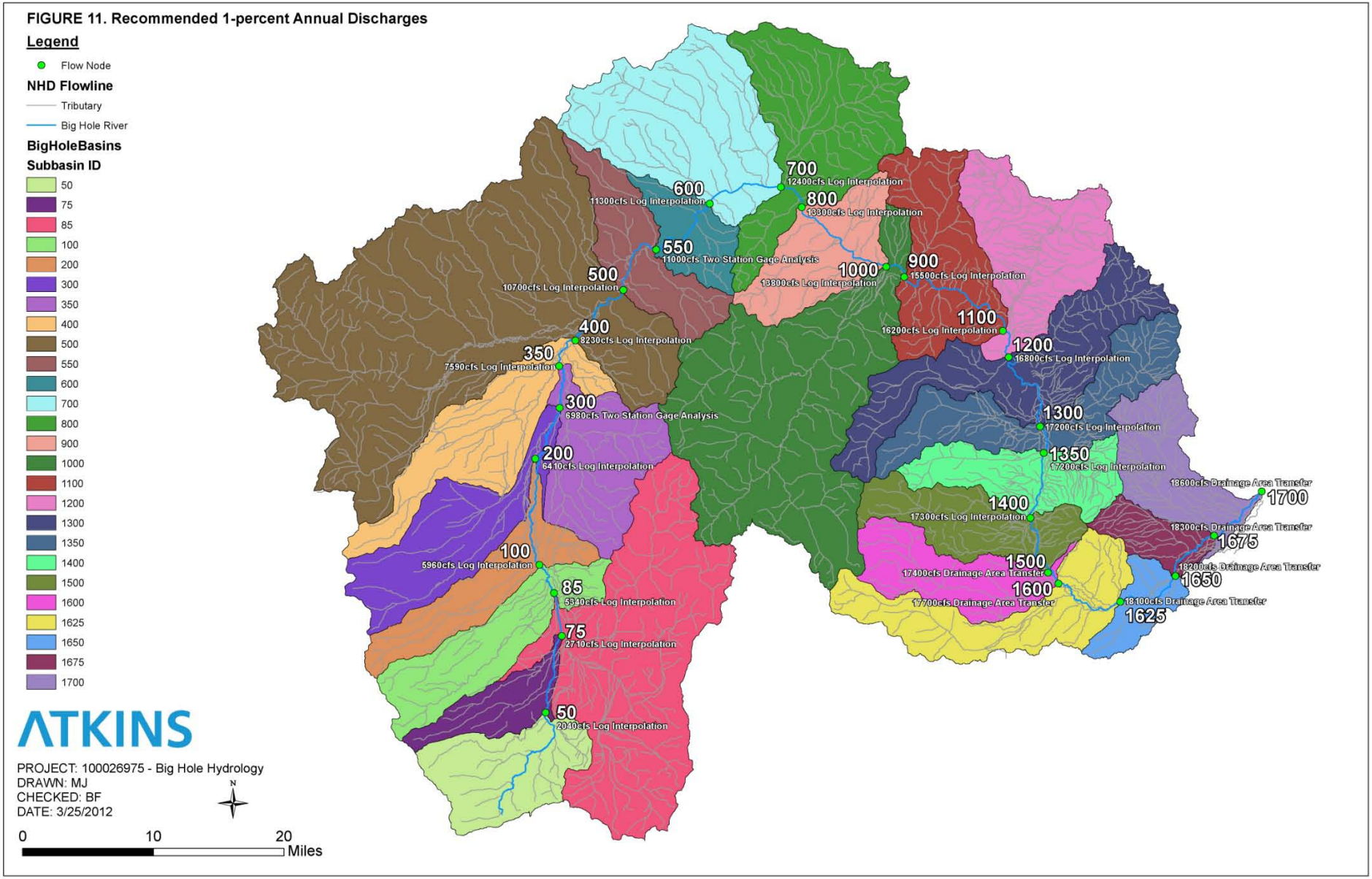

Big Hole Gage Transformation
10-year
25-year
50-year
100-year
500-year
Discharge (cfs)
Drainage Area (mi²)
30,000
25,000
20,000
15,000
10,000
5,000
0
0
500
1,000
1,500
2,000
2,500
3,000
USGS 06023500
USGS 06024450
USGS 06024540
USGS 06025250
USGS 06025500
USGS 06026210

Recommended Flows for Flood Study

- Gage analyses with Two Station Comparison

- Transferred through USGS 06026210 to remove spike

FIGURE 11. Recommended 1-percent Annual Discharges



Summary

- 26 flow nodes established
- Several hydrologic methods evaluated
- Regression results generally low or unreliable due to changing stream type
- Lengthy gage record provides confidence in gage results
- Two Station Comparison method used to improve confidence in gages with limited record
- Selected results are logical and based solely on Big Hole River data

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Flood Frequency Discharge Analysis of the Big Hole River

Questions?