PERENNIAL STREAM CROSSINGS

Frenchman Creek MP 25.8

<table>
<tr><td>Site</td><td>Frenchman Creek MP 25.8</td><td>Date</td><td>08/03/09</td></tr>
<tr><td colspan="2">Done by: GF, ML</td><td colspan="2">Review: EG</td></tr>
</table>

<table>
<tr><th colspan="9">Regional Regression Analysis</th></tr>
<tr><th rowspan="2">Source</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Omang (1992)</td><td>366.8*</td><td>2,656</td><td>619</td><td>1,787</td><td>2,924</td><td>4,735</td><td>6,472</td><td>8,337</td></tr>
</table>

*163mi^2 of watershed area is located in USA. An evaluation of the relief map showed more than twice of the amount of the watershed is within Canada.

<table>
<tr><td colspan="10">Geomorphology</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of pipeline crossing)</td></tr>
<tr><td colspan="5">Channel</td><td colspan="5">Valley</td></tr>
<tr><td colspan="5">Gradient (%): <0.01</td><td colspan="5">Gradient (%): <0.01</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">width</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td>34</td><td>61</td><td>47</td><td>10</td><td>429</td><td>864</td><td>633</td><td>164</td></tr>
<tr><td colspan="5">meander wavelength (ft) 1020</td><td colspan="5">describe geology:</td></tr>
<tr><td colspan="5">meander amplitude (ft) 456</td><td colspan="5">Alluvium of modern channels and flood plains 3151 ft wide at crossing</td></tr>
<tr><td colspan="5">Sinuosity 1.63</td><td colspan="5">Both sides Judith River Fm: Light brown to light gray, fine- to coarse-grained sandstone with interbeds of gray to black carbonaceous shale, silty shale, and thin coal.
US both sides Bearpaw Fm: Shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds.</td></tr>
<tr><td rowspan="9">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><td colspan="5">Floodplain</td></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA N if yes, describe widths below</td></tr>
<tr><td rowspan="2">width</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>213</td><td>388</td><td>731</td><td>326</td><td colspan="5"></td></tr>
<tr><td>941</td><td>245</td><td>1784</td><td>227</td><td colspan="5">describe abundance and location(s) of:</td></tr>
<tr><td>1906</td><td>165</td><td>2207</td><td>275</td><td colspan="5">scroll bars:</td></tr>
<tr><td>2767</td><td>199</td><td></td><td></td><td colspan="5">0.6 mi DS</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">Oxbows:</td></tr>
<tr><td colspan="5">channel form:</td><td colspan="5">0.8 mi US, probably enhanced for ag use</td></tr>
<tr><td colspan="5">Single Branch</td><td colspan="5">channel cut-offs:</td></tr>
</table>

channel confinement:	None
12.74	Relic channels 1.3, 1.8 and 2 mi US
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
Same	
Unique features, exceptions, etc	
Tribs: unnamed 0.1, 0.4, 0.6 mi US; 0.5, 0.6, 0.8, 0.9 mi DS. Meanders directly US is especially tortuous (sinuosity=2.43)	
Evidence of landslides upstream or downstream along valley margins (upstream/downstream with distance to pipeline):	
1.6 mi US	
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline):	
Parallel roads 0.85mi from LB; Concrete dam 2.56mi DS with Frenchman Reservoir (1.5 by 0.75 mi wide), road over dam and buildings and road on RB of reservoir	
Describe any direct or indirect evidence of general scour/channel incision:	
None	

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p.
hydraulics	☒	source(s): None
sediment transport	☒	source(s): None
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources

		Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): None
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) USGS 06158000 Frenchman R ab Eastend Re nr Ravenscrag Sask http://waterdata.usgs.gov/mt/nwis/dv/?site_no=06158000&PARAmeter_cd=00060
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Rock Creek MP 39.2

Site	**Rock Creek MP 39.2**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis								
Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Omang (1992)	293.8*	2,603	535	1,570	2,587	4,221	5,791	7,491

*226 mi^2 of watershed area is located in USA. An evaluation of the relief map shows an additional 30% of the watershed area is within Canada.

Geomorphology

NOTE: All measures should be rounded to the nearest whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of pipeline crossing)

Channel	**Valley**
Gradient (%): 0.1	Gradient (%): 0.1

Width (ft)	min	max	mean	std dev	width	min	max	mean	std dev
	26	60	43	14		577	1391	877	307

meander wavelength (ft)1945.0	describe geology (lithology, erodibility):
meander amplitude (ft) 361.0	Floodplain: Quaternary sand and gravel deposits 638 ft and alluvium: gravel, sand, silt, and clay deposits of stream and river channels and floodplains 701 ft at crossing Quaternary landslide deposits 560 ft on RB
Sinuosity 1.45	Claggett Shale on LB: shale with thin, gray sandstone laminae and beds in upper or middle part and calcareous concretions in lower part Judith River Fm on both banks: fine- to coarse-grained sandstone with interbeds of gray to black carbonaceous shale, silty shale, and thin coal.

	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
radius of curvature (ft)	853	217	3608	501
	2073	473	4697	470
	3205	211	6314	311
	3946	233		
	853	217		

Floodplain

FEMA National Database N

if yes, describe widths below

Width (ft)	min	max	mean	std dev

Describe abundance and location(s) of:

scroll bars:

US 0.2, 1.4 mi

oxbows:

None

Channel form (braided, anabranching, single thread):	channel cut-offs:
Single with occasional islands	None
Channel confinement at crossing (W_v / W_c):	Relic channel 1.3 and 1.5 mi DS
37.50	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
The channel is incised because the floodplain elevation is greater than the channel’s water surface	

Unique features, exceptions, etc:
Tribs: unnamed stream US 0.1, 0.5, 0.77, 0.81, 1.5 mi; DS 0.1, 0.3, 1.2, 0.3 mi.
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
See geology above, Listed as high risk by PHMSA NPMS Landslide Hazard Map
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
A number of small roads running parallel to the creek on both sides and a group of buildings 0.9 DS.
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): Environmental Impact Statement Rock Cr. http://www.deq.state.mt.us/pcd/RockCreek/Volume%20III.pdf
Reports on local/regional:		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.

bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) USGS 06209010 Rock Cr bl Glacier Lake nr Red Lodge MT http://waterdata.usgs.gov/mt/nwis/dv/?site_no=06209010&PARAmeter_cd=00060
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Willow Creek MP 40.4

<table>
<tr><td>Site</td><td>**Willow Creek MP 40.4**</td><td>Date</td><td>08/03/09</td></tr>
<tr><td colspan="2">Done by: GF, ML</td><td colspan="2">Review: EG</td></tr>
</table>

<table>
<tr><th colspan="10">Regional regression and peak flow analysis</th></tr>
<tr><th colspan="10">Regional Regression</th></tr>
<tr><th colspan="2" rowspan="2">Source</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2" colspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td colspan="2">Omang (1992)</td><td>273.2</td><td colspan="2">2,658</td><td>505</td><td>1,475</td><td>2,428</td><td>3,953</td><td>5,419</td><td>6,999</td></tr>
<tr><th colspan="11">Peak Flood Flow</th></tr>
<tr><th rowspan="2">Gauge Name and Number</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Up or Down-stream</th><th rowspan="2">Distance to Crossing (mi)</th><th rowspan="2">Range of Data (years)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>06170200 Willow Creek near Hinsdale MT (Regional Regression)</td><td>283.0</td><td>DS</td><td>1.45</td><td>8 (1965-1973)</td><td>517</td><td>1,509</td><td>2,482</td><td>4,039</td><td>5,535</td><td>7,146</td></tr>
</table>

<table>
<tr><td colspan="10">**Geomorphology**
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">**For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)**</td></tr>
<tr><th colspan="5">Channel</th><th colspan="5">Valley</th></tr>
<tr><td colspan="5">Gradient (%): <0.001</td><td colspan="5">Gradient (%): 0.002</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">width</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td>27</td><td>49</td><td>36</td><td>7</td><td>27</td><td>49</td><td>36</td><td>7</td></tr>
<tr><td colspan="5">meander wavelength (ft): 1288</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft): 1078</td><td colspan="5">Quaternary sand and gravel deposits from stream and floodplains 2558 ft at crossing</td></tr>
<tr><td colspan="5">Sinuosity: 2.58</td><td colspan="5">Both sides--Judith River Fm: Light brown to light gray, fine- to coarse-grained sandstone with interbeds of gray to black carbonaceous shale, silty shale, and thin coal.
Both sides, from just US of crossing DS-- Claggett Formation: shale with thin, gray sandstone laminae and beds in upper or middle part and calcareous concretions in lower part
DS on RB landslide deposit</td></tr>
<tr><td rowspan="4">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><th colspan="5">Floodplain</th></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

	805	689	2562	301	
	1141	597	4936	739	Describe abundance and location(s) of:
	2074	402	6422	350	scroll bars:
	2614	390	8095	409	1.6 mi DS and on trib 0.9 mi US
					oxbows:
					none
Channel form (braided, anabranching, single thread):					channel cut-offs:
Single Thread but several relic channels, river right					Relic channel US 0.4 mi, DS 0.3, 0.6, 1, 1.4 mi
Channel confinement at crossing (W_v / W_c):					
29.31					
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?					
Floodplain is higher than water surface elevation.					
Unique features, exceptions, etc					
Flows into Rock Creek 1.5 mi, unnamed tribs: US 0.5, 0.8 DS 0.2, 0.3, 0.6, US Eagle's Nest Coulee 0.86 mi					
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):					
0.4 mi US. Listed as high risk by PHMSA NPMS Landslide Hazard Map					
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):					
parallel Road crosses at Bridge (DS 0.84 mi)					
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):					
None					

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
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sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm

		Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
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Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) 06211500 Willow Creek near Boyd MT http://waterdata.usgs.gov/mt/nwis/dv/?site_no=06211500&PARAmeter_cd=00060
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Milk River MP 82.7

Site	**Milk River MP 82.7**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional regression and peak flow analysis

Regional Regression

Source	Drainage Area (mi^2)	Average Elevation (ft)	Recurrence Interval					
			2	5	10	25	50	100
Omang (1992)	22,324*							

Peak Flood Flow

Gauge Name and Number	Drainage Area (mi^2)	Up or Down-stream	Distance to Crossing (mi)	Range of Data (years)	Recurrence Interval					
					2	5	10	25	50	100
06174500 Milk River at Nashua MT: Exceedence Probability	22,332	DS	2.49	70 (1939-2009)	5,750	12,200	17,200	23,700	28,600	33,400
06174500 Milk River at Nashua MT: Bulletin 17B	22,332	DS	2.49	70 (1939-2009)	5,452	11,118	15,392	19,673	25,313	29,540

*Regional Regression developed for watersheds under 2,500 mi^2

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): <.001					Gradient (%): <0.01				
width	min	max	mean	std dev	width	min	max	mean	std dev
	84	104	95	8		2624	3019	2785	148
meander wavelength (ft): 3343					describe geology (lithology, erodibility):				
meander amplitude (ft): 1266					Alluvium of modern channels and flood plain 8683 ft wide at crossing DS RB Alluvium colluvium				
Sinuosity: 2.80					RB glacial deposits undivided Bearpaw Fm: Shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds				
radius of curvature	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance	radius of	distance	radius of	FEMA National Database N				

<table>
<tr><td rowspan="8">(ft)</td><td rowspan="3">from crossing</td><td rowspan="3">curvature</td><td rowspan="3">from crossing</td><td rowspan="3">curvature</td><td colspan="5">if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>1765</td><td>1012</td><td>2175</td><td>1248</td><td colspan="5"></td></tr>
<tr><td>15137</td><td>3513</td><td>7278</td><td>932</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>21140</td><td>2096</td><td>8836</td><td>842</td><td colspan="5">scroll bars:</td></tr>
<tr><td>26145</td><td>2703</td><td>11244</td><td>1384</td><td colspan="5">DS 2.4 mi; US 1.1 mi, 1.9 mi</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">oxbows:</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">Oxbow or man made pond DS 1.9 mi; US 0.15 mi,</td></tr>
<tr><td colspan="5">Single thread</td><td colspan="5">channel cut-offs:</td></tr>
<tr><td colspan="5">Channel confinement at crossing (W_v / W_c):</td><td colspan="5">none</td></tr>
<tr><td colspan="5">90.98</td><td colspan="5">Relic channel</td></tr>
<tr><td colspan="5"></td><td colspan="5">DS 0.5 mi, US 1.1 mi, 1.9 mi, 2.45 mi</td></tr>
<tr><td colspan="10">What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?</td></tr>
<tr><td colspan="10">Incised, the floodplain surrounding the channel has a higher elevation than the channel</td></tr>
<tr><td colspan="10">Unique features, exceptions, etc</td></tr>
<tr><td colspan="10">Trib US 2.3 mi, Porcupine Creek 2.6 mi DS, numerous irrigation canals, flows into Missouri River 6.1 mi</td></tr>
<tr><td colspan="10">Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):</td></tr>
<tr><td colspan="10">US 0.34 mi, mapped for high landslide hazard by the PHMSA in NPMS</td></tr>
<tr><td colspan="10">Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel)</td></tr>
<tr><td colspan="10">US: 1. Road (River right 0.15 mi, per. and river left 0.26 mi par.) 2. Railroad (River left 0.26 mi, par.) 3. scattered residences, including 580 feet from crossing 1. DS: 2. Bridge 0.6 mi, Sewage disposal ponds 1.6 mi, Town of Nashua 1.4 mi</td></tr>
<tr><td colspan="10">If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):</td></tr>
<tr><td colspan="10">None</td></tr>
</table>

<table>
<tr><td colspan="3">LITERATURE REVIEW
(check box when searched for, if none, note under source)</td></tr>
<tr><td>Existing channel migration zone determination</td><td>☒</td><td>source(s):
Fluvial process and the establishment of bottomland trees, Milk River
http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V93-3VWF7VK-N&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=976668765&_rerunOrigin=google&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=aa6e4538e8adce064615367ef6cc7d40</td></tr>
<tr><td>Reports on local/regional</td><td></td><td></td></tr>
<tr><td>Hydrology</td><td>☒</td><td>source(s):
Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p.

Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.]

U.S. Geological Survey Water-Data Report</td></tr>
</table>

hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p.

		http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) 06132200 South Fork Milk River near Babb MT 06132500 S F Milk River nr internat'l boundary nr Brown 06132700 Milk River near Del Bonita MT 06133500 N F Milk River ab St. Mary canal nr Browning M
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Missouri River MP 89

Site	**Missouri River MP 89**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional regression and peak flow analysis									
Regional Regression*									
Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**		**Recurrence Interval**					
				2	**5**	**10**	**25**	**50**	**100**
Omang (1992)	57,565	--		--	--	--	--	--	--
Peak Flood Flow									
Gauge Name and Number	**Drainage Area (mi^2)**	**Up or Down-stream**	**Distance to Crossing (mi)**	**Range of Data (years)**	**Recurrence Interval**				
					2	**5**	**10**	**25**	**50**	**100**
06132000 Missouri River below Fort Peck Dam MT: Bulletin 17B-regional skew	57,556	US	1.81	74 (1934-2008)	16,900	23,900	28,700	34,800	39,500	44,300
06132000 Missouri River below Fort Peck Dam MT: Bulletin 17B-station skew	57,556	US	1.81	74 (1934-2008)	16,127	23,332	28,554	33,985	41,321	47,229

*Regional regression used is for watersheds less than 2,500 mi^2

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.02					Gradient (%): 0.03				
width	min	max	mean	std dev	width	min	max	mean	std dev
	656	987	811	147		3289	4380	3780	358
meander wavelength (ft): 15,009					describe geology (lithology, erodibility):				
meander amplitude (ft): 5352					Alluvium of modern channels and flood plains 12,651 ft wide Both sides Quaternary landslide deposits, alluvium-colluvium, glacial deposits undivided				
Sinuosity: 1.35					Both sides Bearpaw Fm: Shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds RB Hell Creek FM: bentonitic claystone that alternates with gray to brown sandstone interbedded with carbonaceous shale RB Fox Hills Fm: fine- to medium-grained, non-calcareous sandstone in upper part, and interbedded sandstone, siltstone, and black shale with calcareous concretion zone in lower part				

<table>
<tr><td rowspan="10">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><td colspan="5">Floodplain</td></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>1765</td><td>7017</td><td>21140</td><td>4255</td><td colspan="5"></td></tr>
<tr><td>15137</td><td>4773</td><td>26145</td><td>2787</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td></td><td></td><td>2175</td><td>2979</td><td colspan="5">scroll bars:</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">US 0.5, 1, 1.8, 3.95 mi, DS 0.5 mi at Milk R confluence, 1.7 mi</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">oxbows:</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">adjacent to crossing</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">channel cut-offs:</td></tr>
<tr><td colspan="5">Single with vegetated islands</td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel confinement at crossing (W_v / W_c):</td><td colspan="5">Relic channel possibly DS, but obscured by ag fields</td></tr>
<tr><td colspan="5">13.17</td><td colspan="5"></td></tr>
<tr><td colspan="10">What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?</td></tr>
<tr><td colspan="10">Incised: the flood plain elevation is higher than the channel.</td></tr>
<tr><td colspan="10">Unique features, exceptions, etc:</td></tr>
<tr><td colspan="10">Milk River confluence 0.2 mi from crossing. Numerous small tribs and irrigation canals.</td></tr>
</table>

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
mapped for high landslide hazard by the Pipeline and Hazardous Materials Safety Administration in their online National Pipeline Mapping System
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
US: 1. Fort Peck Dam 5.5 mi and spillway 0.9 mi, town of Fort Peck and Fort Peck Lake 2. High Voltage Transmission line (0.05mi, perp.) 3. Railroad (0.40 mi left bank par.) DS: 1. Road (0.60 mi river left, par.) 2 reservoirs 3.9 mi US 0.22 sq mi total area, numerous stock ponds off RB
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

<table>
<tr><td colspan="3">LITERATURE REVIEW
(check box when searched for, if none, note under source)</td></tr>
<tr><td>Existing channel migration zone determination</td><td>☒</td><td>source(s):
Channel Processes on the Missouri River, Montana
http://www.docstoc.com/docs/783910/CHANNEL-PROCESSES-on-the-MISSOURI-RIVER-MONTANA</td></tr>
<tr><td>Reports on local/regional</td><td></td><td></td></tr>
<tr><td>Hydrology</td><td>☒</td><td>source(s):
Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p.</td></tr>
</table>

		Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes

		http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) 06058000 Missouri River at Canyon Ferry MT 06058502 Missouri R bl Canyon Ferry Dam nr Helena MT 06074000 Missouri River at Cascade MT 06078200 Missouri River near Ulm MT 06090300 Missouri River near Great Falls MT 06090800 Missouri River at Fort Benton MT 06109000 Missouri River at Loma MT 06109500 Missouri River at Virgelle MT 06115200 Missouri River near Landusky MT 06058000 Missouri River at Canyon Ferry MT 06058502 Missouri R bl Canyon Ferry Dam nr Helena MT 06065500 Missouri River bl Hauser Dam near Helena MT 06066500 Missouri River bl Holter Dam nr Wolf Cr MT 06071500 Missouri River at Craig MT 06132000 Missouri River below Fort Peck Dam MT 06177000 Missouri River near Wolf Point MT 06185500 Missouri River near Culbertson MT
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

West Fork Lost Creek MP 93.8

Site	**West Fork Lost Creek MP 93.8**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis								
Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Jennings et al. (1994)	0.39	2585	14	50	94	176	259	306

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel	**Valley**
Gradient (%): 2.07	Gradient (%): 3.7

Width	min	max	mean	std dev		min	max	mean	std dev
*hard to determine where stream is- Bkf=0.6ft	24	42	30	7	width	224	257	238	13

meander wavelength (ft) 210	describe geology (lithology, erodibility):
meander amplitude (ft) 107	Both sides Hell Creek Fm: bentonitic claystone that alternates with gray to brown sandstone interbedded with carbonaceous shale Both sides Fox Hills Fm: fine- to medium-grained, non-calcareous sandstone in upper part, and interbedded sandstone, siltstone, and shale with calcareous concretion zone in lower part
Sinuosity: 1.54	

	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
radius of curvature (ft)	1059	122	174	55
	886	87	259	83
	676	125		
	508	71		
	361	76		
	31	71		

Floodplain

FEMA National Database N

if yes, describe widths below

Width (ft)	min	max	mean	std dev

Describe abundance and location(s) of:

scroll bars:

None

oxbows:

None

channel cut-offs:

None visible.

Channel form (braided, anabranching, single thread):

Single thread	
Channel confinement at crossing (W_v / W_c):	
9.24	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
The floodplain elevation is greater than the channel surface.	
Unique features, exceptions, etc	
Tribs DS 0.3 and 0.38 mi. Backwater conditions of dam 0.2 mi DS could extend as far upstream as the crossing.	
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):	
Landslide deposits 1.25 mi west on Fort Peck Lake, listed as high hazard in PHMSA NPMS	
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):	
US: 1. Road (0.1mi Par.) 2. Electric Lines (0.50 mi Perp.) DS: Earthen dam with pond 0.2 mi	
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc): None	

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): Watershed Restoration Assessment for Lost Creek http://www.archive.org/stream/watershedrestora00harr/watershedrestora00harr_djvu.txt
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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		Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) 06215500 Lost Creek near Pryor MT 12323840 Lost Creek near Anaconda MT 12323850 Lost Creek near Galen, MT
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Trib. to West Fork Lost Creek MP 94.6

<table>
<tr><td>Site</td><td>Trib. to West Fork Lost Creek MP 94.6</td><td>Date</td><td>08/03/09</td></tr>
<tr><td colspan="2">Done by: GF, ML</td><td colspan="2">Review: EG</td></tr>
</table>

<table>
<tr><th colspan="9">Regional Regression Analysis</th></tr>
<tr><th rowspan="2">Source</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Jennings et al. (1994)</td><td>0.39</td><td>2588</td><td>14</td><td>50</td><td>93</td><td>176</td><td>258</td><td>305</td></tr>
</table>

<table>
<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><td colspan="5">Channel</td><td colspan="5">Valley</td></tr>
<tr><td colspan="5">Gradien (%): 2.9</td><td colspan="5">Gradient (%): 3.6</td></tr>
<tr><td rowspan="2">Width *Vegetation prevented an accurate channel measurement</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">width</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td>34</td><td>47</td><td>39</td><td>5</td><td>37</td><td>62</td><td>47</td><td>8</td></tr>
<tr><td colspan="5">meander wavelength (ft): 420</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft) 111</td><td colspan="5">Both sides Hell Creek Fm: bentonitic claystone that alternates with gray to brown sandstone interbedded with carbonaceous shale
Both sides Fox Hills Fm: fine- to medium-grained, non-calcareous sandstone in upper part, and interbedded sandstone, siltstone, and shale with calcareous concretion zone in lower part</td></tr>
<tr><td colspan="5">Sinuosity 1.23</td><td colspan="5">RB Bearpaw Fm: Shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds</td></tr>
<tr><td rowspan="10">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><td colspan="5">Floodplain</td></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>640</td><td>97</td><td>93</td><td>90</td><td colspan="5"></td></tr>
<tr><td>410</td><td>63</td><td>227</td><td>57</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td></td><td></td><td>441</td><td>102</td><td colspan="5">scroll bars:</td></tr>
<tr><td></td><td></td><td>731</td><td>64</td><td colspan="5">None</td></tr>
<tr><td></td><td></td><td>1302</td><td>86</td><td colspan="5">oxbows:</td></tr>
<tr><td></td><td></td><td>1588</td><td>51</td><td colspan="5">None</td></tr>
</table>

			1814	85	channel cut-offs:
Channel form (braided, anabranching, single thread):					None
Single Thread					
Channel confinement at crossing (W_v / W_c):					
4.21					
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?					
The floodplain elevation is greater than the channel.					
Unique features, exceptions, etc					
Trib right at crossing, There is a straightened section of channel 0.25 mi US of crossing (at the stream crossing with the electricity lines), possible incision location.					
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):					
listed as high hazard in PHMSA NPMS, landslide deposits 2 miles west on Fort Peck Lake					
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):					
US: 1. Electricity lines (0.25 mi, perp.) 2. Hwy 24 with culvert (0.6 mi, perp.)					
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc): None					

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf

		Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) 06215500 Lost Creek near Pryor MT
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

East Fork Prairie Elk Creek MP 127.6

Site	**East Fork Prairie Elk Creek MP 127.6**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional regression and peak flow analysis								
Regional Regression								
Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Omang (1992)	20.39	2,581	125	407	734	1,278	1,801	2,130

Peak Flood Flow										
Gauge Name and Number	**Drainage Area (mi^2)**	**Up or Down-stream**	**Distance to Crossing (mi)**	**Range of Data (years)**	**Recurrence Interval**					
					2	**5**	**10**	**25**	**50**	**100**
06175540 Prairie Elk Creek near Oswego MT	352.0	DS	39.2	10 (1975-1985)	5,563	18,034	30,150	44,504	56,098	58,943

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): <0.1					Gradient (%): 0.4				
Width (ft)	min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	12	60	26	16		367	830	538	167
meander wavelength (ft) 869					describe geology (lithology, erodibility):				
meander amplitude (ft) 594					Alluvium of modern channels and flood plains 505 ft wide at crossing Alluvium colluvium US both sides				
Sinuosity 2.08					Fort Union Fm: Tullock Member both side just upstream to DS: sandstone interbedded with subordinate shale and thin beds of coal Lebo member both sides US: carbonaceous shale, bentonitic claystone, sandstone, and coal Tongue River Member both side US sandstone, sandy and silty carbonaceous shale, and coal				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	std dev
	256	217	567	263					
	1254	240	1194	226	Describe abundance and location(s) of:				

	1969	133	1988	211	scroll bars:
	2779	373	2762	311	None
	3897	184			Oxbows:
					None
Channel form (braided, anabranching, single thread):					channel cut-offs:
single					None
Channel confinement at crossing (W_v / W_c):					
11.59					
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?					
It appears to be perched in some sections. The elevation of the free water surface appears to be higher in some places than the surrounding flood plain, (0.00-0.40 mi US and DS of crossing)					
Unique features, exceptions, etc:					
US, 125 ft unnamed stream with dam 0.2 mi from confluence, 0.3 mi another unnamed trib also with source at pond behind dam.					
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):					
Possibly US 0.3 mi					
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):					
US 1. residence (0.8 mi, river left) 2. road crossing (no bridge or culvert) 0.5 mi, perp.)					
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):					
None					

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional:		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Montana Dept. of Transportation Bridge Scour Database: http://www3.mdt.mt.gov:7783/db-pub/pontis40_site.htm Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.

bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6 thousand bridges in the state): http://www3.mdt.mt.gov:7783/db-pub/pontis40_site.htm Evaluation of Potential Bridge Scour in Montana http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck. USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) 06175540 Prairie Elk Creek near Oswego MT
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Redwater River MP 146.6

Site	**Redwater River MP 146.6**	Date	08/05/09
Done by: GF, ML		Review: EG	

Regional regression and peak flow analysis								
Regional Regression*								
Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Omang (1992)	668.3	2765	746	2,269	3,964	6,468	8,846	10,539

Peak Flood Flow										
Gauge Name and Number	**Drainage Area (mi^2)**	**Up or Down-stream**	**Distance to Crossing (mi)**	**Range of Data (years)**	**Recurrence Interval**					
					2	**5**	**10**	**25**	**50**	**100**
06177500 Redwater River at Circle MT (Bulletin 17B)	547.0	US	3.9	85 (1929-2004)	427	2,253	4,752	8,290	14,575	20,505

*Use gauge data sine the only major addition to Redwater River between gauge and crossing is Buffalo Spring Creek.

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): <0.10					Gradien (%): <0.10				
Width (ft)	min	max	mean	Stnd Dev.	width	min	max	mean	variance
	21	98	73	25		2,043	3,211	2,781	4,53
meander wavelength (ft) 2,309					describe geology (lithology, erodibility):				
meander amplitude (ft) 1,495					Alluvium of modern channels and flood plains 2202 ft wide at crossing. Alluvial terrace deposits in places US on LB and DS on RB				
Sinuosity: 2.18					Tongue River Member of Fort union FM: sandstone, sandy and silty carbonaceous shale, and coal.				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	variance
	2051	1089	638	1563					
	3677	2703	3516	1499	Describe abundance and location(s) of:				
	6255	923	12641	2415	scroll bars:				

	4841	920	9105	2332	on Buffalo Springs Ck trib US 0.1 mi RB
	7237	1263	6143	1650	oxbows:
					None
Channel form (braided, anabranching, single thread):					channel cut-offs:
Single Thread					None
Channel confinement at crossing (W_v / W_c):					Relic channels adjacent, US 0.25
12.09					
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?					
The flood plain elevation is greater than the channel's surface elevation.					
Unique features, exceptions, etc					
Tribs: Buffalo Springs Creek 665 ft US; Lone Tree Creek 0.2 mi US; unnamed creeks 0.3, 0.7, and 0.8 mi US, unnamed 0.7 mi DS. All are crossed by parallel roads (see below).					
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?					
None					
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel)					
US 1. Power lines (0.32, river left, par.) 2. Par roads (0. 4 from RB) 3. Road (0.5 from LB) 4. Road and railroad crossings with bridges 1.2 mi 4. Sewage disposal ponds 1.5 mi 5. City of Circle, MT 2.2 mi 6. local airport 1.1 mi					
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):					
None					

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S.

		Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) 06177650 Redwater River near Richey MT
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Buffalo Springs Creek MP 150

<table>
<tr><td>Site</td><td>Buffalo Springs Creek MP 150</td><td>Date</td><td>08/03/09</td></tr>
<tr><td colspan="2">Done by: GF, ML</td><td colspan="2">Review: EG</td></tr>
</table>

<table>
<tr><th colspan="9">Regional Regression Analysis</th></tr>
<tr><th rowspan="2">Source</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Omang (1992)</td><td>152.4</td><td>2805</td><td>119</td><td>335</td><td>555</td><td>937</td><td>1,65</td><td>1,715</td></tr>
</table>

<table>
<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><td colspan="5">Channel</td><td colspan="5">Valley</td></tr>
<tr><td colspan="5">Gradient (%): 0.6</td><td colspan="5">Gradient (%): 0.8</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">width</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td>12</td><td>21</td><td>15</td><td>3</td><td>165</td><td>499</td><td>383</td><td>118</td></tr>
<tr><td colspan="5">meander wavelength (ft) 855</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft) 759</td><td colspan="5">Alluvium of modern channels and flood plains 650 ft wide at crossing</td></tr>
<tr><td colspan="5">Sinuosity 1.52</td><td colspan="5">Tongue River Member Fort Union Fm: sandstone, sandy and silty carbonaceous shale, and coal.</td></tr>
<tr><td rowspan="11">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><td colspan="5">Floodplain</td></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>2247</td><td>222</td><td>725</td><td>116</td><td colspan="5"></td></tr>
<tr><td>3083</td><td>155</td><td>1215</td><td>153</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>4184</td><td>103</td><td>2258</td><td>148</td><td colspan="5">scroll bars:</td></tr>
<tr><td>5029</td><td>215</td><td>3474</td><td>265</td><td colspan="5">None</td></tr>
<tr><td></td><td></td><td>5776</td><td>271</td><td colspan="5">oxbows:</td></tr>
<tr><td></td><td></td><td>6822</td><td>214</td><td colspan="5">none</td></tr>
<tr><td></td><td></td><td>725</td><td>116</td><td colspan="5">channel cut-offs</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">None</td></tr>
<tr><td colspan="5">Single Thread</td><td colspan="5">Relic channels</td></tr>
<tr><td colspan="5">Channel confinement at crossing (W_v / W_c):</td><td colspan="5">DS. 0.3 mi LB</td></tr>
<tr><td colspan="5">23.01</td><td colspan="5"></td></tr>
<tr><td colspan="10">What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?</td></tr>
<tr><td colspan="10">The channel appears to be incised because the floodplain elevation is greater than the channel's water surface elevation.</td></tr>
</table>

Unique features, exceptions, etc
Tribs: unnamed US 0.17mi and West Fork Buffalo Springs Creek 1.8 mi US, confluence with Redwater River 3.2 mi DS
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
DS 0.2 mi RB
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Creek in straightened channel bypass starting 0.14 mi US to 0.1 mi DS. DS Road and railway cross at 0.1 mi, then run parallel, Electric Lines parallel to RB
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
There appears to be scour US of bridge due the presence of the levee and constriction of the valley due to the bridge.

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.]
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-

		90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Berry Creek MP 159.2

Site	**Berry Creek MP 159.2**	Date:	8/02/09
Done by: GF, EG, ML		Review: EG	

Regional Regression Analysis								
Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Jennings et al. (1994)	2.47	2996	29	100	185	341	496	595

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel	**Valley**
Gradient (%): 0.2	Gradient (%): 2.4

Width (ft)	min	max	mean	std dev
	33	134	92	35

Width (ft)	min	max	mean	std dev
	264	633	432	137

meander wavelength (ft): 426	describe geology (lithology, erodibility):
meander amplitude (ft): 390	Both sides Tongue River Member, Fort Union Fm: Sandstone, sandy and silty carbonaceous shale, and coal.
Sinuosity: 4.62	

	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
radius of curvature (ft)	322	49	920	73
	1010	67	1573	49
	1278	74	1842	87
	1739	41	2052	44
	2175	81	2358	103
	183	52		
	444	131		

Floodplain

FEMA National Database No

if yes, describe widths below

Width (ft)	min	max	mean	Stnd Dev

Describe abundance and location(s) of:

scroll bars:

None

oxbows:

None

channel cut-offs:

None

Channel form (braided, anabranching, single thread):

Single

Channel confinement at crossing (W_v / W_c): 4.94

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?

Appears perched on DEM from 0.1 to 0.2 mi DS where channel is above floodplain and 0.1 mi US where floodplain is about 20 ft below channel.

Unique features, exceptions, etc

0.25 mi DS of crossing, confluence into Cottonwood Creek (which pipeline also crosses 0.28 mi NE). Channel widens considerably from 640 - 1780 feet US due to an obstruction (natural sediment dam?) at 700 ft US. Also straightens above that point for .4 mi
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
1 mi US on RB valley wall
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Major road crosses at 0.3 mi DS probably with culvert, spur road parallel 630 ft from RB. Road crosses 0.7 mi US
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
Straightened reach 0.25 mi above crossing may be susceptible to scour.

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p.

		Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Clear Creek MP 175.2

Site	**Clear Creek MP 175.2**	Date:	08/02/09
Done by: GF, EG, ML	Review: EG		

Regional regression and peak flow analysis

Regional Regression

Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Jennings et al. (1994)	73.10	3018	187	594	1,064	1,829	2,573	3,093

Peak Flood Flow

Gauge Name and Number	**Drainage Area (mi^2)**	**Up or Down-stream**	**Distance to Crossing (mi)**	**Range of Data (years)**	**Recurrence Interval**					
					2	**5**	**10**	**25**	**50**	**100**
06326952 Clear Creek near Lindsay MT: regional regression	101.0	DS	9.50	6 (1982-1988)	2,194	7,253	12,343	18,899	24,342	25,911

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel

Gradient (%): 0.03

Width (ft)	min	max	mean	std dev
(hard to see channel with vegetation)	22	72	44	19

meander wavelength (ft): 1031

meander amplitude (ft): 895

Sinuosity: 8.37

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	2259	830	285	609
	3469	624	1142	496
	4140	144	2078	437

Valley

Gradient (%): 0.34

Width (ft)	min	max	mean	std dev
	2019	3280	2502	437

describe geology (lithology, erodibility):

Modern alluvium 1208 ft wide at crossing

US off RB Alluvial terrace deposit

Both sides Tongue River Member of Fort Union Fm: Sandstone, sandy and silty carbonaceous shale & coal.

Floodplain

FEMA National Database: No

if yes, describe widths below

Width (ft)	min	max	mean	Stnd Dev

Describe abundance and location(s) of:

scroll bars:

	5011	367	3249	1211	none
	5427	161	4280	286	oxbows:
	5955	402	5381	646	None
Channel form (braided, anabranching, single thread):					channel cut-offs:
Single					US meander adjacent to crossing
Channel confinement at crossing (W_v / W_c):					Relic channel 0.6 mi US, 0.2 mi DS
48.8					
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?					
Perched at 0.3 mi US, channel is at 2733 feet while the floodplain is at 2720 ft					
Unique features, exceptions, etc					
Tribs: South Fork Clear Creek 0.2 mi US, unnamed trib 0.8 mi DS, Cigar Creek 1.4 mi DS, irrigation ditch 0.6 mi US and joins with Cigar Creek					

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
US: road with bridge 1.3 mi, parallel road directly on LB; small roads cross 0.4 mi. DS and 0.4 mi US; parallel road directly on RB from 164 ft US down valley, group of building DS 1.1 mi
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.

bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) 06142000 Clear Creek near Bearpaw MT 06142400 Clear Creek near Chinook MT
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Side Channel of Yellowstone River MP 195.7

<table>
<tr><td>Site</td><td>Side Channel of Yellowstone River MP 195.7</td><td>Date:</td><td>08/02/09</td></tr>
<tr><td colspan="2">Done by: GF, EG, ML</td><td colspan="2">Review: EG</td></tr>
</table>

<table>
<tr><th colspan="11">Regional regression and peak flow analysis</th></tr>
<tr><th colspan="11">Regional Regression*</th></tr>
<tr><th colspan="2" rowspan="2">Source</th><th>Drainage Area (mi^2)</th><th colspan="2" rowspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th></th><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td colspan="2">Omang (1992)</td><td>52,246</td><td colspan="2">--</td><td>--</td><td>--</td><td>--</td><td>--</td><td>--</td><td>--</td></tr>
<tr><th colspan="11">Peak Flood Flow</th></tr>
<tr><th rowspan="2">Gauge Name and Number</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Up or Down-stream</th><th rowspan="2">Distance to Crossing (mi)</th><th rowspan="2">Range of Data (years)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>06309000 Yellowstone River at Miles City MT (Bulletin 17B)</td><td>48,253</td><td>US</td><td>55.3</td><td>87 (1922-2009)</td><td>49,918</td><td>64,660</td><td>73,305</td><td>80,910</td><td>89,945</td><td>96,232</td></tr>
<tr><td>06327500 Yellowstone River at Glendive MT (Bulletin 17B)</td><td>66,739</td><td>DS</td><td>20.3</td><td>112 (1897-2009)</td><td>60,923</td><td>81,241</td><td>94,015</td><td>105,828</td><td>120,616</td><td>131,420</td></tr>
</table>

*The regional regression equation is for watersheds (0.04 mi^2-2,250 mi^2)

<table>
<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><th colspan="5">Channel</th><th colspan="5">Valley</th></tr>
<tr><td colspan="5">Gradient (%): 0.02</td><td colspan="5">Gradient (%): 0.4</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td>31</td><td>66</td><td>47</td><td>12</td><td>2057</td><td>2720</td><td>2355</td><td>241</td></tr>
<tr><td colspan="5">meander wavelength (ft): 3032</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft): 635</td><td colspan="5">Modern alluvium 2203 ft wide at crossing
Both sides alluvial terrace deposit; alluvium/colluvium</td></tr>
<tr><td colspan="5">Sinuosity: 1.25</td><td colspan="5">Fort Union Fm:
Both sides Lebo Member: Dark gray carbonaceous shale, bentonitic claystone, sandstone, and coal.
Both sides Tongue River Member: Yellowish orange sandstone, sandy
RB Ludlow Member: Gray and brown shale, siltstone, silty or bentonitic claystone, sandstone, and coal.</td></tr>
<tr><td rowspan="2">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><th colspan="5">Floodplain</th></tr>
<tr><td>distance from</td><td>radius of curvature</td><td>distance from</td><td>radius of curvature</td><td colspan="5">FEMA National Database No
if yes, describe widths below</td></tr>
</table>

	crossing		crossing		Width (ft)	min	max	mean	Stnd Dev
	429	304	1801	1079					
	1373	2046	3185	1342	Describe abundance and location(s) of:				
	3925	871			scroll bars:				
					Adjacent to crossing, possible set DS 0.5 mi RB				
					oxbows:				
					none				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single side channel of anabranching river					none				
Channel confinement at crossing (W_v / W_c):									
68.99									
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?									
Based on DEM, water surface is 15 ft below elevation of floodplain within 0.25 mi of crossing in either direction.									
Unique features, exceptions, etc									
Most of valley floor at LB is covered in agricultural fields, so more features may have present before modification.									

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Road parallel to entire side channel .25 mi from LB; cluster of buildings 0.4 mi US off this road. DS: building 0.5 mi, 0.25 mi from LB. Farm roads throughout valley bottom on LB
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
Scour pool at inlet to side channel on DEM

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): Yellowstone River Channel Migration Zone Mapping Tony Thatcher, Bryan Swindell DTM Consulting, Inc. 211 N Grand Ave, Suite J. Bozeman, MT 59715 http://dnrc.mt.gov/cardd/yellowstonerivercouncil/2008ChannelMigration/cmzFinalReport.pdf
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report

hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p.

		http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) 06186500 Yellowstone River at Yellowstone Lk Outlet YNP 06191500 Yellowstone River at Corwin Springs MT 06192500 Yellowstone River near Livingston MT 06195600 Shields River nr Livingston MT 06195750 Yellowstone River at Springdale, MT 06195950 Yellowstone River at Big Timber, MT 06207500 Clarks Fork Yellowstone River nr Belfry MT 06208000 Clarks Fork Yellowstone River at Fromberg MT 06208500 Clarks Fork Yellowstone River at Edgar MT 06208800 Clarks Fork Yellowstone River nr Silesia MT
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Yellowstone River MP 196

<table>
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<table>
<tr><th colspan="9">Regional regression and peak flow analysis</th></tr>
<tr><th colspan="9">Regional Regression*</th></tr>
<tr><th rowspan="2">Source</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Omang (1992)</td><td>50,246</td><td>--</td><td>--</td><td>--</td><td>--</td><td>--</td><td>--</td><td>--</td></tr>
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<table>
<tr><th colspan="11">Peak Flood Flow</th></tr>
<tr><th rowspan="2">Gauge Name and Number</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Up or Down-stream</th><th rowspan="2">Distance to Crossing (mi)</th><th rowspan="2">Range of Data (years)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>06309000 Yellowstone River at Miles City MT (Bulletin 17B)</td><td>48,253</td><td>US</td><td>55.3</td><td>87 (1922-2009)</td><td>49,918</td><td>64,660</td><td>73,305</td><td>80,910</td><td>89,945</td><td>96,232</td></tr>
<tr><td>06327500 Yellowstone River at Glendive MT (Bulletin 17B)</td><td>66,739</td><td>DS</td><td>20.3</td><td>112 (1897-2009)</td><td>60,923</td><td>81,241</td><td>94,015</td><td>105,828</td><td>120,616</td><td>131,420</td></tr>
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*The regional regression equation is for watersheds 0.04 mi^2-2,250 mi^2.

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<tr><th colspan="5">Channel</th><th colspan="5">Valley</th></tr>
<tr><td colspan="5">Gradient (%): 0.05</td><td colspan="5">Gradient (%): 0.01</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td>376</td><td>583</td><td>485</td><td>67</td><td>932</td><td>8635</td><td>4131</td><td>2634</td></tr>
<tr><td colspan="5">meander wavelength (ft): 10458</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft): 702</td><td colspan="5">Modern alluvium 2203 ft wide at crossing
Both sides alluvial terrace deposit; alluvium/colluvium</td></tr>
<tr><td colspan="5">Sinuosity: 1.17</td><td colspan="5">Fort Union Fm:
Both sides Lebo Member: Dark gray carbonaceous shale, bentonitic claystone, sandstone, and coal.
Both sides Tongue River Member: Yellowish orange sandstone, sandy
RB Ludlow Member: Gray and brown shale, siltstone, silty or bentonitic claystone, sandstone, and coal.</td></tr>
<tr><td rowspan="2">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><th colspan="5">Floodplain</th></tr>
<tr><td>distance from</td><td>radius of curvature</td><td>distance from</td><td>radius of curvature</td><td colspan="5">FEMA National Database No
if yes, describe widths below</td></tr>
</table>

	crossing		crossing		Width (ft)	min	max	mean	Stnd Dev
	4756	8466	1296	7406	Describe abundance and location(s) of:				
	12654	11483	5901	12477	scroll bars:				
	17889	6442	9601	5665	DS: 1 mi. on LB, 2.5 mi on RB, 5.8 mi on LB US: 3.8 mi, 5 mi on both banks				
	26315	2348	13497	4822	oxbows:				
	32892	3510	17128	4792	none				
	40800	8184	21087	4759	channel cut-offs:				

Channel form (braided, anabranching, single thread):	none
Anabranching	
Channel confinement at crossing (W_v / W_c):	
5.75	

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
Channel is incised based on DEM: water surface is 30 ft below elevation of floodplain.
Unique features, exceptions, etc
Numerous small tribs along study reach, including bad Route Creek 1.4 mi US and Cabin Creek 5.5 mi DS. Most of valley floor on LB is covered in agricultural fields, so more features may have present before modification. Right bank appears to be constrained by terrace of Fort Union Fm overlain by alluvium terrace deposits.

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
US: 5 mi on RB valley wall, 2 more possibly just DS.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
US: 2 Freeway bridges (I-94) cross at 7.2 mi, then I-94 runs parallel 2.5 mi from LB; another road also with bridge next to I94, town of Fallon 1.3 mi from RB at 7.2 mi. Powerline crosses 6.6 mi. Railway on RB, Roads parallel to both banks, 80 ft to 0.75 mi from RB and 150 ft to 1.2 mi from LB. Numerous small farm roads throughout valley bottom.
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
The 5 mi segment US of crossing is straighter and abuts terrace, cross valley slopes also seem steeper here.

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): Yellowstone River Channel Migration Zone Mapping Tony Thatcher, Bryan Swindell DTM Consulting, Inc. 211 N Grand Ave, Suite J. Bozeman, MT 59715 http://dnrc.mt.gov/cardd/yellowstonerivercouncil/2008ChannelMigration/cmzFinalReport.pdf
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey

		Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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		http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
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1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Cabin Creek MP 201.4

Site	**Cabin Creek MP 201.4**	Date:	08/02/09
Done by: GF, EG, ML		Review: EG	

<table>
<tr><th colspan="9">Regional Regression Analysis</th></tr>
<tr><th rowspan="2">Source</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Omang (1992)</td><td>235.7</td><td>2,592</td><td>678</td><td>1,780</td><td>2,842</td><td>4,633</td><td>6,049</td><td>8,228</td></tr>
</table>

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<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><th colspan="5">Channel</th><th colspan="5">Valley</th></tr>
<tr><td colspan="5">Gradient (%): 0.06</td><td colspan="5">Gradient (%): 0.3</td></tr>
<tr><td>Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td>(Hard to see channel in aerials)</td><td>12</td><td>27</td><td>19</td><td>6</td><td>1553</td><td>2471</td><td>1934</td><td>298</td></tr>
<tr><td colspan="5">meander wavelength (ft): 1444</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft): 857</td><td colspan="5">Modern alluvium 2516 ft wide at crossing
Alluvial terrace deposits between left bank and Yellowstone R</td></tr>
<tr><td colspan="5">Sinuosity: 2.40</td><td colspan="5">Fort Union Fm:
Both sides Tongue River Member: sandstone, sandy and silty carbonaceous shale, and coal.
Both sides Ludlow Member: Gray and brown shale, siltstone, silty or bentonitic claystone, sandstone, and coal.</td></tr>
<tr><td rowspan="10">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><th colspan="5">Floodplain</th></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database No
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>Stnd Dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>3407</td><td>851</td><td>81</td><td>218</td><td colspan="5"></td></tr>
<tr><td>4143</td><td>858</td><td>2298</td><td>941</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>5221</td><td>425</td><td>3994</td><td>777</td><td colspan="5">scroll bars:</td></tr>
<tr><td>5914</td><td>237</td><td>5737</td><td>251</td><td colspan="5">US 0.9 and 0.5 mi; DS 0.5 mi</td></tr>
<tr><td>7398</td><td>617</td><td>7169</td><td>420</td><td colspan="5">oxbows:</td></tr>
<tr><td>9269</td><td>421</td><td>8046</td><td>364</td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">channel cut-offs:</td></tr>
<tr><td colspan="5">Single</td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel confinement at crossing (W_v / W_c): 199.31</td><td colspan="5">Relic channels:</td></tr>
<tr><td colspan="5"></td><td colspan="5">US 0.4, 1.4 mi; DS 0.2 mi</td></tr>
</table>

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
Perched at 0.85 mi. US and 0.2 mi DS where floodplain is 10 ft below water surface on DEM.
Unique features, exceptions, etc
Trib: Spring Creek US 0.6 mi with ponding behind a channel-spanning structure 0.65 mi US of confluence. .Another crossing on Cabin Creek 0.5 US. The channel is much straighter and wider between crossings than US or DS.

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
Possibly US 1.9 mi and DS 0.7 on RB valley wall.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
US: Road crosses at 0.3 mi, then runs parallel DS at 0.2 mi away from LB; group of buildings 0.5 mi between Cabin and Spring Creek; perpendicular road from buildings to small parallel road 0.2 to 0.75 mi from LB; series of small farm roads US of buildings; small parallel road 1.5 mi about 0.25 mi from RB. DS: small road 85 feet to 0.5 mi from RB
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
Straight section of channel vulnerable to scour.

LITERATURE REVIEW
(check box when searched for, if none, note under source)

Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
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Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Cabin Creek MP 202

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<tr><td colspan="5">Gradient (%): 0.04</td><td colspan="5">Gradient (%): 0.2</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td>5</td><td>25</td><td>15</td><td>7</td><td>458</td><td>2813</td><td>1532</td><td>1000</td></tr>
<tr><td colspan="5">meander wavelength (ft): 1284</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft): 602</td><td colspan="5">Modern alluvium 1871 ft wide at crossing
Alluvial terrace deposits between left bank and Yellowstone R</td></tr>
<tr><td colspan="5">Sinuosity: 6.13</td><td colspan="5">Fort Union Fm:
Both sides Tongue River Member: sandstone, sandy and silty carbonaceous shale, and coal.
Both sides Ludlow Member: Gray and brown shale, siltstone, silty or bentonitic claystone, sandstone, and coal.</td></tr>
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<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>931</td><td>960</td><td>210</td><td>617</td><td colspan="5"></td></tr>
<tr><td>1544</td><td>464</td><td>1092</td><td>421</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>3064</td><td>851</td><td>4428</td><td>218</td><td colspan="5">scroll bars:</td></tr>
<tr><td>4892</td><td>858</td><td>6605</td><td>941</td><td colspan="5">US 0.5 and 0.1 mi; DS 0.9</td></tr>
<tr><td>7070</td><td>425</td><td>8528</td><td>777</td><td colspan="5">oxbows:</td></tr>
<tr><td>9359</td><td>237</td><td>10116</td><td>251</td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">channel cut-offs:</td></tr>
<tr><td colspan="5">Single</td><td colspan="5">relic channels:</td></tr>
<tr><td colspan="5">Channel confinement at crossing (W_v / W_c): 41.21</td><td colspan="5">US 0.95 mi, adjacent; DS 0.6</td></tr>
</table>

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
Perched at 0.5 mi. US and 1 mi DS where floodplain is 10 ft below water surface on DEM.	
Unique features, exceptions, etc	
Trib: Spring Creek DS and 400 ft across the valley with ponding behind a channel-spanning structure 0.65 mi US of confluence. Another crossing on Cabin Creek 0.5 DS. The channel is much straighter and wider between crossings than US or DS.	

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
Possibly US 1.4 mi and DS 1.1 mi on RB valley wall.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
US: Group of buildings 150 ft between Cabin and Spring Creek; perpendicular road from buildings to small parallel road 0.2 to 0.75 mi from LB; series of small farm roads US of buildings; small parallel road 1.5 mi about 0.25 mi from RB. DS: Road crosses at 750 ft, then runs parallel DS at 0.2 mi away from LB; small spur road runs DS 85 feet to 0.5 mi from RB
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
Straight section of channel vulnerable to scour.

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf

		Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Dry Fork Creek MP 226.9

Site	**Dry Fork Creek MP 226.9**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis

Source	Drainage Area (mi^2)	Average Elevation (ft)	Recurrence Interval					
			2	5	10	25	50	100
Omang (1992)	28.16	2,888	120	390	704	1,228	1,739	2,081

Geomorphology **NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)**									
For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)									
Channel (completed for two sections US East Trib, DS below Dam)					**Valley**				
Gradient (%): 0.2, 0.5					Gradient (%): <0.1, 0.4				
width	min	max	mean	std dev	width	min	max	mean	std dev
	21	80	52	22		761	2276	1496	605
meander wavelength (ft) 531					describe geology (lithology, erodibility):				
meander amplitude (ft) 390					Valley and floodplain on both sides of the creek: Tongue River Member of the Fort Union Formation--Sandstone, sandy and silty shale and coal.				
Sinuosity 2.59, 2.11									
radius of curvature (ft)	Upstream East Trib (ft)		Downstream of Dam(ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	std dev
	1568	134	2434	176					
	2119	75	3159	155	Describe abundance and location(s) of:				
	2621	107	3628	133	scroll bars:				
	3388	92	4451	167	None				
					oxbows:				
					None				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single Thread					DS 0.18 mi				
Channel confinement at crossing (W_v / W_c):					Oxbow and avulsion (0.00-0.20 mi river left)				
29.31					Relic channel 0.5 mi US, 0.4 and 0.55 mi DS				
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?									
The floodplain elevation is higher than the elevation of the channel's water surface on DEM.									

Unique features, exceptions, etc.
DS of the crossing is a dam and the channel's width increases when it reaches the area of the backwater effect. Lawrence Creek 0.2 mi US and an unnamed creek 200 feet DS, irrigation canal 0.26 mi DS
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
DS parallel road (0.20 mi River left) with building 0.75 mi, Dam 0.3 mi DS
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
Straightened channel at 0.00-0.15 mi could be due to backwater affect of dam.

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): Yellowstone River Channel Migration Zone Mapping Tony Thatcher, Bryan Swindell DTM Consulting, Inc. 211 N Grand Ave, Suite J. Bozeman, MT 59715 http://dnrc.mt.gov/cardd/yellowstonerivercouncil/2008ChannelMigration/cmzFinalReport.pdf Channel Processes On The Missouri River, Montana http://www.docstoc.com/docs/783910/CHANNEL-PROCESSES-on-the-MISSOURI-RIVER-MONTANA
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U U.S. Geological Survey Water-Data Report USGS 06158000 Frenchman R ab Eastend Re nr Ravenscrag Sask http://waterdata.usgs.gov/mt/nwis/dv/?site_no=06158000&PARAmeter_cd=00060 USGS 06209010 Rock Cr bl Glacier Lake nr Red Lodge MT http://waterdata.usgs.gov/mt/nwis/dv/?site_no=06209010&PARAmeter_cd=00060 06211500 Willow Creek near Boyd MT http://waterdata.usgs.gov/mt/nwis/dv/?site_no=06211500&PARAmeter_cd=00060
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.

bridge scour	☒	source(s): Montana DOT Bridge Scour Data Base (constructional stability for almost 6 thousand bridges in the state) http://www3.mdt.mt.gov:7783/db-pub/pontis40_site.htm Evaluation of Potential Bridge Scour in Montana http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 1995, Evaluating scour at bridges, 3d ed.: U.S. Department of Transportation, Federal Highway Administration Hydraulic Engineering Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck. USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) 06100000 Dry Fork Marias River near Valier MT 06100500 Dry Fork Marias River at Fowler MT

1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Pennel Creek MP 234.5

Site	**Pennel Creek MP 234.5**	Date	08/03/09
Done by: GF, ML		Review: EG	

TABLE X
Regional Regression Analysis

Source	Drainage Area (mi^2)	Average Elevation (ft)	Recurrence Interval					
			2	5	10	25	50	100
Omang (1992)	67.7	3,034	178	564	1,102	1,743	2,456	2,953

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.1					Gradient (%): 0.3				
Width (ft)	min	max	mean	std dev	width	min	max	mean	std dev
	10	17	13	3		1472	3112	2355	590

meander wavelength (ft) 1,312	describe geology (lithology, erodibility):
meander amplitude (ft) 793	Alluvium of modern channels and flood plains 505 ft wide at crossing
Sinuosity 2.16	Both sides Fort Union Fm: Tongue River Member: sandstone, sandy and silty carbonaceous shale, and coal Ludlow Member: shale, siltstone, silty or bentonitic claystone, sandstone, and coal.
	Both sides Hell Creek Fm: bentonitic claystone that alternates with gray to brown sandstone interbedded with carbonaceous shale
	Both sides Fox Hills Fm: Timber Lake Member: fine- to mediumgrained, noncalcareous, hummocky-bedded sandstone. Trail City Member: wavy-bedded siltstone and black shale with calcareous concretion zone. Both sides Pierre Fm: partly silty shale with abundant bentonite beds and zones of gray, calcareous concretions.

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	2617	745	2932	312
	4497	322	3985	378
	6376	580	4789	159
	7328	292	5776	237

Floodplain

FEMA National Database N

if yes, describe widths below

Width (ft)	min	max	mean	std dev

Describe abundance and location(s) of:

scroll bars:

none

					oxbows:
					None
Channel form (braided, anabranching, single thread):					channel cut-offs:
Single Thread					relic channel
Channel confinement at crossing (W_v / W_c):					DS 0.1, 0.55, 0.65, 0.72 mi; US 0.6, 0.78, 0.95, 1, 1.4
175.1					
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?					
The channel's surface water elevation is mostly lower than the surrounding flood plain.					
Unique features, exceptions, etc					
Tribs: 0.1, 0.5, 1.1 mi; DS 1.65, 1.8 mi US. Numerous stock ponds on tribs in valley, including 3 on closest trib 0.5, 0.66, 1. mi from confluence.					

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
DS 1. Road Crossing Bridge or culvert (0..28 mi, perp.) 2. Private residence (0.30 mi, river left,), US road crossing and buildings 1.54 mi
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.

bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Little Beaver Creek MP 262.4

Site	**Little Beaver Creek MP 262.4**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis								
Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Omang (1992)	391.9	3,385	412	1,118	1,828	3,3038	4,032	5,427

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel	**Valley**
Gradient (%): 0.20	Gradient (%): 0.40

Width (ft)	min	max	mean	std dev	width	Min	max	mean	std dev
	18	44	29	10		1607	2246	1891	237

meander wavelength (ft) 2158	describe geology (lithology, erodibility):
meander amplitude (ft): 1548	Alluvium of modern channels and flood plains 1604 ft wide at crossing Alluvial terrace deposit DS on river right
Sinuosity: 2.34	DS both sides--Pierre Shale: partly silty shale with abundant bentonite beds and zones of calcareous concretions. Adjacent and US both sides--Hell Creek Fm: bentonitic claystone that alternates with sandstone interbedded with carbonaceous shale. Further US--Ludlow Member Fort Union Fm: shale, siltstone, silty or bentonitic claystone, sandstone, and coal.

	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
radius of curvature (ft)	8945	892	2680	706
	4336	1335	5865	669
	2040	612		
	420	553		

Floodplain				
FEMA National Database N if yes, describe widths below				
Width (ft)	min	max	mean	std dev

Describe abundance and location(s) of:

scroll bars:

DS 0.82 mi

oxbows:

None

Channel form (braided, anabranching, single thread):	channel cut-offs

Single Thread	None
Channel confinement at crossing (W_v / W_c):	Relic channels DS 0.47 mi and 0.7 mi and US 1.2 mil
72.0	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
The elevation of the floodplain is at the same elevation or higher than the water surface elevation	
Unique features, exceptions, etc:	
Unnamed tribs US 0.42, 0.67, 0.87 mi; DS 0.2, 1, and 1.2 mi	
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):	
None	
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):	
US Private residence (0.55 mi River left) with small road parallel to trib, DS 1.3 mi additional small roads with crossing	
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):	
None	

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s):
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S.

		Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) 06167500 Beaver Creek near Hinsdale MT
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Boxelder Creek MP 291.4

Site	**Boxelder Creek MP 291.4**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional regression and peak flow analysis

Regional Regression

Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Omang (1992)	1088.9	3,408	709	1,885	3,055	5,028	6,608	8,890

Peak Flood Flow

Gauge Name and Number	**Drainage Area (mi^2)**	**Up or Down-stream**	**Distance to Crossing (mi)**	**Range of Data (years)**	**Recurrence Interval**					
					2	**5**	**10**	**25**	**50**	**100**
06334630 Box Elder Creek at Webster MT (Bulletin 17B)	1092.0	DS	1.82	13 (1960-1973)	1,936	5,223	9,001	14,300	24,432	35,223

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.70					Gradient (%): 0.002				
Width (ft)	min	max	mean	std dev	width	min	max	mean	std dev
	38	69	52	11		1168	4303	3017	1134
meander wavelength (ft) 4,188					describe geology (lithology, erodibility):				
meander amplitude (ft) 3,598					Alluvium of modern channels and flood plains 4609 ft wide at crossing Landslide deposits 3.9 mi US				
Sinuosity 2.21					Both sides Ludlow Member Fort Union Fm: shale, siltstone, silty or bentonitic claystone, sandstone, and coal. RB Hell Creek Fm: bentonitic claystone that alternates with sandstone interbedded with carbonaceous shale. LB Ekalaka Member Fort Union Fm: fine- to medium-grained sandstone interbedded with mudstone and thin shale and coal beds.				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database Y/N if yes, describe widths below				
					Width (ft)	min	max	mean	std dev
	6471	1544	6606	847					

	11467	1047	13609	2034	Describe abundance and location(s) of:
	15341	1540	19106	731	scroll bars:
	20185	1458			US 2mi, I mi; DS 0.4 mi
					oxbows:
					None
Channel form (braided, anabranching, single thread):					channel cut-offs:
Single Thread with a few islands, including at crossing					none
Channel confinement at crossing (W_v / W_c):					Relic Channel DS 0.6 mi
51.27					
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?					
The elevation of the flood plain is greater than the channel's water surface elevation.					
Unique features, exceptions, etc:					
Tortuous meanders 2 mi DS Tribs: US Unnamed at 0.85 and 1.6 mi, Horse Creek at 0.5 mi. DS unnamed at 0.2, 0.4, 1.1 mi Coal Bank Creek at 1.8 mi					
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):					
None					
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):					
Buildings and roads 1.1 and 1.8 mi US, and 0.6 mi DS. Dams 2.2 mi on upstream trib that flows in floodplain 650 ft from LB					
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):					
None					

LITERATURE REVIEW
(check box when searched for, if none, note under source)

Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report.
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.

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Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) 06334630 Box Elder Creek at Webster MT
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

INTERMITTENT STREAM CROSSINGS

Corral Coulee MP 20.8

Site	**Corral Coulee MP 20.8**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis

Source	Drainage Area (mi^2)	Average Elevation (ft)	Recurrence Interval					
			2	**5**	**10**	**25**	**50**	**100**
Omang (1992)	8.91	2,768	47	155	272	470	665	885

Geomorphology									
For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)									
Channel					**Valley**				
Gradient (%): 0.9					Gradient (%): 1.2				
Width (ft) vegetation made it difficult to assess channel width	min	max	mean	stnd dev	width	min	max	mean	stnd dev
	15	37	26	7		107	584	278	153
meander wavelength: (ft) 806					describe geology (lithology, erodibility):				
meander amplitude (ft) 218					Floodplain: modern alluvium, approx. 364 feet wide at the crossing				
Sinuosity: 1.33					Both sides of the creek: Bearpaw Formation: shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds. Both sides DS Judith River Fm: fine- to coarse-grained sandstone with interbeds of gray to black carbonaceous shale, silty shale, and thin coal.				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	Max	mean	variance
	244	227	413	199					
	413	165	977	132	Describe abundance and location(s) of:				
	977	110	1469	124	scroll bars:				
			1922	131	None				
					oxbows:				
					None				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single Thread					None				

Channel confinement at crossing (W_v / W_c):	Relic channels
17.45	0.38 mi DS and 0.16 US
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
The channel appears to be incised because the surrounding valley elevation is generally 8.0-10ft above the surface water elevation of the channel in the DEM.	
Unique features, exceptions, etc	
Another crossing on Corral Coulee 0.6 mi DS Unnamed tributaries at crossing, US 1.22 mi, confluence with Frenchman Creek DS 4.5 mi	
Evidence of landslides upstream or downstream along valley margins:	
None, but listed as high risk by PHMSA NPMS Landslide Hazard Map	
Describe any infrastructure (bridges, roads, buildings, powerlines, etc)	
Dam with stock pond on closest trib 0.33 mi from confluence, on US trib 0.12 mi from confluence. Small road crosses 0.4 mi US	
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):	
The channel appears to be incised because of width of the flood plain is almost the same as the width as the river valley.	

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey, various dates, Water resources data, Montana, water year: U.S. Geological Survey Water-Data Report.
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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		No.18, 1995, US. Department of Transportation, http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
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Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Corral Coulee MP 21.5

<table>
<tr><td>Site</td><td>Corral Coulee MP 21.5</td><td>Date</td><td>08/03/09</td></tr>
<tr><td colspan="2">Done by: GF, ML</td><td colspan="2">Review: EG</td></tr>
</table>

<table>
<tr><th colspan="9">Regional Regression Analysis</th></tr>
<tr><th rowspan="2">Source</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Omang (1992)</td><td>9.79</td><td>2,768</td><td>50</td><td>165</td><td>289</td><td>501</td><td>707</td><td>941</td></tr>
</table>

<table>
<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><th colspan="5">Channel</th><th colspan="5">Valley</th></tr>
<tr><td colspan="5">Gradient (%): 1.1</td><td colspan="5">Gradient (%): 1.8</td></tr>
<tr><td rowspan="2">Width (ft) Vegetation made it difficult to determine width</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">width</td><td>Min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td>11</td><td>20</td><td>15</td><td>4</td><td>179</td><td>571</td><td>319</td><td>142</td></tr>
<tr><td colspan="5">meander wavelength (ft) 570</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft) 184</td><td colspan="5">Floodplain: modern alluvium, approx. 350 feet wide at the crossing</td></tr>
<tr><td colspan="5">Sinuosity 1.44</td><td colspan="5">Both sides of the creek: Bearpaw Formation: shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds.
Both sides DS Judith River Fm: fine- to coarse-grained sandstone with interbeds of gray to black carbonaceous shale, silty shale, and thin coal.</td></tr>
<tr><td rowspan="10">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><th colspan="5">Floodplain</th></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>91</td><td>63</td><td>200</td><td>84</td><td colspan="5"></td></tr>
<tr><td>200</td><td>59</td><td>636</td><td>60</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>636</td><td>70</td><td>1062</td><td>137</td><td colspan="5">scroll bars:</td></tr>
<tr><td></td><td></td><td>1426</td><td>79</td><td colspan="5">None</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">oxbows:</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">channel cut-offs:</td></tr>
<tr><td colspan="5">Single</td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel confinement at crossing (W_v / W_c):</td><td colspan="5">Relic channels</td></tr>
</table>

31.0	0.24 US and 0.04 mi DS
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
The channel is incised because the valley's elevation is much greater than the water surface of the channel.	
Unique features, exceptions, etc :	
Another crossing on Corral Coulee 0.6 mi US Unnamed tributary US 0.1 mi, confluence with Frenchman Creek DS 3.8 mi	
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):	
None, but listed as high risk by PHMSA NPMS Landslide Hazard Map	
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):	
Dam with stock pond on closest trib 0.16 mi from confluence.	
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):	
The channel appears to be incised because the flood plain width and valley floor width are about equal and there are steep valley walls.	

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey, various dates, Water resources data, Montana, water year: U.S. Geological Survey Water-Data Report.
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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		http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
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Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Hay Coulee MP 38

Site	**Hay Coulee MP 38**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis

Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	1.68	--	--	--	15	54	99	178	256	348

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel	**Valley**
Gradient (%): 1.6	Gradient (%): 2.1

Width (ft)	min	max	mean	stnd dev	width	min	max	mean	stnd dev
	14	22	17	3		526	240	331	114

meander wavelength (ft) 954	describe geology (lithology, erodibility):
meander amplitude (ft)135	Alluvium from modern channels and flood plains 327 ft
Sinuosity 1.30	Both sides Judith River Fm: Sandstone with interbeds of shale.

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	377	108	413	100
	751	79	647	89
	1502	126	1045	76
	2073	141	1265	70
	54	65		

Floodplain

FEMA National Database N

if yes, describe widths below

Width (ft)	min	max	mean	variance

Describe abundance and location(s) of:

scroll bars:

None

oxbows:

None

channel cut-offs:

US 0.06 mi, inside of meander bend, some threading appears to have occurred

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c):

7.29

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?

Incised. The channel near the crossing is straighter than US and DS. The amplitudes of the meanders are smaller at the crossing than US and DS amplitudes
Unique features, exceptions, etc:
None
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None, Listed as high risk by PHMSA NPMS Landslide Hazard Map
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Bud Reservoir 0.34 and stock pond 0.97 mi US and 0.45 mi DS, small road crosses 0.86 mi DS.
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
The channel appears to be straighter at the crossing than upstream. The confinement ratio is low meaning the channel does not have the ability to move within the confines of the valley

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-

		90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Lime Creek 44.9

Site	**Lime Creek 44.9**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis								
Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Omang (1992)	8.89	2627	48	161	283	495	703	941

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.4					Gradient (%): 0.5				
Width (ft)	min	max	mean	stnd dev.	width	min	max	mean	stnd dev.
	9	15	12	2		107	584	278	154.0
meander wavelength (ft) 551					describe geology (lithology, erodibility):				
meander amplitude (ft) 179					Quaternary Sand and Gravel 705 ft wide at crossing				
Sinuosity 1.81					Both sides Judith River Fm: fine- to coarse-grained sandstone with interbeds of gray to black carbonaceous shale, silty shale, and thin coal. Both sides Bearpaw Formation: shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds.				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	stnd dev.
	172	105	535	84					
	587	143	1348	46	Describe abundance and location(s) of:				
	1174	168	1729	91	scroll bars:				
	1774	146	1988	48	None				
					oxbows:				
					None				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single Thread					None				
Channel confinement at crossing (W_v / W_c): 47.72					Relic channel 0.23, 0.68 mi US, 0.11, 0.38 mi DS				

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
Channel's water surface elevation is lower than the surrounding flood plains.
Unique features, exceptions, etc
Unnamed trib DS 1.4 mi There are several instances of relic channels which appear US and DS of the crossing giving the appearance the channel moves regularly.
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
US 100 ft, Listed as high risk by PHMSA NPMS Landslide Hazard Map. Mapped landslide deposits 3.5 mi west on Rock Creek.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Numerous stock ponds in channel especially US, building 0.5 mi DS, dirt roads parallel
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
There are several scour holes along the stream corridor near the crossing. US. (0.04, 0.20, 0.30 mi). Also: The valley width widens has the stream approaches the crossing and then narrows again DS.

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p.

		Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Brush Fork MP 51.1

Site	**Brush Fork MP 51.1**	Date	08/03/09
Done by: GF, ML		Review: EG	

<table>
<tr><th colspan="9">Regional Regression Analysis</th></tr>
<tr><th rowspan="2">Source</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Omang (1992)</td><td>7.13</td><td>2,726</td><td>40</td><td>136</td><td>239</td><td>417</td><td>592</td><td>790</td></tr>
</table>

<table>
<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><th colspan="5">Channel</th><th colspan="5">Valley</th></tr>
<tr><td colspan="5">Gradient (%): 0.5</td><td colspan="5">Gradient (%): 1.2</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>Min</td><td>max</td><td>mean</td><td>stnd dev.</td><td rowspan="2">width</td><td>min</td><td>max</td><td>mean</td><td>stnd dev.</td></tr>
<tr><td>8</td><td>16</td><td>11</td><td>3</td><td>508</td><td>774</td><td>648</td><td>102</td></tr>
<tr><td colspan="5">meander wavelength (ft) 324</td><td colspan="5">Describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft) 82</td><td colspan="5">Alluvium of modern channels and floodplains 627 ft wide at crossing</td></tr>
<tr><td colspan="5">Sinuosity 1.93</td><td colspan="5">Both sides Bearpaw Fm: Shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds
DS Both sides Judith River Fm: fine- to coarse-grained sandstone with interbeds of carbonaceous shale, silty shale, and thin coal.
US Both sides Flaxville Fm: gravel, sand, and silt with marl and volcanic ash locally</td></tr>
<tr><td rowspan="10">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><th colspan="5">Floodplain</th></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>stnd dev.</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>79</td><td>70</td><td>109</td><td>56</td><td colspan="5"></td></tr>
<tr><td>417</td><td>65</td><td>227</td><td>35</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>866</td><td>70</td><td>571</td><td>58</td><td colspan="5">scroll bars:</td></tr>
<tr><td>699</td><td>64</td><td></td><td></td><td colspan="5">None</td></tr>
<tr><td>1545</td><td>56</td><td></td><td></td><td colspan="5">oxbows:</td></tr>
<tr><td>1747</td><td>70</td><td></td><td></td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">channel cut-offs:</td></tr>
<tr><td colspan="5">Single thread</td><td colspan="5">US 0.08 mi</td></tr>
</table>

Channel confinement at crossing (W_v / W_c):	Relic channel: DS near confluence with Bear Creek 1.39 mi
75.56	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
The flood plain elevation is greater than the elevation of the channel's water surface.	
Unique features, exceptions, etc:	
Flows into Bear Creek 1.39 mi DS	

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
Listed as high risk by PHMSA NPMS Landslide Hazard Map. Mapped landslide deposits 3.5 mi west on Rock Creek. US (0.0-0.10 mi, river right, minor sloughing of material appears to exist)
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
DS road crossing 0.34 mile; Stock ponds 4.5 mi on US trib and 5.5 mi US in channel and more smaller one DS
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
No straightened sections of the channel exist near the crossing.

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf

		Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
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Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Bear Creek MP 52.3

Site	**Bear Creek MP 52.3**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis

Source	Drainage Area (mi^2)	Average Elevation (ft)	Recurrence Interval					
			2	5	10	25	50	100
Omang (1992)	4.49	2,768	29	99	176	310	441	591

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel	**Valley**
Gradient (%): 0.8	Gradient (%): 1.4

Width (ft) vegetation made it difficult to assess channel width	min	max	mean	stnd dev.
	9	18	13	3

width	min	max	mean	stnd dev
	179	394	257	86

meander wavelength (ft) 359	describe geology (lithology, erodibility):
meander amplitude (ft) 224	Alluvium of modern channels and floodplains 906 ft wide
Sinuosity 1.61	Both sides Bearpaw Fm: Shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds DS RB Judith River Fm: fine- to coarse-grained sandstone with interbeds of carbonaceous shale, silty shale, and thin coal. US Both sides Flaxville Fm: gravel, sand, and silt with marl and volcanic ash locally

	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
radius of curvature (ft)	310	52	11	49
	554	60	333	38
	873	160	686	62
	1519	103	1089	56
	213	51		

Floodplain

FEMA National Database N

if yes, describe widths below

Width (ft)	min	max	mean	stnd dev

Describe abundance and location(s) of:

scroll bars:

None

oxbows:

None

channel cut-offs:

Channel form (braided, anabranching, single thread):

Single Thread	None
Channel confinement at crossing (W_v / W_c):	Relic channel:
16.75	Near confluence with Brush Fork 0.8 mi DS

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?

The elevation of the floodplain is great than the elevation of the channel's water surface.

Unique features, exceptions, etc:

Brush Fork joins 0.79 mi DS; unnamed trib 0.89 mi DS; Joins Milk River 6.8 mi DS; US 1. Scour Hole (<0.1 mi, river left)

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):

None, Listed as high risk by PHMSA NPMS Landslide Hazard Map. Mapped landslide deposits 3.5 mi west on Rock Creek.

Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):

Stock pond 0.77 mi DS on trib; small road parallel to left bank

If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):

The valley's width is narrow at some locations US (0.00-0.20 mi). There might be incision at these locations if the channel cannot build a floodplain.

LITERATURE REVIEW
(check box when searched for, if none, note under source)

Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey, various dates, Water resources data, Montana, water year: U.S. Geological Survey Water-Data Report.
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p.

		FHWARD-95-184, “Channel Scour at Bridges in the United. States. ...... FHWA-IP-90-017, HEC No.18, 1995, US. Department of Transportation, http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Unger Coulee MP 53.3

Site	**Unger Coulee MP 53.3**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis								
Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Omang (1992)	4.45	2,686	29	101	180	317	453	609

Geomorphology **NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)**									
For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)									
Channel					**Valley**				
Gradient (%): 0.7					Gradient (%): 1.2				
Width (ft)	min	max	mean	stnd dev.	width	min	max	mean	stnd dev.
	7	13	10	1		289	463	365	58
meander wavelength (ft) 282					describe geology (lithology, erodibility):				
meander amplitude (ft) 90					Alluvium of modern channel and floodplains 552 ft wide				
Sinuosity 1.66					Both sides Bearpaw Fm: shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds DS both sides Judith River Fm: fine- to coarse-grained sandstone with interbeds of carbonaceous shale, silty shale, and thin coal. US both sides Flaxville Fm: gravel, sand, and silt with marl and volcanic ash locally				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	variance
	1179	50	163	40					
	918	43	295	38	Describe abundance and location(s) of:				
	688	28	499	42	scroll bars:				
	71	19	685	28	None				
	210	32			oxbows:				
	355	28			None				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single Thread					None				

Channel confinement at crossing (W_v / W_c):	relic channel
36.79	US 0.8 mi, DS 0.05 mi

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
The elevation of the flood plain appears to be greater than the elevation of the channel's water surface.
Unique features, exceptions, etc
Flows into Buggy Creek 6.4 mi DS, US Scour Holes (0.00-0.25 mi, river center).
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
Listed as high risk by PHMSA NPMS Landslide Hazard Map.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Road crosses 4.5 mi DS with culvert or bridge, stock ponds in channel 0.1 and 0.3 mi US, 0.06 and 0.2 mi DS
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
There appear to be areas that look like scour holes which could be signs of incision.

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey, various dates, Water resources data, Montana, water year: U.S. Geological Survey Water-Data Report.
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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		Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Buggy Creek MP 55.3

Site	**Buggy Creek MP 55.3**	Date	08/03/09
Done by: GF, ML		Review: EG	

<table>
<tr><th colspan="9">Regional regression and peak flow analysis</th></tr>
<tr><th colspan="9">Regional Regression</th></tr>
<tr><th rowspan="2">Source</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Omang (1992)</td><td>92.1</td><td>2,798</td><td>237</td><td>702</td><td>1,172</td><td>1,934</td><td>2,667</td><td>3,467</td></tr>
</table>

<table>
<tr><th colspan="11">Peak Flood Flow</th></tr>
<tr><th rowspan="2">Gauge Name and Number</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Up or Down-stream</th><th rowspan="2">Distance to Crossing (mi)</th><th rowspan="2">Range of Data (years)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>06172200 Buggy Creek near Tampico MT</td><td>105</td><td>DS</td><td>5.41</td><td>10 (1957-1967)</td><td>607</td><td>2,886</td><td>5,248</td><td>7,792</td><td>11,069</td><td>13,326</td></tr>
</table>

<table>
<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><th colspan="5">Channel</th><th colspan="5">Valley</th></tr>
<tr><td colspan="5">Gradient (%): 0.50</td><td colspan="5">Gradient (%): 1.1</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">width</td><td>min</td><td>max</td><td>mean</td><td>stnd dev</td></tr>
<tr><td>9</td><td>14</td><td>11</td><td>2</td><td>381</td><td>977</td><td>719</td><td>208</td></tr>
<tr><td colspan="5">meander wavelength (ft) 669</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft) 176</td><td colspan="5">Alluvium of modern channel and floodplains 1,735 ft wide</td></tr>
<tr><td colspan="5">Sinuosity 1.47</td><td colspan="5">Both sides Bearpaw Fm: shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds
DS both sides Judith River Fm: fine- to coarse-grained sandstone with interbeds of carbonaceous shale, silty shale, and thin coal.
US both sides Flaxville Fm: gravel, sand, and silt with marl and volcanic ash locally</td></tr>
<tr><td rowspan="4">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><th colspan="5">Floodplain</th></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>stnd dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

	55	100	438	72	
	1807	231	758	67	Describe abundance and location(s) of:
	2601	172	1214	121	scroll bars:
	3218	115	1597	153	None
	3418	91	2135	112	oxbows:
	3979	96			None
Channel form (braided, anabranching, single thread):					channel cut-offs:
Single Thread					None
Channel confinement at crossing (W_v / W_c):					Relic Channels
40.98					US. 0.18, 0.75 mi; adjacent, DS 1.8, 0.4 mi
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?					
US 1. (0.25 mi) Channel's surface water elevation appears to be higher than area down slope.					
Unique features, exceptions, etc					
Tribs: US Crooked Creek 0.47 mi, Canyon Creek 1.08 mi; DS Spring Creek 3.8 mi, Unger Coulee 5.2 mi. Joins Milk River 7.5 mi DS US 1. Meander Bend (0.25 mi), wavelength (smaller) and amplitude (greater) are very different than others in this valley. The elevation of the flood plain and channel are higher than the area to the south. 0.4 mi adjacent to crossing straighter than rest of creek					
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):					
None. Listed as high risk by PHMSA NPMS Landslide Hazard Map.					
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):					
DS 1. Road crosses 0.5 mi, Dam with pond on unnamed trib 0.95 mi DS					
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):					
US & DS (0.00-0.30 mi) meander wavelengths are larger here and amplitudes smaller than other places in the river channel, appears straightened. Scouring can be seen from aerial photo.					

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey, various dates, Water resources data, Montana, water year: U.S. Geological Survey Water-Data Report.

hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Spring Creek MP 59.8

<table>
<tr><td>Site</td><td>Spring Creek MP 59.8</td><td>Date</td><td>08/03/09</td></tr>
<tr><td colspan="2">Done by: GF, ML</td><td colspan="2">Review: EG</td></tr>
</table>

<table>
<tr><th colspan="9">Regional Regression Analysis</th></tr>
<tr><th rowspan="2">Source</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Omang (1992)</td><td>10.7</td><td>2,699</td><td>54</td><td>178</td><td>311</td><td>539</td><td>763</td><td>1,016</td></tr>
</table>

<table>
<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><th colspan="5">Channel</th><th colspan="5">Valley</th></tr>
<tr><td colspan="5">Gradient (%): 0.6</td><td colspan="5">Gradient (%): 0.9</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>stnd. dev</td><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>stnd dev.</td></tr>
<tr><td>8</td><td>12</td><td>10</td><td>2</td><td>492</td><td>1099</td><td>7756</td><td>253</td></tr>
<tr><td colspan="5">meander wavelength (ft) 374</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft) 163</td><td colspan="5">Alluvium of modern channels and flood plains 561 ft wide</td></tr>
<tr><td colspan="5">Sinuosity 1.43</td><td colspan="5">Both sides Bearpaw Fm: shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds
DS both sides Judith River Fm: fine- to coarse-grained sandstone with interbeds of carbonaceous shale, silty shale, and thin coal.
US both sides Flaxville Fm: gravel, sand, and silt with marl and volcanic ash locally</td></tr>
<tr><td rowspan="10">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><th colspan="5">Floodplain</th></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>stnd. dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>97</td><td>28</td><td>221</td><td>53</td><td colspan="5"></td></tr>
<tr><td>489</td><td>56</td><td>495</td><td>65</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>817</td><td>58</td><td>738</td><td>71</td><td colspan="5">scroll bars:</td></tr>
<tr><td>1348</td><td>50</td><td>1076</td><td>50</td><td colspan="5">None</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">oxbows:</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">channel cut-offs:</td></tr>
<tr><td colspan="5">Single thread</td><td colspan="5">None</td></tr>
</table>

Channel confinement at crossing (W_v / W_c):	Relic channel
68.88	US and adjacent off RB
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
The channel's water surface elevation is lower than the flood plain's elevation.	
Unique features, exceptions, etc	
Tribs DS: Wire Grass Coulee 0.64 mi, Alkali Coulee 1.7 mi, Buggy Creek 3.3 mi, Unger Coulee 4.4 mi; joins Buggy Creek 3.3 mi DS	
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):	
0.76 mi US. Listed as high risk by PHMSA NPMS Landslide Hazard Map.	
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):	
Stock ponds US 80 ft, 0.34, 0.5 mi, 0.76 mi; road parallel to LB; small road crosses 0.9 mi US; group of building 0.9 mi DS Dam on Wire Grass Coulee with Cornwall Reservoir (empty in photo) 0.77 mi from confluence, dam with stock pond 0.5 mi from confluence, possibly an irrigation ditch between Wire Grass and Spring 0.08 mi DS;	
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):	
None	

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey, various dates, Water resources data, Montana, water year: U.S. Geological Survey Water-Data Report.
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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		FHWARD-95-184, “Channel Scour at Bridges in the United. States. ...... FHWA-IP-90-017, HEC No.18, 1995, US. Department of Transportation, http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
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Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Cherry Creek MP 66.9

Site	**Cherry Creek MP 66.9**	Date	08/03/09
Done by: GF, ML		Review: EG	

TABLE X
Regional Regression Analysis

Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Omang (1992)	54.2	2,657	165	516	877	1,474	2,054	2,697

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

<table>
<tr><th colspan="5">Channel</th><th colspan="5">Valley</th></tr>
<tr><td colspan="5">Gradient (%): 0.3</td><td colspan="5">Gradient (%): 0.3</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>stnd dev</td><td rowspan="2">width</td><td>min</td><td>max</td><td>mean</td><td>stnd dev</td></tr>
<tr><td>10</td><td>16</td><td>12</td><td>2</td><td>695</td><td>1312</td><td>1059</td><td>258</td></tr>
<tr><td colspan="5">meander wavelength (ft) 627</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft) 264</td><td colspan="5">Alluvium of modern channels and flood plains 1,465 ft wide
US on School Section Coulee, DS near milk River Alluvium/colluvium</td></tr>
<tr><td colspan="5">Sinuosity 1.49</td><td colspan="5">Both sides Bearpaw Fm: shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds
US both sides Flaxville Fm: gravel, sand, and silt with marl and volcanic ash locally</td></tr>
<tr><td rowspan="10">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><th colspan="5">Floodplain</th></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>stnd dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>5307</td><td>62</td><td>1617</td><td>86</td><td colspan="5"></td></tr>
<tr><td>5779</td><td>76</td><td>2116</td><td>95</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>6344</td><td>75</td><td>2436</td><td>56</td><td colspan="5">scroll bars:</td></tr>
<tr><td></td><td></td><td>3611</td><td>160</td><td colspan="5">None</td></tr>
<tr><td></td><td></td><td>4595</td><td>73</td><td colspan="5">oxbows:</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">channel cut-offs:</td></tr>
</table>

<table>
<tr><td>Single Thread</td><td>none</td></tr>
<tr><td>Channel confinement at crossing (W_v / W_c):</td><td>Relic channel</td></tr>
<tr><td>47.1</td><td>Adjacent to crossing and US 0.14 mi, 0.5 mi, DS 0.25 mi</td></tr>
<tr><td colspan="2">What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?</td></tr>
<tr><td colspan="2">The floodplain elevation is greater than the elevation of the channel's water surface.</td></tr>
<tr><td colspan="2">Unique features, exceptions, etc: There are several road crossing (possibly with culverts) near this crossing.</td></tr>
<tr><td colspan="2">Tribs: US Unnamed 0.2 mi, School Section Coulee 1.3 mi, West Fork Cherry Creek 6 mi; DS East Fork Cherry 2.2, Martin Coulee 3.7. Joins Milk River 7.7 mi
difficult to determine floodplain features due to land use activity</td></tr>
<tr><td colspan="2">Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):</td></tr>
<tr><td colspan="2">mapped for high landslide hazard by the Pipeline and Hazardous Materials Safety Administration in their online National Pipeline Mapping System.</td></tr>
<tr><td colspan="2">Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):</td></tr>
<tr><td colspan="2">US 1. Road (0.30 mi river left, par.) 2. Road crossing 0.16 and 0.3 mi 2. Buildings (0.40 mi river right) DS 1. Buildings (0.40, 1.1, 1.5 mi) 2. road crossing 1.1 mi with bridge, 1.65 mi</td></tr>
<tr><td colspan="2">If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):</td></tr>
<tr><td colspan="2">It appears that the channel near has longer wavelength and smaller amplitudes at this location as compared to US & DS.</td></tr>
</table>

<table>
<tr><th colspan="3">LITERATURE REVIEW
(check box when searched for, if none, note under source)</th></tr>
<tr><td>Existing channel migration zone determination</td><td>☒</td><td>source(s):
None</td></tr>
<tr><td>Reports on local/regional</td><td></td><td></td></tr>
<tr><td>Hydrology</td><td>☒</td><td>source(s):
Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p.
Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.]
U.S. Geological Survey, various dates, Water resources data, Montana, water year: U.S. Geological Survey Water-Data Report.</td></tr>
<tr><td>hydraulics</td><td>☒</td><td>source(s):
None</td></tr>
<tr><td>sediment transport</td><td>☒</td><td>source(s):
Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p.
Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.</td></tr>
<tr><td>bridge scour</td><td>☒</td><td>source(s):
Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state)
http://mt.water.usgs.gov/cgi-bin/projects?14100</td></tr>
</table>

		Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. FHWARD-95-184, “Channel Scour at Bridges in the United. States. ...... FHWA-IP-90-017, HEC No.18, 1995, US. Department of Transportation, http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
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Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Stock Pond MP 69.2

Site	**Stock Pond MP 69.2**	Date	08/03/09
Done by: GF, ML	Review: EG		

Regional Regression Analysis

Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	0.93	--	--	--	11	40	76	141	207	286

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.8					Gradient (%): 0.7				
Width (ft) *	min	max	mean	stnd dev	width	min	max	mean	stnd dev
	11	19	17	3		169	571	363	166
*The lack of water in the channel made it hard to determine the channel width									
meander wavelength (ft) 1030					describe geology (lithology, erodibility):				
meander amplitude (ft) 233					Both sides Bearpaw Fm: Shale with several zones of calcareous concretions				
Sinuosity 1.24									

	Upstream (ft)		Downstream (ft)		**Floodplain**
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below
radius of curvature (ft)	1099	99	1797	114	
	1788	132	2680	94	Describe abundance and location(s) of:
	2211	88	2977	78	scroll bars:
	2726	177	3563	117	None
					oxbows:
					None

Width (ft)	min	max	mean	stnd dev

Channel form (braided, anabranching, single thread):	channel cut-offs:
Single Thread	None
Channel confinement at crossing (W_v / W_c):	

8.81	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
Not perched, the thalwag of the channel is below the elevation of the floodplain.	
Unique features, exceptions, etc	
The dam created downstream of the crossing could create backwater conditions near the crossing.	
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):	
None, Listed as high risk by PHMSA NPMS Landslide Hazard Map	
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):	
1. Railroad: (US & DS perp.) 2. Road (US & DS <0.30 mi, perp. and Par.), dam that forms pond is 800 ft DS from crossing	
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):	
Near the crossing, the channel could have been straightened at one time during the construction of the dam. There could be incision below the dam.	

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Spring Coulee MP 70.4

Site	**Spring Coulee MP 70.4**	Date	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis								
Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Omang (1992)	18.2	2,624	78	256	446	767	1,081	1,438

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.6					Gradient (%): 1.0				
Width (ft)	min	max	mean	stnd dev	width	Min	max	mean	stnd dev
	10	15	12	2		332	669	431	133
meander wavelength (ft) 468					describe geology (lithology, erodibility):				
meander amplitude (ft) 135					Alluvium/colluvium 597 ft wide				
Sinuosity 1.43					Both sides Bearpaw Fm: shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds US both sides Flaxville Fm: gravel, sand, and silt with marl and volcanic ash locally				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	stnd dev
	93	65	278	59					
	759	66	420	63	Describe abundance and location(s) of:				
	961	56	1804	103	scroll bars:				
	1132	69	2145	65	None				
	1410	141	2441	59	oxbows:				
	1788	86			None				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single Thread					None				
Channel confinement at crossing (W_v / W_c):					Relic channels:				
28.52					1 mi US				

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
The channel's water surface is lower than the elevation of the flood plain.
Unique features, exceptions, etc:
Confluence with East Fork Cherry Creek 0.6 mi, unnamed trib 4.4 mi US

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None, mapped for high landslide hazard by the Pipeline and Hazardous Materials Safety Administration in their online National Pipeline Mapping System.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
US Gravel pit that appears to cut through channel 0.5 mi; Buildings 0.3, 0.9, 1.1 mi; Road with bridge or culvert 1.1 mi. DS road crossings 0.5 mi and 0.6 mi; buildings 0.18 and 0.48 mi. Road parallel 0.5 mi to RB; railway 1 mi from RB
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
The channel appears straightened just US of crossing and does not have the same stream pattern as further US & DS

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
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Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

East Fork Cherry Creek MP 70.9

Site	**East Fork Cherry Creek MP 70.9**	Date	08/03/09
Done by: GF, ML		Review: EG	

<table>
<tr><th colspan="9">Regional Regression Analysis</th></tr>
<tr><th rowspan="2">Source</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Omang (1992)</td><td>27.7*</td><td>2,496</td><td>107</td><td>348</td><td>605</td><td>1,042</td><td>1,470</td><td>1,955</td></tr>
</table>

*The crossing is assumed to occur downstream of the confluence of the two tributaries

<table>
<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><td colspan="5">Channel</td><td colspan="5">Valley</td></tr>
<tr><td colspan="5">Gradient (%): 0.3</td><td colspan="5">Gradient (%): 0.3</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>Min</td><td>max</td><td>mean</td><td>stnd dev.</td><td rowspan="2">width</td><td>min</td><td>max</td><td>mean</td><td>stnd dev.</td></tr>
<tr><td>7</td><td>14</td><td>11</td><td>3</td><td>289</td><td>963</td><td>556</td><td>263</td></tr>
<tr><td colspan="5">meander wavelength (ft) 549</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft) 70</td><td colspan="5">Alluvium of modern channels and floodplains 1138 ft wide
US on Hawk Coulee and near confluence Alluvium/colluvium</td></tr>
<tr><td colspan="5">Sinuosity 1.26</td><td colspan="5">Both sides Bearpaw Fm: shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds
US both sides Flaxville Fm: gravel, sand, and silt with marl and volcanic ash locally</td></tr>
<tr><td rowspan="10">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><td colspan="5">Floodplain</td></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>stnd dev.</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>739</td><td>70</td><td>197</td><td>63</td><td colspan="5"></td></tr>
<tr><td>1042</td><td>86</td><td>141</td><td>45</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>1374</td><td>46</td><td>1014</td><td>81</td><td colspan="5">scroll bars:</td></tr>
<tr><td>1485</td><td>41</td><td>1358</td><td>58</td><td colspan="5">None</td></tr>
<tr><td>1694</td><td>74</td><td>1583</td><td>67</td><td colspan="5">oxbows:</td></tr>
<tr><td>1883</td><td>46</td><td></td><td></td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">channel cut-offs:</td></tr>
<tr><td colspan="5">Single Thread</td><td colspan="5">none</td></tr>
</table>

Channel confinement at crossing (W_v / W_c):	Relic Channels:
32	US 1 mi
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
The elevation of the flood plain is greater than the elevation of the channel's water surface.	
Unique features, exceptions, etc.	
Tribs: US unnamed 2.9 mi, Hawk Coulee 80 ft; DS Spring Coulee 0.7 mi, Foss Coulee 2.2 mi; joins Cherry Creek 3.1 mi DS 1. Deep incision (0.15 mi, River right,)	

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None. Listed as high risk by PHMSA NPMS Landslide Hazard Map.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
US & DS 1. Transmission Lines (0.15 mi, river left, perp.) US buildings 1.3 mi, small road crossing 0.8 mi DS 1. Road (<0.10 mi, river left, par.) 2. Residence (<0.10 mi, river left), small gravel pit 0.4 mi , road crossing with bridge 1 mi, small roads and buildings in vicinity of Spring Coulee confluence 0.7 mi, gravel pit at 1.74 mi, 2.2 mi, 2.8 mi
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
The valley narrows near the crossing, DS 0.15 mi, there is evidence of incision, river left.

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140

		p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Espiel Coulee MP 77.9

Site	**Espiel Coulee MP 77.9**	Date	08/03/09
Done by: GF, EG, ML		Review: EG	

TABLE X
Regional Regression Analysis

Source	**Drainage Area (mi^2)**	**Average Elevation (ft)**	**Recurrence Interval**					
			2	**5**	**10**	**25**	**50**	**100**
Omang (1992)	5.86	2,368	37	132	238	426	613	833

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.89					Gradient (%): 0.53				
width	min	max	mean	stnd dev	width	min	max	mean	stnd dev
	12	39	21	75		344	820	579	172
meander wavelength: 1033					describe geology (lithology, erodibility):				
meander amplitude: 541					Alluvium/colluvium 375 ft wide at crossing				
Sinuosity: 1.62					Both sides of valley--Bearpaw Fm: Shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds.				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database No if yes, describe widths below				
					Width (ft)	min	max	mean	stnd dev
	135	370	35	232					
	1713	128	155	111	Describe abundance and location(s) of:				
	2957	382	319	49	scroll bars:				
	3729	606	572	81	None				
	4457	86	820	482	oxbows:				
	5909	249	1282	75	None				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
single					None				
Channel confinement at crossing (W_v / W_c):					Relic channel 0.5 mi US				
25.7									
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?									
There may be some incision--DEM elev. of valley is 2164-2254 ft and channel is 2253-2286 ft.									

Unique features, exceptions, etc
Tribs: unnamed creeks 0.1 and 0.8 mile upstream on the right and 0.3 mile downstream left bank. Flows into Milk River 2.3 mi
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Dam on trib (0.8 mi US) 340 ft from confluence, perpendicular road 0.3 mi US of crossing with groups of buildings associated.
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc): None

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey, various dates, Water resources data, Montana, water year: U.S. Geological Survey Water-Data Report.
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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		Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
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Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Shade Creek MP 110.4

Site	**Shade Creek MP 110.4**	Date:	08/02/09
Done by: GF, EG, ML		Review: EG	

Peak Flood Frequency Analysis (from regional regression equation and stream gage shapefile or report if available)

Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	8.99	--	--	--	87	291	529	930	1,317	1,551

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.1					Gradient (%): 1.1				
Width (ft)*	min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	7	12	8	2		365	1715	668	467
*Very difficult to see channel at the resolution of aerials.									
meander wavelength (ft): 337					describe geology (lithology, erodibility):				
meander amplitude (ft): 186					Modern alluvium 480 ft				
Sinuosity: 6.80					Both sides Hell Creek Fm: Light gray, bentonitic claystone alternates with gray to brown sandstone interbedded with carbonaceous shale.				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database No if yes, describe widths below				
					Width (ft)	min	Max	mean	Stnd Dev
	204	184	142	133					
	409	130	390	79	Describe abundance and location(s) of:				
	773	149	710	56	scroll bars:				
	1187	218	883	169	None				
	1464	180	1345	134	oxbows:				
	1797	119	1873	271	Possibly US 120 ft on RB and DS 340 ft on LB.				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single					Relic channel US 270 ft on RB; 550 ft RB;				
Channel confinement at crossing (W_v / W_c):									
82.97									

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
Meander 0.2 mi US is 3-4 feet above floodplain in DEM.
Unique features, exceptions, etc
The 3 Shade Creek crossings are all within 300 feet of each other.
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
landslide deposits mapped in geology (1:100,000) layer in hills 1 mi from RB of creek but only 0.4 mi from pipeline.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Parallel (but looping away) road 2.4 mi from LB. Stock pond 0.2 mi up trib 0.3 mi DS, Goose Island Reservoir 0.1 mi up trib 1 mi US, Teds Reservoir 0.5 mi up trib 1.7 mi US
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc): None

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
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Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Shade Creek MP 110.5

Site	**Shade Creek MP 110.5**	Date:	08/02/09
Done by: GF, EG, ML		Review: EG	

Peak Flood Frequency Analysis (from regional regression equation and stream gage shapefile or report if available)

Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	8.99	--	--	--	87	291	529	930	1,317	1,551

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel	**Valley**
Gradient (%): 0.1	Gradient(%): 1.1

	min	max	mean	std dev		min	max	mean	std dev
Width (ft)*	7	12	8	2	Width (ft)	365	1715	668	467

*Very difficult to see channel at the resolution of aerials.	
meander wavelength (ft): 337	describe geology (lithology, erodibility):
meander amplitude (ft): 186	Modern alluvium 480 ft
Sinuosity: 6.80	Both sides Hell Creek Fm: Light gray, bentonitic claystone alternates with gray to brown sandstone interbedded with carbonaceous shale.

	Upstream (ft)		Downstream (ft)		**Floodplain**
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database No if yes, describe widths below
radius of curvature (ft)	102	133	60	79	
	121	184	157	56	Describe abundance and location(s) of:
	184	130	210	169	scroll bars:
	295	149	351	134	None
	421	218	512	271	oxbows:
	505	180	594	184	Possibly US 200 ft on RB and DS 260 ft on LB.

	min	Max	mean	Stnd Dev
Width (ft)				

Channel form (braided, anabranching, single thread):	channel cut-offs:
Single	Relic channel US 190 ft on RB; 630 ft RB;
Channel confinement at crossing (W_v / W_c):	
86.93	

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
Meander 0.2 mi US is 3-4 feet above floodplain in DEM.
Unique features, exceptions, etc
The 3 Shade Creek crossings are all within 300 feet of each other.
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
Landslide deposits mapped in geology (1:100,000) layer in hills 1 mi from RB of creek but only 0.4 mi from pipeline.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Parallel (but looping away) road 2.4 mi from LB. Stock pond 0.2 mi up trib 0.3 mi DS, Goose Island Reservoir 0.1 mi up trib 1 mi US, Teds Reservoir 0.5 mi up trib 1.7 mi US
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc): None

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
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hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p.

		Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Shade Creek MP 110.55

Site	**Shade Creek MP 110.55**	Date:	08/02/09
Done by: GF, EG,ML		Review: EG	

Regional Regression Analysis										
Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	8.99	--	--	--	87	291	529	930	1,317	1,551

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.1					Gradient (%): 1.1				
Width (ft)*	min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	7	12	8	2		365	1715	668	467
*Very difficult to see channel at the resolution of aerials.									
meander wavelength (ft): 337					describe geology (lithology, erodibility):				
meander amplitude (ft): 186					Modern alluvium 480 ft				
Sinuosity: 6.80					Both sides Hell Creek Fm: Light gray, bentonitic claystone alternates with gray to brown sandstone interbedded with carbonaceous shale.				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database No if yes, describe widths below				
					Width (ft)	min	Max	mean	Stnd Dev
	63	80	42	56					
	141	133	95	169	Describe abundance and location(s) of:				
	236	184	236	134	scroll bars:				
	299	130	397	271	None				
	410	149	479	184	oxbows:				
	536	218	548	113	Possibly US 360 ft on RB and DS 100 ft on LB.				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single					Relic channel				
Channel confinement at crossing (W_v / W_c):					US 350 ft on RB; 630 ft RB				
79.38									
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?									

Meander 0.2 mi US is 3-4 feet above floodplain in DEM.
Unique features, exceptions, etc
The 3 Shade Creek crossings are all within 300 feet of each other.
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
Landslide deposits mapped in geology (1:100,000) layer in hills 1 mi from RB of creek but only 0.4 mi from pipeline.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Parallel (but looping away) road 2.4 mi from LB. Stock pond 0.2 mi up trib 0.3 mi DS, Goose Island Reservoir 0.1 mi up trib 1 mi US, Teds Reservoir 0.5 mi up trib 1.7 mi US
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc): None

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic

		Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

South Fork Shade Creek MP 114.2

Site	**South Fork Shade Creek MP 114.2**	Date:	08/02/09
Done by: GF, EG, ML		Review: EG	

Regional Regression Analysis										
Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	4.88	--	--	--	61	204	374	666	950	1,120

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.17					Gradient (%): 0.36				
Width (ft)*	min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	9	13	11	2		265	1020	581	275
* Difficult to see channel with resolution of aerial photos.									
meander wavelength (ft): 427					describe geology (lithology, erodibility):				
meander amplitude (ft): 255					Modern alluvium 400 ft				
Sinuosity: 6.23					Both sides Hell Creek Fm: Light gray, bentonitic claystone alternates with gray to brown sandstone interbedded with carbonaceous shale. RB and US Tullock Member of Fort union Fm: Yellow sandstone interbedded with subordinate grayish brown and black shale and thin beds of coal.				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database No if yes, describe widths below				
					Width (ft)	min	max	mean	Stnd Dev
	88	145	157	116					
	362	124	587	141	Describe abundance and location(s) of:				
	757	102	1211	124	scroll bars:				
	1036	113	1581	90	none				
	1299	115	1978	92	oxbows:				
	1552	84	2497	101	none				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single					US 900 ft				

Channel confinement at crossing (W_v / W_c):	Relic channels US 75 ft LB, 400 ft on LB and RB, 900 ft RB. DS 275 ft, 0.2 mi and possibly 930 ft.
78.14	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
US 775 ft and DS 700ft and 0.2 from crossing channel is 1-4 ft above floodplain based on DEM.	
Unique features, exceptions, etc	
Confluence with unnamed creeks US 410 ft and DS 600 ft.	

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
US 0.2 and 0.4 mi right, DS 1.1 mi left, several landslide deposits mapped 2 to 3 mi west
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Stock ponds 0.1 mi and 1 mi up trib 0.1 mi DS, 0.1 mi up trib 0.95 mi DS, small road crosses 0.38 mi US
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
Although aerial photo resolution is low for size of creek, channel appears to very mobile in floodplain.

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of

		Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Flying V Creek MP 118.6

Site	**Flying V Creek MP 118.6**	Date:	08/02/09
Done by: GF, EG, ML		Review: EG	

Regional Regression Analysis										
Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	7.21	--	--	--	73	244	444	786	1,118	1,320

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 1.2					Gradient (%): 3.5				
Width (ft)	min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	8	23	14	5		524	1092	864	211
meander wavelength (ft): 346					describe geology (lithology, erodibility):				
meander amplitude (ft): 162					Modern alluvium 635 ft				
Sinuosity: 2.04					Fort Union Fm: Both sides Tullock Member: sandstone interbedded with subordinate shale and thin beds of coal. Both sides Lebo Member: carbonaceous shale, bentonitic claystone, sandstone, and coal.				
radius of curvature (ft)*	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database Y/N if yes, describe widths below				
					Width (ft)	min	max	mean	Stnd Dev
	29	122	382	112					
*Last 2 US meanders are behind dam	226	154	601	53	Describe abundance and location(s) of:				
	576	143	848	47	scroll bars:				
	745	72	985	40	none				
	1801	271	1142	73	oxbows:				
	2043	211	1306	171	US: 500 ft and possibly 0.2 mi on LB				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single					US: 320 ft RB; DS: 720 ft LB				
Channel confinement at crossing (W_v / W_c):									
70.69									

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
DS of crossing, channel is about 5 ft above floodplain at a cutoff on DEM.
Unique features, exceptions, etc
Channel much straighter directly DS of earthen dam for 0.2 mi (see infrastructure note below) ; channel widening effects of dam extend US 0.25 mi. Confluence with unnamed creek 475 ft DS.
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
US: stock pond 0.2 mi, 1.4 mi. 2.3 mi and 2.8 mi; stock pond 0.35 up trib that joins at 0.2 mi and 1.8 mi up trib that joins 0.7 mi US; road crosses at 0.8 mi then runs DS parallel to LB 0.25 mi away; small spur road to dammed pond. DS: stock pond 2.3 mi, road crosses 1.7 mi
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
Straightened reach below dam appears to be incised in aerial photos.

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic

		Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Figure 8 Creek MP 122.3

Site	**Figure 8 Creek MP 122.3**	Date:	08/02/09
Done by: GF, EG, ML		Review: EG	

Regional Regression Analysis										
Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	19.63	--	--	--	126	414	746	1,296	1,825	2,155

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.11					Gradient (%): 0.81				
Width (ft)	min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	8	14	10	2		208	703	476	204
meander wavelength (ft): 370					describe geology (lithology, erodibility):				
meander amplitude (ft): 215					Modern alluvium 534 ft; alluvium-colluvium				
Sinuosity: 2.19					Fort Union Fm: Both sides Tullock Member: sandstone interbedded with subordinate shale and thin coal beds. Both sides Lebo Member: carbonaceous shale, bentonitic claystone, sandstone, and coal.				
	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database No if yes, describe widths below				
					Width (ft)	min	max	mean	Stnd Dev
radius of curvature (ft)	418	110	172	225					
	671	129	392	82	Describe abundance and location(s) of:				
	1096	122	469	84	scroll bars:				
	1633	56	549	129	None				
	1759	70	812	91	oxbows:				
	2059	105	1007	174	None				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single					None				
Channel confinement at crossing (W_v / W_c):									
25.78									

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
DS of crossing channel is about 3 ft above floodplain in DEM.
Unique features, exceptions, etc
Terrace of alluvium-colluvium about 2 feet above floodplain along length of study reach. Confluence DS 750 ft with trib that has a dammed pond 580 feet US of confluence.
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance along valley axis?):
1.9 mi US Right
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
DS: Road with bridge or culvert at 0.3 mi; group of buildings off this road 0.9 mi from RB; Parallel road 0.6 mi from LB. stock pond 0.2 mi. Stock ponds 1.2 mi and 0.33 mi up trib at 0.14 mi US Stock pond 0.8 mi up trib that joins 0.4 mi, 0.3 mi up trib 1.7 mi. small road crosses 1.5 mi
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
From limited resolution of aerials, channel seems to be incising floodplain.

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic

		Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Lone Tree Creek MP 146.2

Site	**Lone Tree Creek MP 146.2**	Date:	08/02/09
Done by: GF, EG, ML		Review: EG	

Regional Regression Analysis

Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	8.51	--	--	--	78	261	475	840	1,194	1,141

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel	**Valley**
Gradient (%): 0.87	Gradient (%): 2.2

Width (ft)*	min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	13	28	20	5		266	1222	731	369

*Difficult to see channel in aerial photos.

meander wavelength (ft): 292	describe geology (lithology, erodibility):
meander amplitude (ft): 152	Modern alluvium 1770 ft
Sinuosity: 2.26	Both sides Tongue River Member of Fort Union Formation: sandstone, sandy and silty carbonaceous shale, coal.

	Upstream (ft)		Downstream (ft)*		**Floodplain**
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database No if yes, describe widths below
radius of curvature (ft) * Crossing at last meander US of confluence with Redwater River	0	244	*No meanders DS		
	315	143			Describe abundance and location(s) of:
	523	97			scroll bars:
	947	109			US: possibly 440 ft
	1346	171			oxbows:
	2301	168			None
	2504	74			channel cut-offs:

Width (ft)	min	max	mean	Stnd Dev

Channel form (braided, anabranching, single thread):	US: 0.3 mi
Single	Relic channel 600 ft (just DS of road crossing)
Channel confinement at crossing (W_v / W_c):	
60.30	

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
Channel 250 ft US is 6 to 15 feet above floodplain in DEM.
Unique features, exceptions, etc
Confluence with Redwater River 250 ft DS, confluence with unnamed creek 0.25 mi US
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (US/DS with distance to pipeline, right or left bank, perp. or parallel):
US: road crossing at 700 ft and 2.7 mi —looks like creek is in culverts under road; spur road 475 ft from LB; small farm road 0.4 mi from LB roughly parallel; small road crossing at 1.79 Stock ponds 0.9 mi US and at 0.3 mi and 0.75 mi up trib at 1.85 mi US
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
DEM shows scour pool just below confluence with Redwater River 600 ft DS of crossing.

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p.

		Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Buffalo Springs Creek MP 147.5

Site	**Buffalo Springs Creek MP 147.5**	Date:	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis										
Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	18.82	--	--	--	141	393	648	1,089	1,466	1,989

Geomorphology **NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)**									
For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)									
Channel					**Valley**				
Gradient (%): <0.1					Gradient (%): <0.1				
Width (ft)	min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	7	12	10	2		179	449	285	84
meander wavelength (ft) 877					describe geology (lithology, erodibility):				
meander amplitude (ft) 281					Alluvium of modern channels and floodplains 711 ft				
Sinuosity 1.45					Both sides Tongue River Member of the Fort Union Fm: Sandstone, sandy and silty shale and coal.				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	Stnd Dev
	547	101	124	92					
	955	134	406	86	Describe abundance and location(s) of:				
	1772	308	947	101	scroll bars:				
	2680	129	670	78	None				
			2929	156	oxbows:				
			3552	117	None				
			4097	127	channel cut-offs:				
Channel form (braided, anabranching, single thread):					DS (0.10, river left, 0.30 mi, river right)				
Single Thread									
Channel confinement at crossing (W_v / W_c):									

18.28	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
The elevation of the floodplain is lower than the channel's water surface	
Unique features, exceptions, etc	
None	
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):	
None	
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):	
US & DS 1. Road (0.40 mi river left) US. 1. Transmission line (<0.10 mi, perp.) 2. Residence (0.20 mi, river left) 3. Electric Line (0.30 mi, river right par.) DS 1. Road crosses 0.58 mi with culvert, US road crosses 1.65 mi	
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):	
Near the crossing the valley is narrower than US & DS. There could be incision at this location.	

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p.

		Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Buffalo Springs Creek MP153.2

Site	**Buffalo Springs Creek MP153.2**	Date:	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis										
Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	0.01	--	--	--	2	6	11	21	30	41

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 3.3					Gradient (%): 3.8				
Width (ft)	min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	7	10	8	1		322	636	457	100
meander wavelength (ft) 1092					describe geology (lithology, erodibility):				
meander amplitude (ft) 142					Alluvium of modern channels and floodplains DS				
Sinuosity 1.13					Both sides Tongue River Member of the Fort Union Fm: Sandstone, sandy and silty shale and coal.				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	Stnd Dev
	470	111	No Meanders DS						
	465	70			Describe abundance and location(s) of:				
	1598	135			scroll bars:				
					None				
					oxbows:				
					None				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single					None				
Channel confinement at crossing (W_v / W_c):									
This channel's valley width is part of the larger Buffalo Creek valley.									
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?									

The elevation of the channel is lower than the surrounding flood plain.
Unique features, exceptions, etc
The channel appears to be a drainage ditch because there is a 0.01 mi^2 watershed and low sinuosity.

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
US 1. Small road crosses 420 ft
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
There is low sinuosity and the channel appears to be straightened, especially near the crossing with the unnamed road.

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p.

		Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Cottonwood Creek MP 156.7

Site	**Cottonwood Creek MP 156.7**	Date:	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis										
Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	5.02	--	--	--	56	161	272	466	638	864

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel	**Valley**
Gradient (%): 0.5	Gradient (%): 0.6

Width (ft)	min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	7	12	9	2		153	544	349	158

meander wavelength (ft) 771	describe geology (lithology, erodibility):
meander amplitude (ft) 134	Alluvium of modern channels and floodplains 274 ft
Sinuosity 1.22	Both sides Tongue River Member of the Fort Union Fm: Sandstone, sandy and silty shale and coal.

	Upstream (ft)		Downstream (ft)		**Floodplain**
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below
radius of curvature (ft)	103	49	875	137	
	354	30	1322	214	Describe abundance and location(s) of:
	598	57	1783	165	scroll bars:
	1506	55	2280	136	None
	2114	150			oxbows:
	488	88			None

Width (ft)	min	max	mean	Stnd Dev

Channel form (braided, anabranching, single thread):	channel cut-offs:
Single Channel	DS (0.15, river right,)
Channel confinement at crossing (W_v / W_c):	
17.03	

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?

US (0.10-0.30 mi) the elevation of the channel's water surface appears to be higher than the floodplain elevation
Unique features, exceptions, etc
None

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
1.5 mi US river left
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Stock pond 0.1 mi up trib that joins 0.4 mi US. Road crossing 0.8 mi US and 0.2 mi DS with culvert. 2. Electric line (0.50 mi, perp. DS)
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
The channel appears t o be straightened DS (0.10-0.20 mi) of crossing to accommodate the road crossing

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p.

		Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Hay Creek MP 163.1

Site	**Hay Creek MP 163.1**	Date:	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis										
Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	4.04	--	--	--	41	119	203	351	485	654

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): <0.1					Gradient: (%) 0.2				
Width (ft)*	Min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	8	14	11	2		168	694	326	192
*Vegetation made it difficult to determine channel width									
meander wavelength (ft) 293					describe geology (lithology, erodibility):				
meander amplitude (ft) 104					Alluvial terrace deposit 226 ft				
Sinuosity 1.42					Tongue River Member: sandstone, sandy and silty carbonaceous shale, and coal Tongue River Member: sandstone, sandy and silty carbonaceous shale, and coal				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	Stnd Dev
	32	34	108	37					
	138	34	296	51	Describe abundance and location(s) of:				
	413	55	501	37	scroll bars:				
	664	33	743	71	None				
	1117	87			oxbows:				
					None				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single Channel					None				
Channel confinement at crossing (W_v / W_c):									
22.41									

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence? DS.
The main channel's elevation is higher than its floodplain near the confluence of the DS tributary.
Unique features, exceptions, etc
The valley floor widens greatly DS 0.10 mi as another tributary enters the main channel. The main channel is at a higher elevation DS than its floodplain.

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
US & DS 1. Road (0.10 mi river right, par.) 2. Railroad (0.10 mi, river right, par.), stock pond 725 ft US on a trib 0.4 mi DS
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic

		Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Upper Seven Mile Creek MP 166.2

Site	**Upper Seven Mile Creek MP 166.2**	Date:	08/03/09
Done by: GF, ML		Review: EG	

Peak Flood Frequency Analysis (from regional regression equation and stream gage shapefile or report if available)										
Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	6.16	--	--	--	82	151	255	440	605	816

eomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.1					Gradient (%): 0.3				
Width (ft)	min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	7	13	9	3		144	562	248	149
meander wavelength (ft) 765					describe geology (lithology, erodibility):				
meander amplitude (ft) 412					Alluvium of modern channels and floodplains 539 ft				
Sinuosity 1.67					Both sides Tongue River Member: sandstone, sandy and silty carbonaceous shale, and coal				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	Stnd Dev
	452	51	953	116					
	997	124	1565	138	Describe abundance and location(s) of:				
	1829	78	2185	118	scroll bars:				
			2768	124	None				
			3162	73	oxbows:				
					US 1. (0.20 mi, in channel) DS 1. (0.20 mi, in channel)				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single Thread					None.				
Channel confinement at crossing (W_v / W_c):									
14.11									
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?									

The flood plain's elevation is higher than the water surface elevation of the channel.
Unique features, exceptions, etc
It appears the channel is cutting into river left valley walls near the crossing as shown by the step transition from the upper terrace to the valley floor.
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
0.79 mi DS on river right
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
US 1. Roads cross at 0.40 mi, 1.46 mi, US & DS 1. Road (0.20 mi, river right, perp.), Stock pond 0.15 mi up trib at 0.48 mi DS
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
US. The valley is narrower near the crossing and it appears the channel is cutting into the valley walls as seen through river right bank failure.

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-

		90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

West Fork Hay Creek MP 208

Site	**West Fork Hay Creek MP 208**	Date:	08/03/09
Done by: GF, ML		Review: EG	

<table>
<tr><th colspan="11">Regional Regression Analysis</th></tr>
<tr><th rowspan="2">Source or Gage name and number</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Upstream / Downstream</th><th rowspan="2">Distance to crossing (mi)</th><th rowspan="2">Range of data (years)</th><th colspan="6">recurrence interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Omang</td><td>8.62</td><td>--</td><td>--</td><td>--</td><td>110</td><td>307</td><td>507</td><td>855</td><td>1,154</td><td>1,569</td></tr>
</table>

<table>
<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><td colspan="5">Channel</td><td colspan="5">Valley</td></tr>
<tr><td colspan="5">Gradient (%): 0.2</td><td colspan="5">Gradient (%): 0.4</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td>9.0</td><td>11</td><td>10</td><td>1</td><td>345</td><td>747</td><td>546</td><td>170</td></tr>
<tr><td colspan="5">meander wavelength (ft) 696</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft) 465</td><td colspan="5">Modern alluvium 718 ft wide</td></tr>
<tr><td colspan="5">Sinuosity 2.07</td><td colspan="5">Both sides Tongue River Member: sandstone, sandy and silty carbonaceous shale, and coal</td></tr>
<tr><td rowspan="10">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><td colspan="5">Floodplain</td></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>Stnd Dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>115</td><td>112</td><td>454</td><td>98</td><td colspan="5"></td></tr>
<tr><td>1421</td><td>249</td><td>1099</td><td>182</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>2224</td><td>141</td><td>4002</td><td>101</td><td colspan="5">scroll bars:</td></tr>
<tr><td>2868</td><td>137</td><td>4602</td><td>121</td><td colspan="5">None</td></tr>
<tr><td>3478</td><td>193</td><td>5384</td><td>105</td><td colspan="5">oxbows:</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">channel cut-offs:</td></tr>
<tr><td colspan="5">Single Thread</td><td colspan="5">US (0.15 mi river left)</td></tr>
<tr><td colspan="5">Channel confinement at crossing (W_v / W_c):</td><td colspan="5"></td></tr>
<tr><td colspan="5">71.46</td><td colspan="5"></td></tr>
<tr><td colspan="10">What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?</td></tr>
<tr><td colspan="10">The elevation of the flood plain is greater than the water surface of the channel.</td></tr>
</table>

Unique features, exceptions, etc.
None

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
US 1. Road (0.50 mi river left, par.) Road crossing 1.2 mi DS
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
none

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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		at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Hay Creek MP 209.1

Site	**Hay Creek MP 209.1**	Date:	08/02/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis										
Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	6.57	--	--	--	94	265	439	742	1,005	1,367

Geomorphology **NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)**									
For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)									
Channel					**Valley**				
Gradient (%): 0.4					Gradient (%): 0.5				
Width (ft)	min	max	mean	std dev	Width (ft)	min	max	mean	std dev
	6	12	9	2		243	663	486	145
meander wavelength (ft) 368					describe geology (lithology, erodibility):				
meander amplitude (ft) 276					Alluvium of modern channels and floodplains 545 ft				
Sinuosity 1.65					Both sides Tongue River Member: sandstone, sandy and silty carbonaceous shale, and coal				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	Stnd Dev
	58	36	1133	29					
	235	55	1403	88	Describe abundance and location(s) of:				
	389	45	1809	98	scroll bars:				
	684	83	2451	138	None				
	1117	87			oxbows:				
					None				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single Thread					None				
Channel confinement at crossing (W_v / W_c):									
84.47									
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?									
The elevation of the flood plain is greater the channel’s water surface.									

Unique features, exceptions, etc:
The straightened section of channel immediately DS might be evidence of incision, the valley also narrows DS of the crossing

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
DS 1. Road (1.30 mi river left, par.), Buckley Dam 1.22 mi US
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
DS (0.00) There is a straighter section of channel that does not resemble the US or DS meander pattern.

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability

		at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Sandstone Creek MP 244.3

Site	**Sandstone Creek MP 244.3**	Date:	08/03/09
Done by: GF, ML		Review: EG	

<table>
<tr><th colspan="11">Regional Regression Analysis</th></tr>
<tr><th rowspan="2">Source or Gage name and number</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Upstream / Downstream</th><th rowspan="2">Distance to crossing (mi)</th><th rowspan="2">Range of data (years)</th><th colspan="6">recurrence interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Omang (1992)</td><td>53.3</td><td>--</td><td>--</td><td>--</td><td>185</td><td>514</td><td>848</td><td>1,423</td><td>1,911</td><td>2,584</td></tr>
</table>

<table>
<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><td colspan="5">Channel</td><td colspan="5">Valley</td></tr>
<tr><td colspan="5">Gradient (%): 0.2</td><td colspan="5">Gradient (%): 0.6</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">Width (ft)</td><td>Min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td>11</td><td>16</td><td>14</td><td>2</td><td>395</td><td>870</td><td>695</td><td>165</td></tr>
<tr><td colspan="5">meander wavelength (ft) 815</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft) 532</td><td colspan="5">Alluvium of modern channels and floodplains 400 ft</td></tr>
<tr><td colspan="5">Sinuosity 2.10</td><td colspan="5">Both sides Ludlow Member of Fort Union Fm: Gray and brown shale, siltstone, silty or bentonitic claystone, sandstone, and coal.
RB US Hell Creek Fm: bentonitic claystone that alternates with gray to brown sandstone interbedded with carbonaceous shale</td></tr>
<tr><td rowspan="10">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><td colspan="5">Floodplain</td></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>Stnd Dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>89</td><td>228</td><td>41</td><td>135</td><td colspan="5"></td></tr>
<tr><td>751</td><td>149</td><td>52</td><td>171</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>1659</td><td>179</td><td>58</td><td>191</td><td colspan="5">scroll bars:</td></tr>
<tr><td>2271</td><td>224</td><td>42</td><td>138</td><td colspan="5">None</td></tr>
<tr><td></td><td></td><td>63</td><td>206</td><td colspan="5">oxbows:</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">DS (0.30, 0.40 mi, river left) US (0.10 mi, river left)</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">channel cut-offs:</td></tr>
<tr><td colspan="5">Single Thread</td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel confinement at crossing (W_v / W_c):</td><td colspan="5"></td></tr>
</table>

73.07	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
The surface of the water channel appears to be higher than its flood plain near the crossing US & DS (0.00-0.30) mi	
Unique features, exceptions, etc Several Oxbows DS.	
Valley rim (river right) delineated by railroad bed. Valley expands as it approaches crossing	

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Stock pond on floodplain 0.77 mi, 3 sewage disposal ponds 1.3 mi, Lake Baker and town of Baker 2.75 mi US. DS 0.1 mi up trib 1 mi, 0.36 up trib 0.36 mi. Railroad and road cross with bridge 2.27 mi US.
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p.

		Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Red Butte Creek MP 246.2

<table>
<tr><td>Site</td><td>Red Butte Creek MP 246.2</td><td>Date:</td><td>08/03/09</td></tr>
<tr><td colspan="2">Done by: GF, ML</td><td colspan="2">Review: EG</td></tr>
</table>

<table>
<tr><th colspan="11">Regional Regression Analysis</th></tr>
<tr><td rowspan="2">Source or Gage name and number</td><td rowspan="2">Drainage Area (mi^2)</td><td rowspan="2">Upstream / Downstream</td><td rowspan="2">Distance to crossing (mi)</td><td rowspan="2">Range of data (years)</td><td colspan="6">recurrence interval</td></tr>
<tr><td>2</td><td>5</td><td>10</td><td>25</td><td>50</td><td>100</td></tr>
<tr><td>Omang (1992)</td><td>16.06</td><td>--</td><td>--</td><td>--</td><td>92</td><td>263</td><td>439</td><td>747</td><td>1,016</td><td>1,373</td></tr>
</table>

<table>
<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><td colspan="5">Channel</td><td colspan="5">Valley</td></tr>
<tr><td colspan="5">Gradient (%): 0.3</td><td colspan="5">Gradient (%): 0.5</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>std dev</td></tr>
<tr><td>7</td><td>12</td><td>11</td><td>2</td><td>429</td><td>1489</td><td>858</td><td>331</td></tr>
<tr><td colspan="5">meander wavelength (ft) 637</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft) 232</td><td colspan="5">Both sides Ludlow Member: Gray and brown shale, siltstone, silty or bentonitic claystone, sandstone, and coal.</td></tr>
<tr><td colspan="5">Sinuosity 1.66</td><td colspan="5">Both sides US Hell Creek Fm: bentonitic claystone that alternates with gray to brown sandstone interbedded with carbonaceous shale</td></tr>
<tr><td rowspan="10">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><td colspan="5">Floodplain</td></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database N
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>Stnd Dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>63</td><td>172</td><td>541</td><td>74</td><td colspan="5"></td></tr>
<tr><td>677</td><td>135</td><td>823</td><td>72</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>1684</td><td>208</td><td>1062</td><td>61</td><td colspan="5">scroll bars:</td></tr>
<tr><td>2722</td><td>82</td><td>1334</td><td>67</td><td colspan="5">none</td></tr>
<tr><td>3067</td><td>42</td><td></td><td></td><td colspan="5">oxbows:</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="5">US (0.10, river right) DS (0.20, 0.30 river right)</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">channel cut-offs:</td></tr>
<tr><td colspan="5">Single Thread</td><td colspan="5">US 1. (0.20, 0.30 river right) DS (0.20, river right)</td></tr>
<tr><td colspan="5">Channel confinement at crossing (W_v / W_c):</td><td colspan="5"></td></tr>
<tr><td colspan="5">73.89</td><td colspan="5"></td></tr>
</table>

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
DS 1. (0.10-0.40 mi) The creek's surface water elevation appears higher than the flood plain elevation.
Unique features, exceptions, etc:
The valley width expands as the creek approaches the crossing due to several tributaries entering the valley near the crossing. DS 1. Possible avulsion (0.20 mi, river right) leading to the oxbows.

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Red Butte Dam 1.1 mi DS. Stock pond 0.5 mi up trib at 0.3 mi US. Road crosses with bridge 0.96 mi US. Road (0.60 mi river left, par.), Residence (1.1 mi, river right) US
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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		bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
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Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Hidden Water Creek MP 258.4

Site	**Hidden Water Creek MP 258.4**	Date:	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis										
Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	25.25	--	--	--	108	306	511	868	1,178	1,589

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.1					Gradient (%): 0.3				
Width (ft)	min	max	mean	std dev	Width (ft)	min	max	mean	Std dev
	13	19	16	3		124	672	446	215
meander wavelength (ft) 1304					describe geology (lithology, erodibility):				
meander amplitude (ft) 322					Alluvium of modern channels and floodplains 1268 ft				
Sinuosity 1.92					Both sides Pierre Formation: partly silty shale with abundant bentonite beds and zones of gray, calcareous concretions. Both sides US Hell Creek Fm: bentonitic claystone that alternates with gray to brown sandstone interbedded with carbonaceous shale.				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	Stnd Dev
	807	266	271	160					
	3674	266	1109	108	Describe abundance and location(s) of:				
	5770	156	2125	161	scroll bars:				
	7331	303	2739	117	None				
	8243	188	3280	193	oxbows:				
					DS (0.10, river left)				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single Branch					US (0.00, 0.50 mi, river left, 0.30 0.60, river right DS (0.00 river right)				
Channel confinement at crossing (W_v / W_c):									

27.14	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
US (0.20 mi,) the channel's water surface elevation appears to be higher than the elevation of the flood plain.	
Unique features, exceptions, etc:	
The valley appears to narrow considerably upstream of crossing (0.20 mi) and than expands at the crossing. US (0.30 river right) there appears to be a section of bank failure on the outside of the meander bend.	

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
1.1 mi US on LB
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Stock pond 0.67 mi up trib at 0.6 mi DS, 0.24 mi up trib 1.37 mi US. Road crossing 1 mi DS, small road crosses 0.97 mi US. Road (1.0 mi, river left, par.)
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p.

		Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Soda Creek MP 272.1

Site	**Soda Creek MP 272.1**	Date:	08/03/09
Done by: GF, ML		Review: EG	

Regional Regression Analysis

Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	1.16	--	--	--	20	61	105	183	256	346

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel	**Valley**
Gradient (%): 0.05	Gradient (%): 0.3

	min	max	mean	std dev		min	max	mean	std dev
Width (ft) *	4	14	9	2	Width (ft)	109	303	167	66

*Difficult to determine from aerial due to vegetation	
meander wavelength (ft) 342	describe geology (lithology, erodibility):
meander amplitude (ft) 83	Both sides Hell Creek Fm: bentonitic claystone that alternates with sandstone interbedded with carbonaceous shale
Sinuosity 1.24	Both sides US Ludlow Member Fort Union Fm: shale, siltstone, silty or bentonitic claystone, sandstone, and coal.

	Upstream (ft)		Downstream (ft)	
radius of curvature (ft)	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	169	33	307	48
	321	41	497	40
	687	47	648	34
	947	35	937	86
	1049	108		

Floodplain

FEMA National Database N

if yes, describe widths below

	min	Max	mean	Stnd Dev
Width (ft)				

Describe abundance and location(s) of:

scroll bars:

None

oxbows:

None

Channel form (braided, anabranching, single thread):	channel cut-offs:
Single Thread	US (0.20 mi river right)
Channel confinement at crossing (W_v / W_c):	

19.14	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
The elevation of the floodplain is greater than the elevation of the channel’s water surface.	
Unique features, exceptions, etc:	
Another crossing 100 ft to the south called Soda Creek 272.2 is actually on trib that joins 100 ft DS.	

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Stock ponds 1.5 mi US and on tribs at 0.63 and 1.15 mi US and 2 at 0.45 and 0.55 mi up trib that joins 100 ft DS.
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

		LITERATURE REVIEW **(check box when searched for, if none, note under source)**
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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		bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

Soda Creek MP 272.2

Site	**Soda Creek MP 272.2**	Date:	08/05/09
Done by: GF, ML	Review: EG		

Regional Regression Analysis										
Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	1.76	--	--	--	26	76	131	228	318	429

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.7					Gradient (%): 0.4				
Width (ft)*	min	max	mean	std dev	Width (ft)	Min	max	mean	std dev
	7	14	10	2		129	303	174	60
*Difficult to determine from aerial because of vegetation									
meander wavelength (ft): 259					describe geology (lithology, erodibility):				
meander amplitude (ft): 59					Both sides Hell Creek Fm: bentonitic claystone that alternates with sandstone interbedded with carbonaceous shale				
Sinuosity 1.30					Both sides US Ludlow Member Fort Union Fm: shale, siltstone, silty or bentonitic claystone, sandstone, and coal.				
radius of curvature (ft)	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	Stnd Dev
	148	40	307	48					
	258	38	497	40	Describe abundance and location(s) of:				
	352	36	648	34	scroll bars:				
	500	34	937	86	None				
					oxbows:				
					A pond exists 0.50 mi upstream, probably man made				
Channel form (braided, anabranching, single thread):					channel cut-offs:				
Single Thread					None				
Channel confinement at crossing (W_v / W_c):									

22.6	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
The surface of the floodplain is higher than the water surface of the channel.	
Unique features, exceptions, etc: none:	
Another crossing 100 ft to the north called Soda Creek 272.1 on main branch of Soda Creek that joins 100 ft DS.	
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):	
None	
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):	
Stock ponds at 0.45 and 0.55 mi US. Stock ponds 1.5 mi US on main branch and on tribs. Road (0.50 mi, river right, par.)	
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):	
none	

LITERATURE REVIEW (check box when searched for, if none, note under source)		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
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		Engineering Circular 18, Publication FHWA-IP-90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

North Fork Coal Bank Creek MP 276.1

Site	**North Fork Coal Bank Creek MP 276.1**	Date	08/03/09
Done by: GF, EG, ML		Review: EG	

Regional Regression Analysis

Source or Gage name and number	Drainage Area (mi^2)	Upstream / Downstream	Distance to crossing (mi)	Range of data (years)	recurrence interval					
					2	5	10	25	50	100
Omang (1992)	8.97	--	--	--	62	180	304	521	714	964

Geomorphology

NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)

For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)

Channel					**Valley**				
Gradient (%): 0.25					Gradient (%): 0.69				
width	min	max	mean	stnd dev	width	min	max	mean	stnd dev
	6	27	11	48		377	1620	1005	390
meander wavelength: 1185					describe geology (lithology, erodibility):				
meander amplitude: 507					Alluvium of modern channels and floodplains 668 ft				
Sinuosity: 1.98					Fort Union Fm: Both sides Ludlow Member: shale, siltstone, silty or bentonitic claystone, sandstone and coal. RB US Ekalaka Member: Fine- to medium-grained sandstone interbedded with mudstone and thin shale and coal beds.				
	Upstream (ft)		Downstream (ft)		**Floodplain**				
	distance from crossing	radius of curvature	distance from crossing	radius of curvature	FEMA National Database N if yes, describe widths below				
					Width (ft)	min	max	mean	stnd dev
radius of curvature (ft)	591	132	103	62	Describe abundance and location(s) of:				
	1874	156	1135	87	scroll bars				
	2825	92	1915	102	possibly 1575 ft US on left bank				
	3847	60	2978	87	oxbows:				
	4710	46	3573	51	none				
	5193	49			channel cut-offs:				
	6503	56			none				
Channel form (braided, anabranching, single thread):					Relic channels:				
Single					400 feet, 0.44 mi, 0.66 mi US				

Channel confinement at crossing (W_v / W_c):	
79.68	

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
(0.2 mi DS of crossing, channel may be incised based on DEM cross valley slopes
Unique features, exceptions, etc
Meanders downstream from crossing at confluence with unnamed creek are very tortuous

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Stock ponds on tribs that join 0.17, 1 and 2.1 mi US and 0.34 mi DS. Road crosses with culvert 2.7 mi US and small road crosses 235 ft DS; group of buildings on DS road about 0.5 mile from left bank of crossing.
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report.
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf

		Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP- 90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp

South Fork Coal Bank Creek MP 279.2

<table>
<tr><td>Site</td><td>South Fork Coal Bank Creek MP 279.2</td><td>Date</td><td>07/27/09</td></tr>
<tr><td colspan="2">Done by: GF, EG, ML</td><td colspan="2">Review: EG</td></tr>
</table>

<table>
<tr><th colspan="9">Regional Regression Analysis</th></tr>
<tr><th rowspan="2">Source</th><th rowspan="2">Drainage Area (mi^2)</th><th rowspan="2">Average Elevation (ft)</th><th colspan="6">Recurrence Interval</th></tr>
<tr><th>2</th><th>5</th><th>10</th><th>25</th><th>50</th><th>100</th></tr>
<tr><td>Omang (1992)</td><td>13.80</td><td>3,191</td><td>78</td><td>223</td><td>375</td><td>641</td><td>875</td><td>1,181</td></tr>
</table>

<table>
<tr><td colspan="10">Geomorphology
NOTE: All measures rounded to whole number, except for drainage area and ratios like sinuosity or confinement)</td></tr>
<tr><td colspan="10">For Reach (extending at least 3 meander wavelengths or 20 channel widths upstream and downstream of crossing)</td></tr>
<tr><th colspan="5">Channel</th><th colspan="5">Valley</th></tr>
<tr><td colspan="5">Gradient (%): 0.4</td><td colspan="5">Gradient (%): 0.02</td></tr>
<tr><td rowspan="2">width</td><td>min</td><td>max</td><td>mean</td><td>Stnd Dev</td><td rowspan="2">width</td><td>min</td><td>max</td><td>mean</td><td>Stnd Dev</td></tr>
<tr><td>10</td><td>39</td><td>18</td><td>10</td><td>230</td><td>1086</td><td>554</td><td>309</td></tr>
<tr><td colspan="5">meander wavelength (ft): 453</td><td colspan="5">describe geology (lithology, erodibility):</td></tr>
<tr><td colspan="5">meander amplitude (ft): 406</td><td colspan="5">Alluvium of modern channels and floodplains 643 ft wide</td></tr>
<tr><td colspan="5">Sinuosity: 2.1</td><td colspan="5">Ludlow member of the Fort Union Fm:
Gray and brown shale, siltstone, silty or bentonitic claystone, sandstone and coal.
Some outcrops US LB of Ekalaka Member: fine- to medium-grained sandstone interbedded with mudstone and thin shale and coal beds.</td></tr>
<tr><td rowspan="10">radius of curvature (ft)</td><td colspan="2">Upstream (ft)</td><td colspan="2">Downstream (ft)</td><td colspan="5">Floodplain</td></tr>
<tr><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td rowspan="3">distance from crossing</td><td rowspan="3">radius of curvature</td><td colspan="5">FEMA National Database: No
if yes, describe widths below</td></tr>
<tr><td rowspan="2">Width (ft)</td><td>min</td><td>max</td><td>mean</td><td>Stnd Dev</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>564</td><td>33</td><td>46</td><td>49</td><td colspan="5"></td></tr>
<tr><td>787</td><td>41</td><td>597</td><td>49</td><td colspan="5">Describe abundance and location(s) of:</td></tr>
<tr><td>1168</td><td>90</td><td>1253</td><td>69</td><td colspan="5">scroll bars:</td></tr>
<tr><td>1879</td><td>46</td><td>2188</td><td>59</td><td colspan="5">None</td></tr>
<tr><td>2545</td><td>33</td><td>2549</td><td>49</td><td colspan="5">oxbows:</td></tr>
<tr><td>2988</td><td>56</td><td>3559</td><td>167</td><td colspan="5">None</td></tr>
<tr><td colspan="5">Channel form (braided, anabranching, single thread):</td><td colspan="5">channel cut-offs:</td></tr>
<tr><td colspan="5">Single</td><td colspan="5">none</td></tr>
<tr><td colspan="5">Channel confinement at crossing (W_v / W_c):</td><td colspan="5">Relic channels</td></tr>
<tr><td colspan="5">106.8</td><td colspan="5">US 0.3 mi, DS 0.2 mi</td></tr>
<tr><td colspan="10">What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?</td></tr>
</table>

Stream elev. is 10 to 30 feet below valley on DEM. Incision on downstream end of study area where stream elev. and valley elev. diverge more. At crossing, floodplain on right bank may be higher that channel on DEM.
Unique features, exceptions, etc
Tribs: US unnamed 4.1 mi, meets North Fork Coal Bank Creek to form Coal Bank Creek 0.72 DS

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
Dams US 1.5 mi and 1.9 mi, latter associated with buildings and 480 foot wide pond. Small road crosses US at 0.4 mi, then runs parallel US; a perpendicular road crosses with culvert at 0.57 mi US of crossing.
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
Possibly some incision further downstream, about 0.37 mi from crossing, based on DEM.

LITERATURE REVIEW **(check box when searched for, if none, note under source)**		
Existing channel migration zone determination	☒	source(s): None
Reports on local/regional		
Hydrology	☒	source(s): Parrett, Charles, and Johnson, D.R., 2004, Methods for estimating flood frequency in Montana based on data through water year 1998: U.S. Geological Survey Water-Resources Investigations Report 03-4308, 101 p. Parrett, Charles, Holnbeck, S.R, and Chase, K.J., 2004, Water-surface elevation data and flood and floodway boundaries for the upper Yellowstone River, Montana: U.S. Geological Survey Scientific Investigations Map SIM 2868. [Available online only at http://water.usgs.gov/pubs/sim/2004/2868.] U.S. Geological Survey Water-Data Report
hydraulics	☒	source(s): None
sediment transport	☒	source(s): Holnbeck, S.R., 2005, Sediment-transport investigations of the upper Yellowstone River, Montana, 1999 through 2001: Data collection, analysis, and simulation of sediment transport: U.S. Geological Survey Scientific Investigations Report 2005-5234, 69 p. Lambing, J.H., 1998, Estimated 1996-97 and long-term average annual loads for suspended sediment and selected trace metals in streamflow of the upper Clark Fork basin from Warm Springs to Missoula, Montana: U.S. Geological Survey Water-Resources Investigations Report 98-4137, 35 p.
bridge scour	☒	source(s): Montana DOT Bridge Scour Database (constructional stability for almost 6000 bridges in the state) http://mt.water.usgs.gov/cgi-bin/projects?14100 Landers, M.N., and Mueller, D.S., 1996, Channel scour at bridges in the United States: U.S. Department of Transportation, Federal Highway Administration Publication FHWARD- 95-184, 140 p. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_516.pdf Richardson, E.V., and Davis, S.R., 2001, Evaluating scour at bridges, 4th ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA NHI 01-001, 378 p. Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges, 2d ed.: U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular 18, Publication FHWA-IP-

		90-017, 132 p. Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., and Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation Publication FHWA-IP-90-014, Hydraulic Engineering Circular 20, 195 p. Montana Department of Natural Resources and Conservation, 1976, River mile index of the Yellowstone River: Montana Department of Natural Resources and Conservation, Water Resources Division, 61 p. Personal Communication Sources Steve Holnbeck USGS Montana Water Science Center 3162 Bozeman Avenue Helena Mt 59601-6456 Phone: (406) 457-5929 Email: holnbeck@usgs.gov Kent Barnes, P.E. Bridge Bureau Montana Department of Transportation PO Box 201001 2701 Prospect Helena, MT 59620-1001 406-444-6260 Fax 406-444-6155 Mark Goodman Montana Department of Transportation 40-444-6246
Ice jams	☒	source(s): Ice Jams in Montana U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire http://www.crrel.usace.army.mil/ierd/tectran/IEbul19.pdf Montana Ice Jam. River Ice and River Ice Processes http://www.wrh.noaa.gov/tfx/icejam/ Montana Severe Storms, Ice Jams, Snowmelt, Flooding, Extreme Soil Saturation http://www.fema.gov/news/event.fema?id=635
Turbidity	☒	source(s): Blevins, D.W., 2006, The response of suspended sediment, turbidity, and velocity to historical alterations of the Missouri River: U.S. Geological Survey Circular 1301, 8 p. http://www.nwk.usace.army.mil/regulatory/MO%20River%20Dredging/USGS%20Historical%20Alterations.pdf
Stream gages	☒	source(s): (note if managed flow, e.g. canals or flow during summer only) None
1:24000 geologic maps	☒	source(s): State Geologic Mapping Program http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp