KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Frenchman Creek MP 25.8			Surveyors	Eriesson
GPS	WP:	N:	E:	Date/Time	4:30pm 08/05/09
Flow Condition	low to none				
General Site Characteristics / Comments	meandering river in hydric soils (clay rich) abund and salix present providing abundant root strength				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)	
	D_{16}	clay
	D_{50}	silt
	D_{84}	silt
	% sand	5-10%
	SOIL CLASS SYMBOL	CL
Bed (sub-surface)	D_{16}	
	D_{50}	
	D_{84}	NA
	% sand	
	SOIL CLASS SYMBOL	
Bars	D_{16}	
	D_{50}	
	D_{84}	NA
	% sand	
	SOIL CLASS SYMBOL	

Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}	same as bed	D_{50}	same as bed
	D_{84}		D_{84}	
	% sand		% sand	
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	

Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}	clay	D_{16}	
	D_{50}	silt	D_{50}	same as RB FP
	D_{84}	silt	D_{84}	
	% sand	5	% sand	
	SOIL CLASS SYMBOL	CL	SOIL CLASS SYMBOL	

Comments:

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 2.5'			Bank Height (ft) 2		
Bank Slope (°) 45-90°			Bank Slope (°) 45		
Woody Cover (%) 100			Woody Cover (%) 100		
Dominant Species Salix			Dominant Species Salix		
Root Depth (ft) 2.5 Observed (Y)/N			Root Depth (ft) 2.5 Observed Y/(N)		
Undercutting (Y)/N)			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y/(N)	Potential (Y)/N	Gradual Migration	Present Y/(N)	Potential Y/(N)
Slumping	Present (Y)/N	Potential (Y)/N	Slumping	Present Y/(N)	Potential Y/(N)
Landsliding	Present Y/(N)	Potential Y/(N)	Landsliding	Present Y/(N)	Potential Y/(N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: outside of meander bend			Notes: inside of meander bend		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity moderate		Soil Maturity moderate	
Natural Levees (Y/N)		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees ((Y)/N)	
Description:		Description: not at site but u.s. and d.s.	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft)		Woody Riparian Buffer Width (ft) 50	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,(H))	
Dominant Woody Species		Dominant Woody Species Salix	
Crevasse Splays (Y/N)		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/N)		Crevasse Channels (Y/(N))	
Notes:		Notes:	

no access to left bank FR however looks very similar to R.S. FR.

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 60	Bridges (Y/N)
Bankfull Depth (ft) ?	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) bank	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 50	
	Roads (Y/N)
Incision Evidence NA	(RR, LB, US, DS)
	Other Infrastructure dam downstream
Aggradation Evidence NA	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) ?	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams possible one is in the process of being built? (see picture)	In-stream structures
Debris flow	
NA	Flow Diversion
Landslides	NA
	Debris
Woody debris	
Other:	Other:

PHOTO CHECKLIST		
Site Overview	☐	345-349 panaramic
Channel US Showing Both Banks	☐	341
Channel DS Showing Both Banks	☐	342
Channel Bed Surface Alluvium	☐	344
Channel Bed Sub-Surface Alluvium	☐	NA
Bar Alluvium	☐	NA
Bars Overview	☐	NA
Islands Overview	☐	NA
Left Bank Alluvium	☒	NA
Left Bank Toe Detail	☒	NA
Left Bank Top of Bank Detail	☒	NA
Left Bank Overview	☒	337
Left Floodplain Alluvium	☐	NA no access
Left Floodplain Overview	☐	NA no access
Left Floodplain Landforms	☐	NA no access
Right Bank Alluvium	☒	338
Right Bank Toe Detail	☐	—
Right Bank Top of Bank Detail	☐	—
Right Bank Overview	☒	339
Right Floodplain Alluvium	☒	338
Right Floodplain Overview	☒	~~339~~ 340
Right Floodplain Landforms	☐	NA
Infrastructure	☐	NA
Disturbance/Instability	☒	336, beaver dam

PHOTO LOG		
Photo ID	View Direction	Description

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA

Site	Frenchman's Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression	366.8*	--	--	--	983	4,153	7,932	15,533	34,267	66,508
No Gage Data Available										

*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.

Geomorphology

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

Channel

Gradient <0.01

Width (ft)	min	max	mean	std dev
	34	61	47	10

meander wavelength (ft) 1020

meander amplitude (ft) 456

Sinuosity 1.11

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	213	1220	731	1023
	941	771	1784	712
	1906	518	2207	863
	2767	627		

channel form: Single Branch

channel confinement: 12.74

elevation of the channel relative to the floodplain (is it in the low spot in the valley?): No

Valley

Gradient <0.01

width	min	max	mean	std dev
	429	864	633	164

describe geology:

Alluvium of modern channels and flood plains

Floodplain

FEMA N if yes, describe widths below

width	min	max	mean	std dev

describe abundance and location(s) of:

scroll bars: N/A

oxbows: N/A

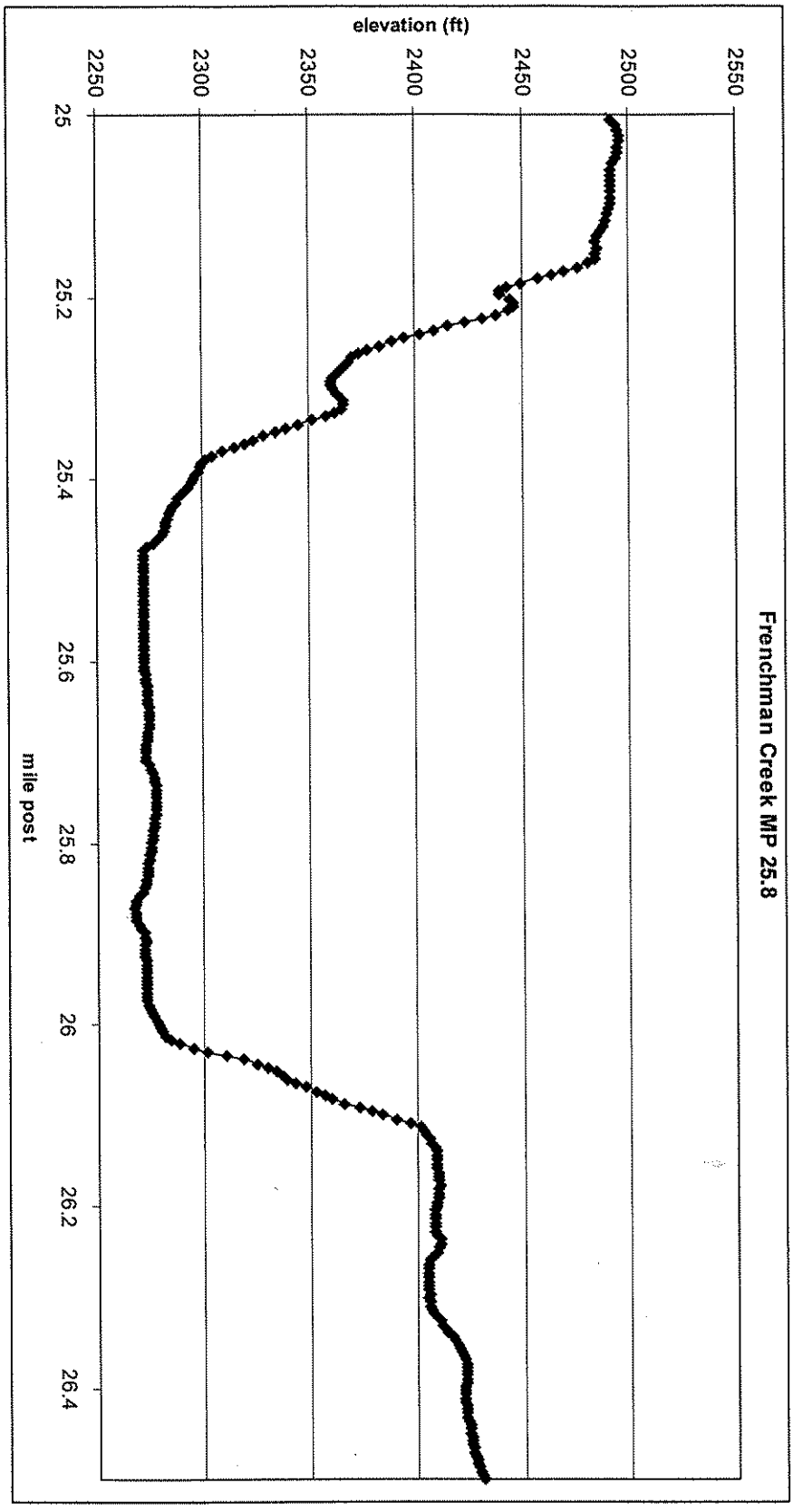
channel cut-offs:

0.78mi Upstream of site, there is a relic channel or manmade ditch which reconnects with the Creek downstream of site.

Evidence of landslides upstream or downstream along valley margins (upstream/downstream with distance to pipeline):
None
Describe any direct or indirect evidence of general scour/channel incision:
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline):
Roads: 0.25mi East of Crossing (unnamed)
Dam: 2.56mi DS

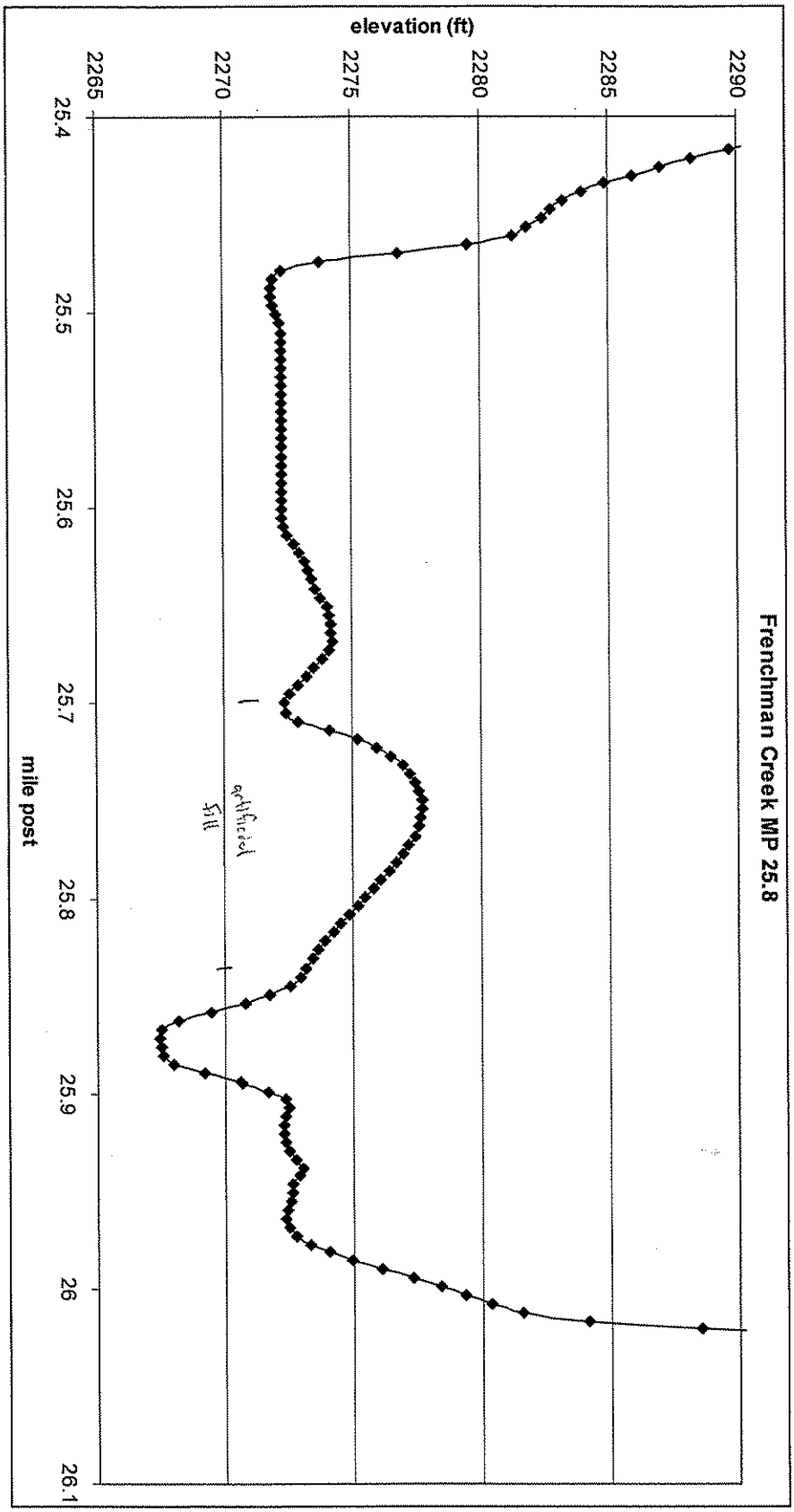
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

- Background turbidity is already high. All surrounding soils are silt/clay rich so any excavation could contribute fines.

- incision seems unlikely, the system is fine grained and low energy (slope) with a dam downstream. Lateral incision seems unlikely given gradient and grainsize.

- unlikey

- extend to CMZ? (Need to examine historic air photos for ~~more~~ potential evidence more closely).

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Rock Creek MP 39.2			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/5/09
Flow Condition	no surface flow evident - series of ponded water reaches				

General Site Characteristics / Comments

low gradient, meandering rim w/ well defined floodplain & terrace that periodically flow into channel & Fairfield Rim formation

- muddy water

- similar morphology to Redeater Rim, high variability in channel width

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/(N)) If Yes, enter Bed (subsurface)			
	D_{16} 2			
	D_{50} 8mm			
	D_{84} 32			
	% sand 30			
	SOIL CLASS SYMBOL	GW		
Bed (sub-surface)	D_{16}	Same as SFL		
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL	GW		
Bars	D_{16}			
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL	GW, SP		
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}	FS-VFS	D_{50}	FS-VFS
	D_{84}		D_{84}	
	% sand	> 90	% sand	> 90
	SOIL CLASS SYMBOL	SP	SOIL CLASS SYMBOL	SP
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	NA
	D_{50}	VFS	D_{50}	
	D_{84}		D_{84}	
	% sand	> 90	% sand	
	SOIL CLASS SYMBOL	SP	SOIL CLASS SYMBOL	

Comments: Ustic Torrifluvents soil

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

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FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
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		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
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		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) low ~3', high 15-20'			Bank Height (ft) 2'@ low FP, 15-20'@ outer bend		
Bank Slope (°) low 45°, high 50°			Bank Slope (°) low bank 25°, high bank 70-90°		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species herbaceous - see RB notes			Dominant Species herbaceous - see photos 219-220		
Root Depth (ft) 0.5 Observed (Y) / N			Root Depth (ft) 0.5 Observed (Y) / N		
Undercutting (Y/N)			Undercutting (Y/N) dense grass, stable does		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / (N)	Potential (Y) / N	Gradual Migration	Present Y / (N)	Potential (Y) N
Slumping	Present Y / (N)	Potential (Y) / N	Slumping	Present Y / (N)	Potential (Y) / N
Landsliding	Present Y / (N)	Potential Y / (N)	Landsliding	Present Y / (N)	Potential Y / (N)
Other: –	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: landsliding on outer bend ~750' US - potential for slow migration			Notes: landslide potential ~700' DS on steep outer bank - potential for slow migration		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity NA		Soil Maturity little	
Natural Levees (Y/N)		Natural Levees (Y/N)	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Woody Riparian Buffer Width (ft)		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species		Dominant Woody Species herbaceous	
Crevasse Splays (Y/N)		Crevasse Splays (Y/N)	
Crevasse Channels (Y/N)		Crevasse Channels (Y/N)	
Notes:		Notes:	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 100' 125' from high banks	Bridges (Y/N)
Bankfull Depth (ft) 3-4'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) low FP on RB	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 45	
	Roads (Y/N)
Incision Evidence NO	(RR, LB, US, DS)
	Other Infrastructure None
Aggradation Evidence NO	
Bars (Y/N) sandy gravel bar ~ 50' DS Xing	
Vegetated islands (Y/N)	
Pool Depths (ft) ~ 4'	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides see previous notes on landslides US + DS of Xing	
	Debris
Woody debris	
Other:	Other:

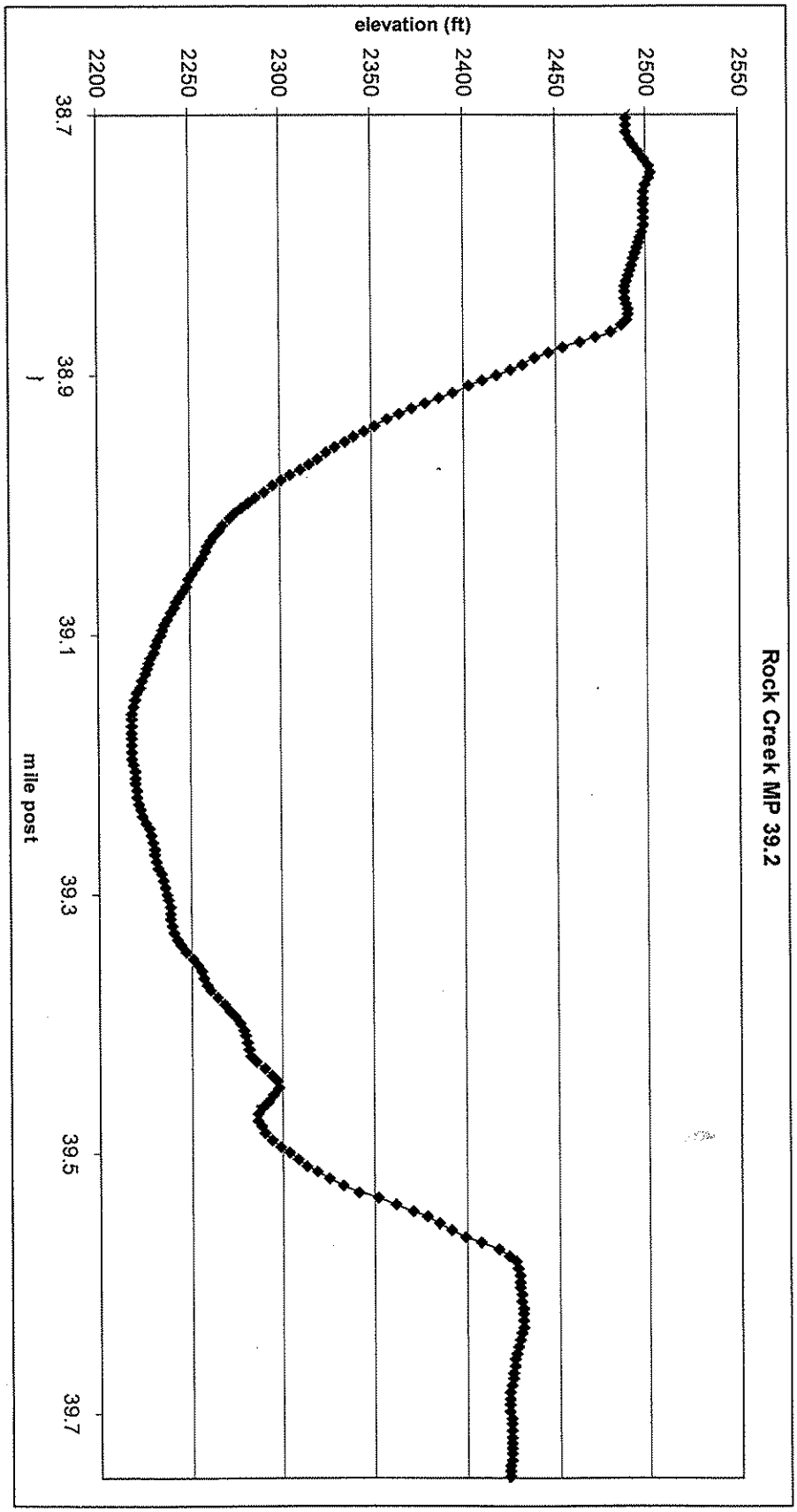
PHOTO CHECKLIST		
Site Overview	☒	U/S to D/S order 226, 227, 228, 229, 230, 231, 232
Channel US Showing Both Banks	☒	208-210 (208-210 @ X-ing)
Channel DS Showing Both Banks	☒	205-207
Channel Bed Surface Alluvium	☒	200
Channel Bed Sub-Surface Alluvium	☒	200
Bar Alluvium	☒	201, 202
Bars Overview	☒	203 DS, 204 DS
Islands Overview	☒	NA
Left Bank Alluvium	☒	221, 222
Left Bank Toe Detail	☒	223
Left Bank Top of Bank Detail	☒	224
Left Bank Overview	☒	218, 225
Left Floodplain Alluvium	☒	N/A
Left Floodplain Overview	☒	NA L. FP is ~75-100' US of X-ing
Left Floodplain Landforms	☒	NA
Right Bank Alluvium	☒	214
Right Bank Toe Detail	☒	215
Right Bank Top of Bank Detail	☒	216
Right Bank Overview	☒	217
Right Floodplain Alluvium	☒	212, 213
Right Floodplain Overview	☒	211 (US view)
Right Floodplain Landforms	☒	NA
Infrastructure	☒	NA
Disturbance/Instability	☒	750' D/S of site R bank 233

PHOTO LOG		
Photo ID	View Direction	Description
219, 220	RB	Dominant veg. species on banks
234, 235	US	possible relict channel depression on left high FP/low terrace
236	DS	" "
237	LD	low terrace or high FP along X-ing alignment
238	RB	" "
241, 242	DS	from where we parked cars - X-ing & water in distance
243-245	US	" " US view of valley from US of X-ing

239 - video site overview
240 - US landsliding

VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM

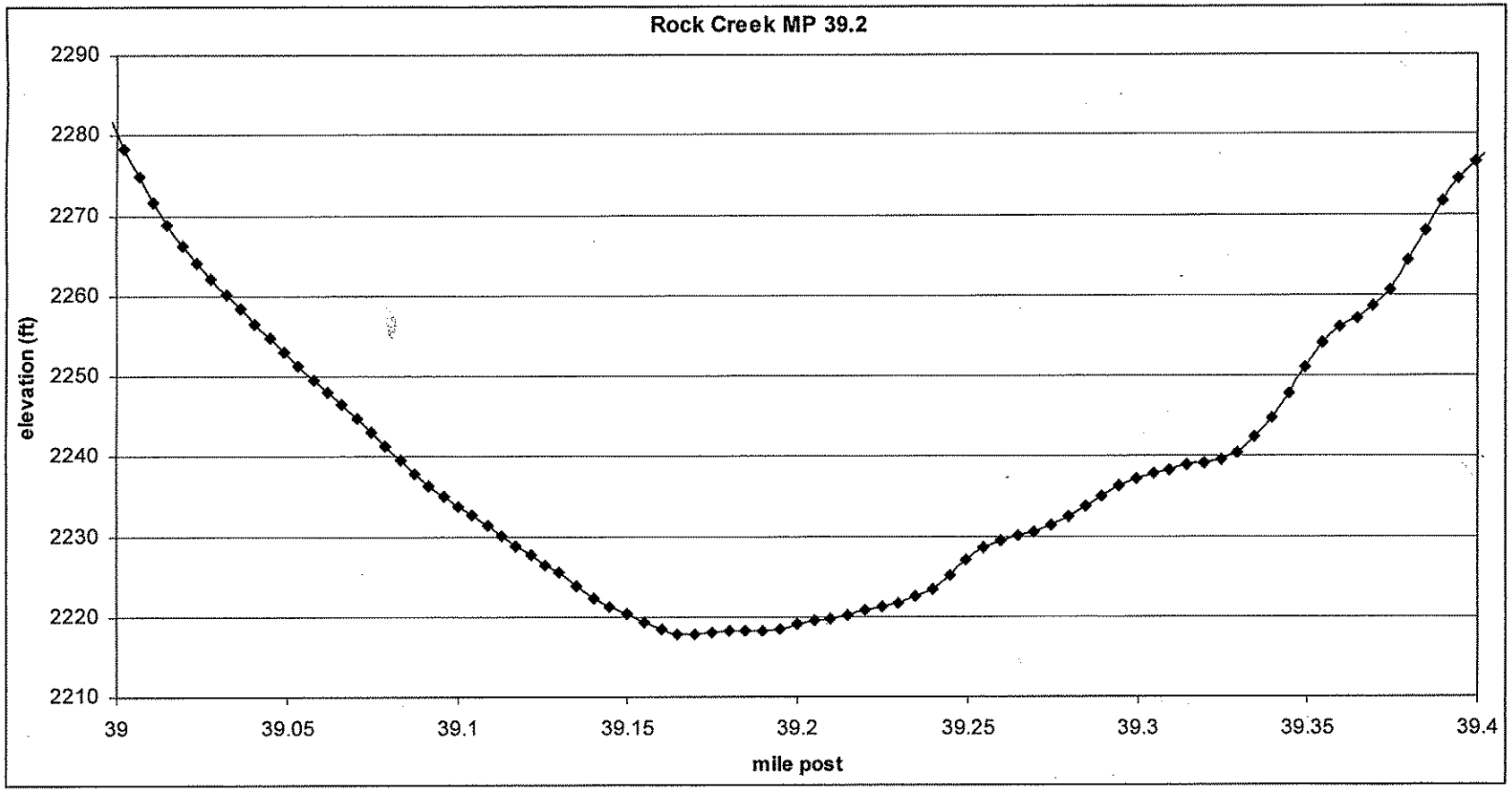


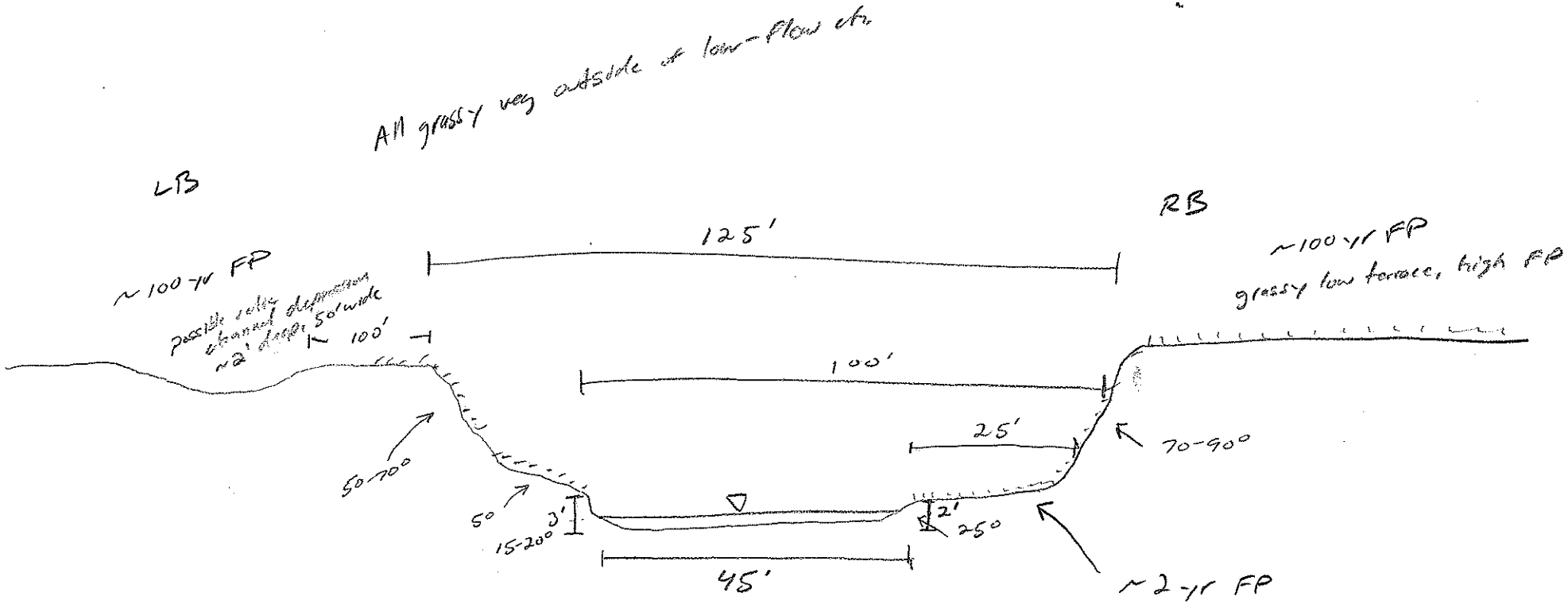
PLANVIEW MAP

*notes – image background date:

CHANNEL CROSS-SECTION SKETCH

*notes -- channel cross-section derived from 30 / 10 meter USGS DEM





- little scour potential
- little evidence for rapid ch. migration
- Drop pipe ≥ 20' from edge of high banks

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA

Site	Rock Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression	293.8*	–	–	–	850	3,647	7,015	13,843	30,792	60,247
No Gage Data Available										

*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

Gradient: 0.1

Width (ft)	min	max	mean	std dev
	26	60	43	14

meander wavelength (ft)1945.0

meander amplitude (ft) 361.0

Sinuosity 1.45

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	3608	1574	853	682
	4697	1476	2073	1486
	6314	977	3205	663
			3946	731

Channel form (braided, anabranching, single thread): Single

Channel confinement at crossing (W_v / W_c): 37.50

Valley

Gradient 0.1

width	min	max	mean	std dev
	577	1391	877	307

describe geology (lithology, erodibility):

Sand and Gravel deposits from recent channel migration.

Shale with thin sandstone in upper or middle part. Thickness 558ft

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:

US 0.13 mi, river right

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
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
US 0.20 mi, river left, outside of meander bend, small amounts of sloughing appears to be present.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
None
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

Rock Creek

Questions:

What is the likelihood the project will impact turbidity at the site?
already muddy water @ site - not flowing in August

What is the potential impact on incision and erosion?
pipe will not affect incision or erosion

Will the project activate historical instability?
no

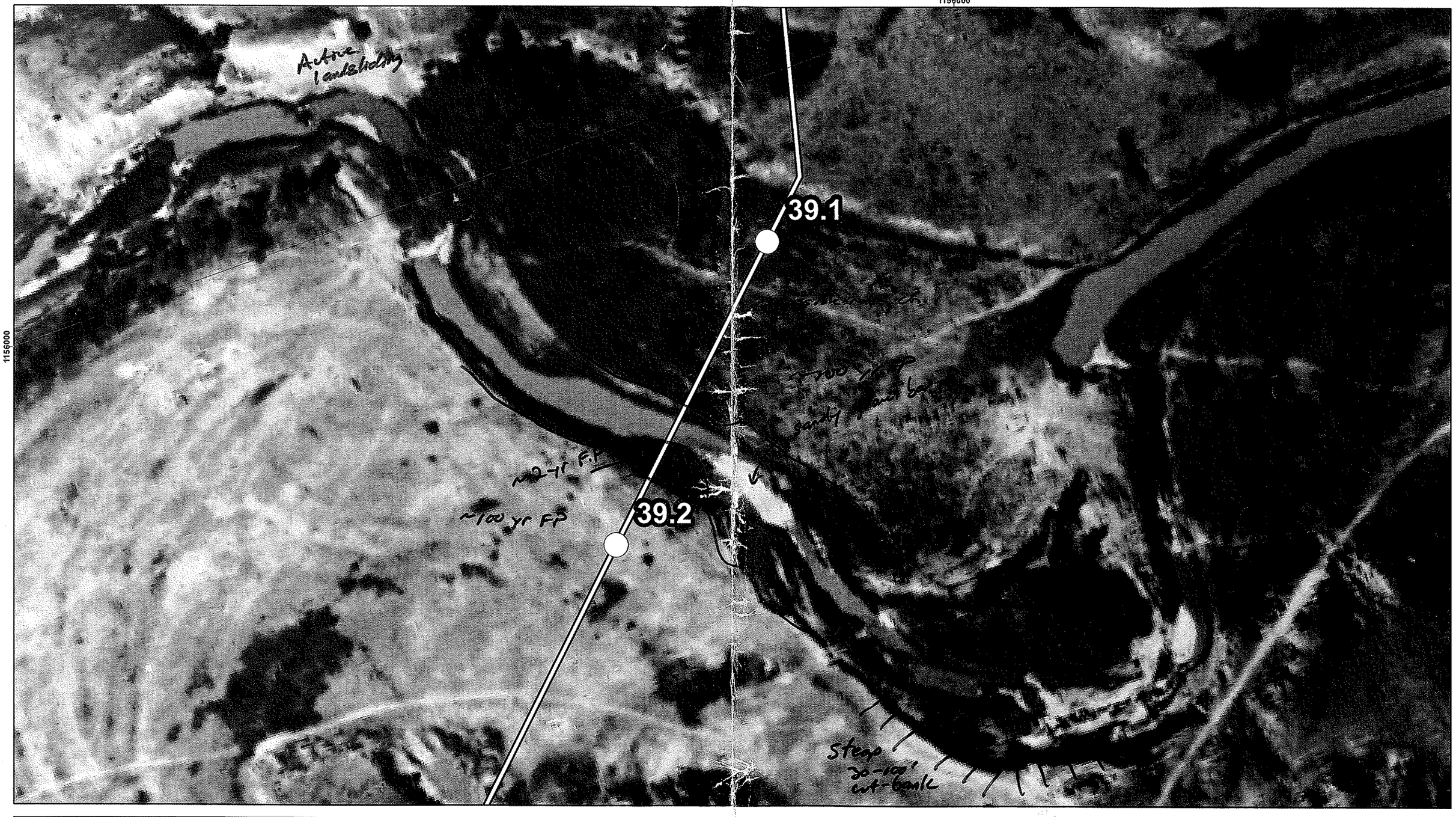
What actions or alternatives can mitigate project effects?
drop pipe elev. ≥ 20' from terrace / high FP banks

Are there any cumulative effects of pipeline?
no

General Notes:

1156000

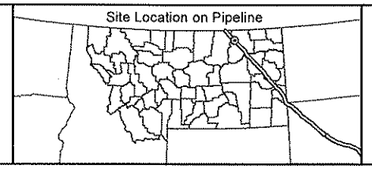
1156000



- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Rock Creek - MILE POST 39.2
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 62.5 125 250 Feet

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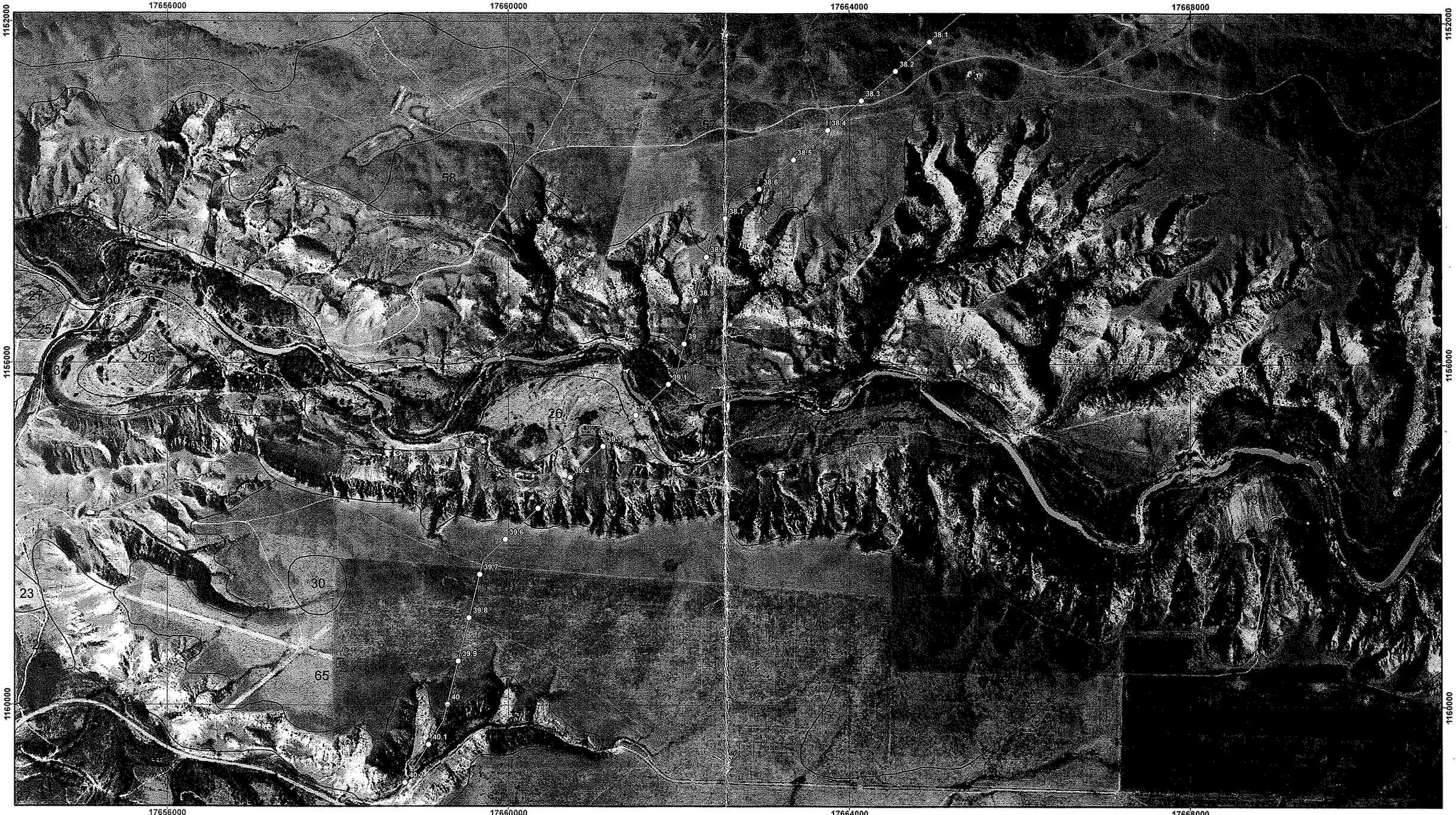
File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

17656000 17660000 17664000 17668000

1162000 1156000 1160000

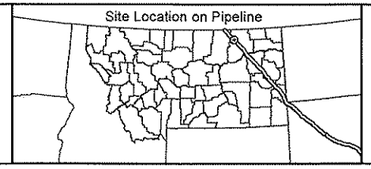


17656000 17660000 17664000 17668000

- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Rock Creek - MILE POST 39.2
NRCS Ssurgo Soils

ENTRIX
200 1st Ave W Ste 500, Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 500 1,000 2,000 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Willow Creek MP 40.4			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/5/09
Flow Condition	No Flow - ponded water				
General Site Characteristics / Comments	low gradient, meandering sand + gravel bed channel w/ high banks on both sides and no low floodplains				
	Trapezoidal channel shape				
	- muddy water				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) if Yes, enter Bed (subsurface)			
	D_{16}	2		
	D_{50}	16		
	D_{84}	32		
	% sand	20		
	SOIL CLASS SYMBOL	GW		
Bed (sub-surface)	D_{16}	2		
	D_{50}	16		
	D_{84}	32		
	% sand	20		
	SOIL CLASS SYMBOL	GW		
Bars	D_{16}	2		
	D_{50}	16		
	D_{84}	32		
	% sand	20		
	SOIL CLASS SYMBOL	GW		
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}	VFS	D_{50}	VFS
	D_{84}		D_{84}	
	% sand	70	% sand	70
	SOIL CLASS SYMBOL	SM	SOIL CLASS SYMBOL	SM
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}	VFS	D_{50}	VFS
	D_{84}		D_{84}	
	% sand	70	% sand	70
	SOIL CLASS SYMBOL	SM	SOIL CLASS SYMBOL	SM

Comments: FP is infrequently inundated, likely a terrace

Ustic Torrifluvents Soil 75

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 10-12			Bank Height (ft) 10-12		
Bank Slope (°) 70° upper 8', 90° lower 3'			Bank Slope (°) 50-60° upper 8', lower 70°-90° 3'		
Woody Cover (%) 60			Woody Cover (%) 25 willows @ toe		
Dominant Species willows Dense willows			Dominant Species willows		
Root Depth (ft) >1 Observed Y / N			Root Depth (ft) >1' Observed Y / N		
Undercutting (Y/N)			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / N	Potential Y / N	Gradual Migration	Present Y / N	Potential Y / N
Slumping	Present Y / N	Potential Y / N	Slumping	Present Y / N	Potential Y / N
Landsliding	Present Y / N	Potential Y / N	Landsliding	Present Y / N	Potential Y / N
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: evidence of minor slumping @ toe			Notes: See ←		
banks are stable + vegetated throughout					
Dense willows					

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity little		Soil Maturity little	
Natural Levees (Y/N)		Natural Levees (Y/N)	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species scattered		Dominant Woody Species sage, see photos 325-327	
cotton woods see photos 325-327			
Crevasse Splays (Y/N)		Crevasse Splays (Y/N)	
Crevasse Channels (Y/N)		Crevasse Channels (Y/N)	
Notes: High alluvial flat is likely flooded infrequently- sage species		Notes: ← see	

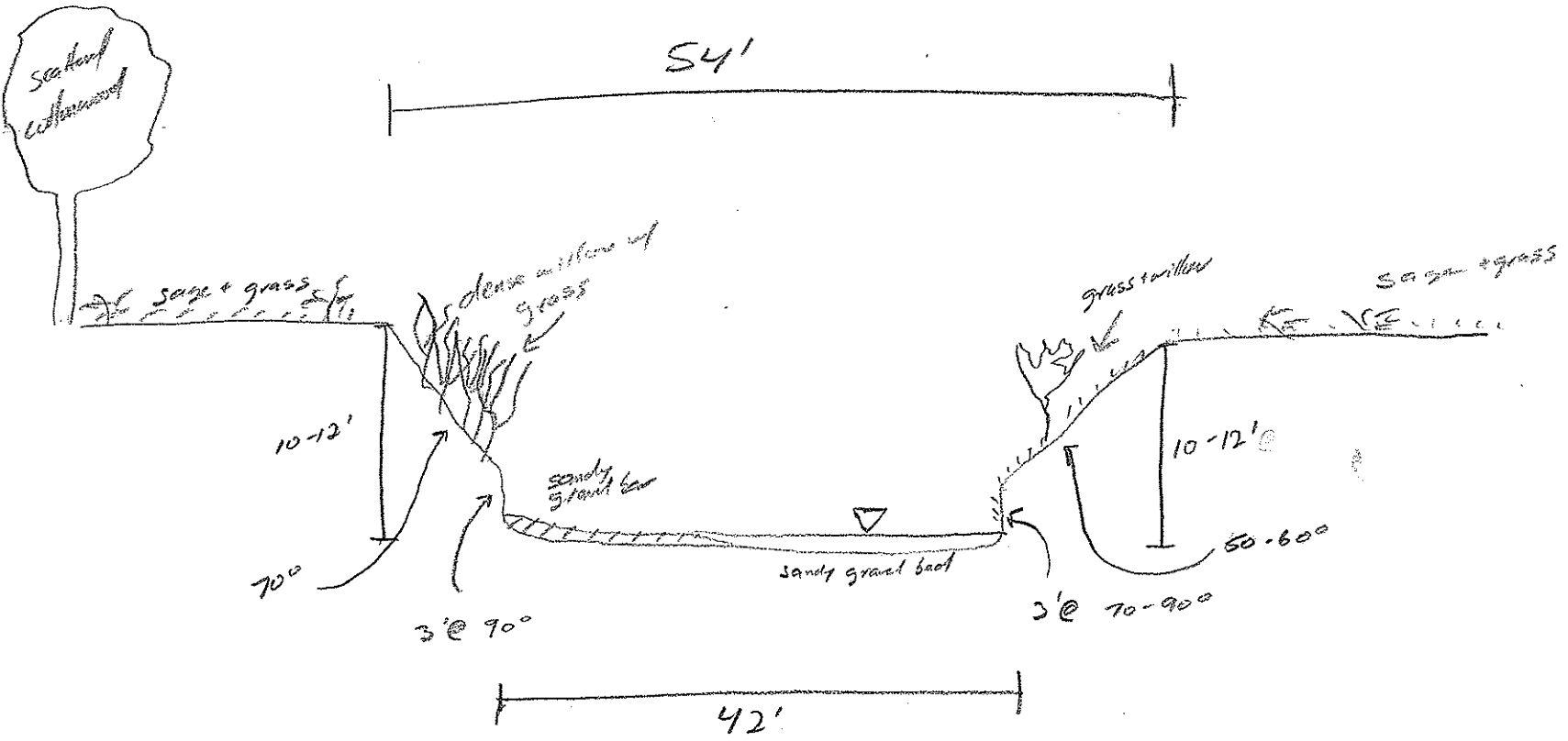
CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 54	Bridges (Y/(N))
Bankfull Depth (ft) 10-12'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) high FP / terrace flat	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 42	
	Roads (Y/(N)) > 200' from RB
Incision Evidence NO	((RR)/LB, US, DS)
	Other Infrastructure
Aggradation Evidence NO	
Bars (Y/(N)) alternate bars ~30' long by 25' wide	
widely inundated when ch. flows	
Vegetated Islands (Y/(N))	
Pool Depths (ft) ~2-3'	
Channel In Low Elevation of Valley Floor (Y/(N))	
Notes: NO 1-2-yr RI FP surface	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS NONE	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

PHOTO CHECKLIST		
Site Overview	☒	283-288 starting US - DS, LB - end on RB
Channel US Showing Both Banks	☒	250-252
Channel DS Showing Both Banks	☒	253-255
Channel Bed Surface Alluvium	☒	248, 249
Channel Bed Sub-Surface Alluvium	☒	248, 249
Bar Alluvium	☒	248, 249
Bars Overview	☒	256 US
Islands Overview	☒	NA
Left Bank Alluvium	☒	263-265
Left Bank Toe Detail	☒	257
Left Bank Top of Bank Detail	☒	258
Left Bank Overview	☒	259
Left Floodplain Alluvium	☒	266, 267
Left Floodplain Overview	☒	268-271
Left Floodplain Landforms	☒	NA
Right Bank Alluvium	☒	246
Right Bank Toe Detail	☒	260
Right Bank Top of Bank Detail	☒	261
Right Bank Overview	☒	262
Right Floodplain Alluvium	☒	247 - high FP / terrace
Right Floodplain Overview	☒	272-274
Right Floodplain Landforms	☒	NA
Infrastructure	☒	NA
Disturbance/Instability	☒	NA

PHOTO LOG		
Photo ID	View Direction	Description
275-277		Dominant high FP - terrace species on Left + Right
278	RB	landsliding on RB ~ 125' US X-ing
279-282	DS to US	left terrace photos

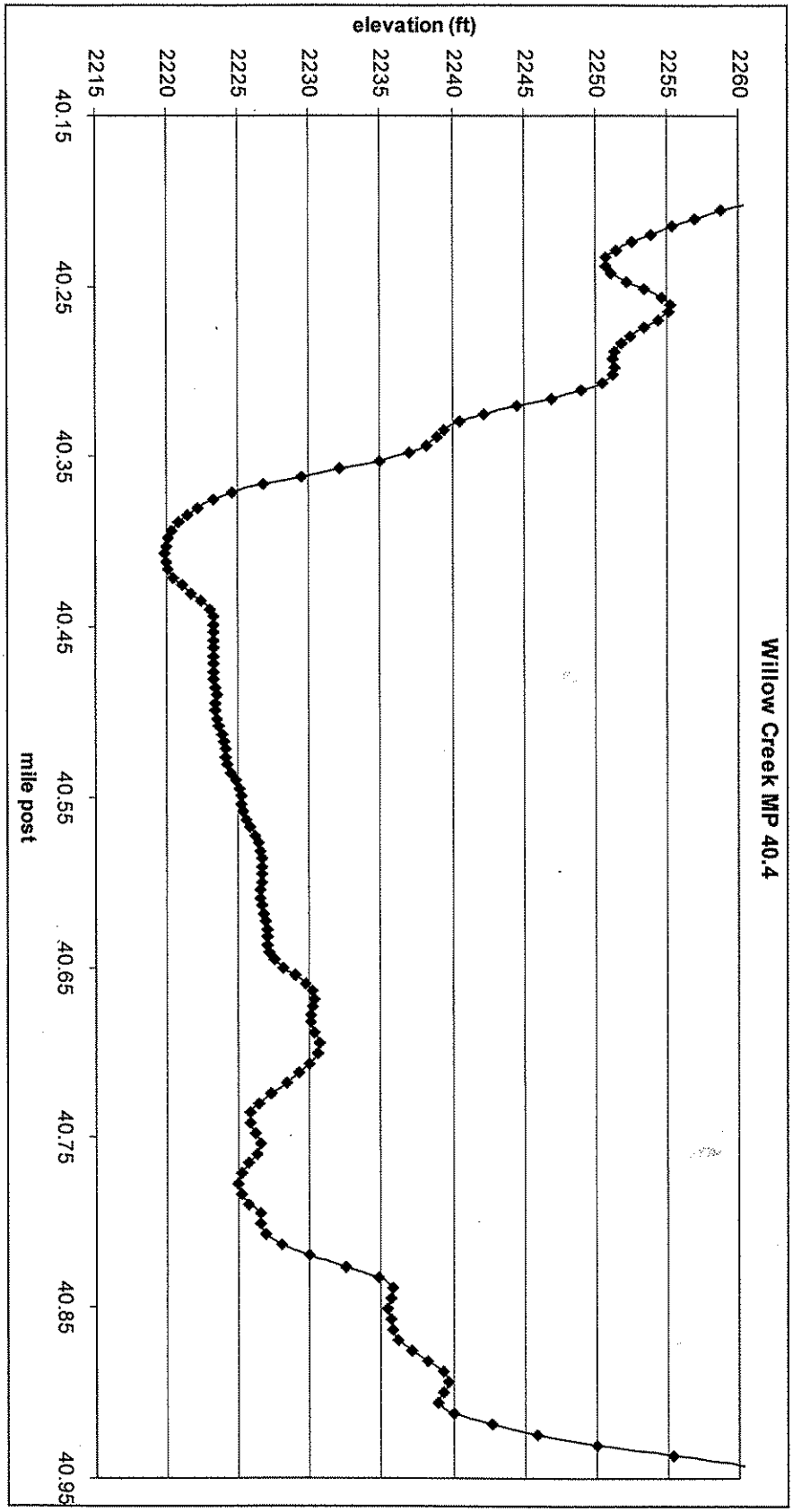
289 site overview video



- low lateral migration potential
- little to no scour potential

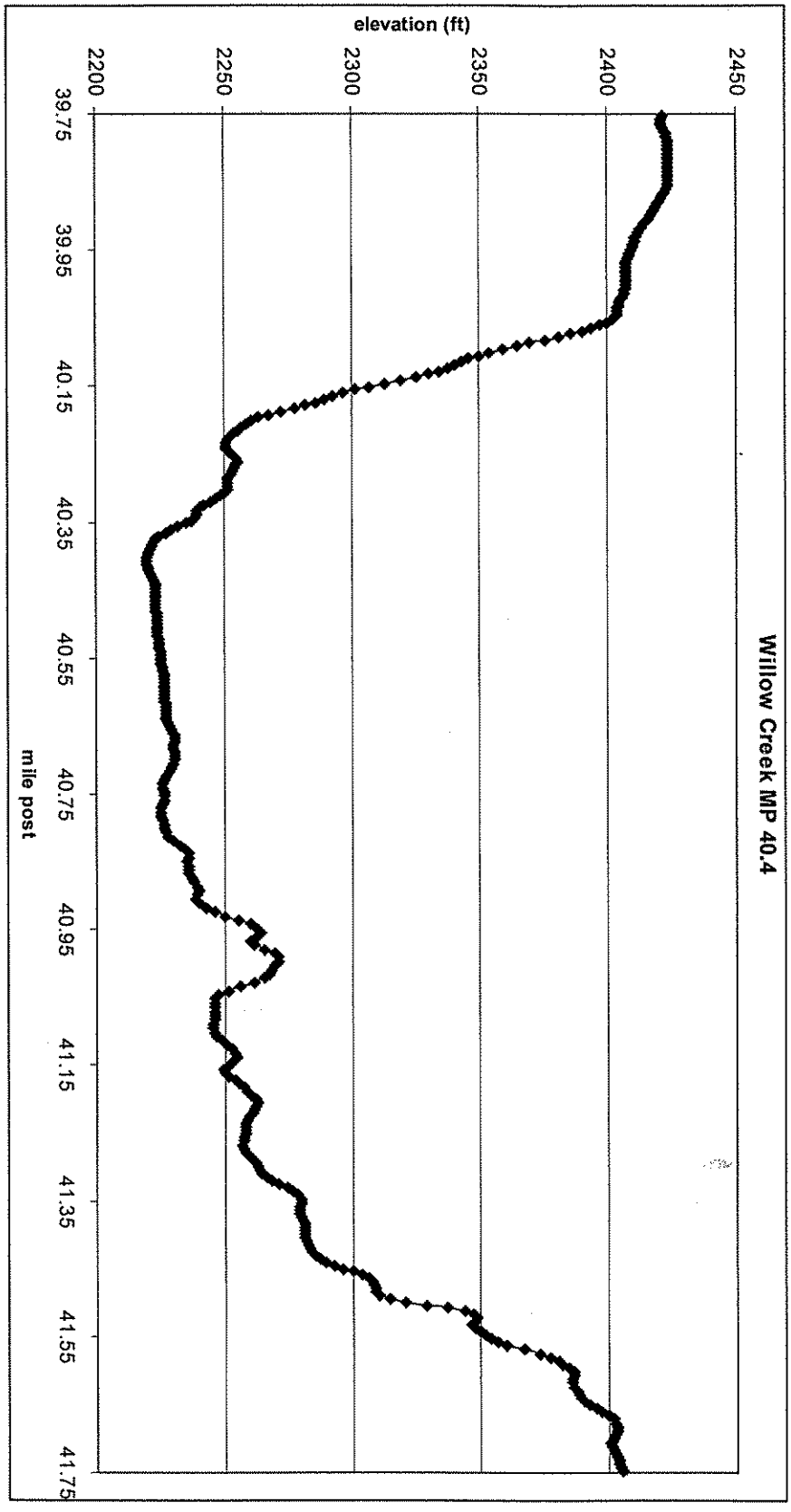
CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA

Site	**Willow Creek**	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression	273.2	–	–	–	802	3,427	6,584	12,967	28,769	56,157
06170200 Willow Creek near Hinsdale MT: Regional Regression	283.0	DS	1.45	8 (1965-1973)	821	3,507	6,731	8,701	29,373	57,296

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<0.001

Width (ft)	min	max	mean	std dev
	27	49	36	7

meander wavelength (ft): 1288

meander amplitude (ft): 1078

Sinuosity: 2.58

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	805	2165	2562	945
	1141	1876	4936	2322
	2074	1263	6422	1099
	2614	1227	8095	1286

Channel form (braided, anabranching, single thread):

Single Thread but several relic channels, river right

Channel confinement at crossing (W_v / W_c): 58.29

Valley

Gradient 0.002

width	min	max	mean	std dev
	27	49	36	7

describe geology (lithology, erodibility):

Sand and Gravel deposits from stream and floodplains

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:

Several relic channels, river right

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
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
Upstream 0 to 0.3 mi; Downstream 0 to 0.25 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):
1. Road (par. 120ft RB) 2. Bridge (DS 0.84 mi)
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

Willow Creek

Questions:

What is the likelihood the project will impact turbidity at the site?

relatively low, fairly high turbidity @ site during inspection

What is the potential impact on incision and erosion?

None - stable channel

Will the project activate historical instability?

no

What actions or alternatives can mitigate project effects?

Are there any cumulative effects of pipeline?

none known

General Notes:

KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Willow Creek - MILE POST 40.4
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

N W E S

0 125 250 500 Feet

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KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Milk River MP 82.7			Surveyors	Ericsson
GPS	WP:	N:	E:	Date/Time	8/7/2009 12:30
Flow Condition	~100 cfs (30'-40' wide x 4'? deep @ 1/2 ft/sec)				
General Site Characteristics / Comments	~~meandering~~ entrenched meandering stream crossing is on ~~outside~~ apex of meander bend. HDD crossing @ ~30' below thalweg. Mature cottonwoods (~18"-20" DBH) forest on left bank floodplain above bankfull.				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	clay		
	D_{50}	1/10 mm		
	D_{84}	1/4 mm		
	% sand	80		
	SOIL CLASS SYMBOL	SM		
Bed (sub-surface)	D_{16}			
	D_{50}			
	D_{84}	NA		
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}			
	D_{84}	NA		
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}	clay	D_{16}	
	D_{50}	1/12 mm	D_{50}	
	D_{84}	1/8 mm	D_{84}	NA
	% sand	30	% sand	
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}	clay	D_{16}	
	D_{50}	1/8 mm	D_{50}	
	D_{84}	1/4 mm	D_{84}	NA
	% sand	40	% sand	
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	

Comments:

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft)			Bank Height (ft) 3'		
Bank Slope (°)			Bank Slope (°) 90°		
Woody Cover (%)			Woody Cover (%) ~~0~~ 5		
Dominant Species			Dominant Species ~~n/a~~ willow		
Root Depth (ft) Observed Y / N			Root Depth (ft) 3'+ Observed Y / (N)		
Undercutting (Y/N)			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / N	Potential Y / N	Gradual Migration	Present Y / (N)	Potential (Y) / N
Slumping	Present Y / N	Potential Y / N	Slumping	Present Y / (N)	Potential (Y) / N
Landsliding	Present Y / N	Potential Y / N	Landsliding	Present Y / (N)	Potential Y / (N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / (N)	Potential Y / N
Notes:			Notes: bankfull / floodplain bank		
			woody cover @ bf/fp bank only		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity		Soil Maturity young	
Natural Levees (Y/N)		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft)		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H) ~~n/a~~ very low (<10%)	
Dominant Woody Species		Dominant Woody Species — salix?	
Crevasse Splays (Y/N)		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/N)		Crevasse Channels (Y/(N))	
Notes:		Notes:	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 120'	Bridges (Y/N)
Bankfull Depth (ft) 4' ?	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) bank, veg	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 40'	
	Roads (Y/N)
Incision Evidence NA	(RR, LB, US, DS) 2 crossing on high terrace
	Other Infrastructure
Aggradation Evidence NA	
Bars (Y/N) downstream on right bank	
Vegetated Islands (Y/N)	
Pool Depths (ft) ?	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes: Fine grained low velocity meandering system, minimal lateral migration due to confinement and clay soils	Notes:

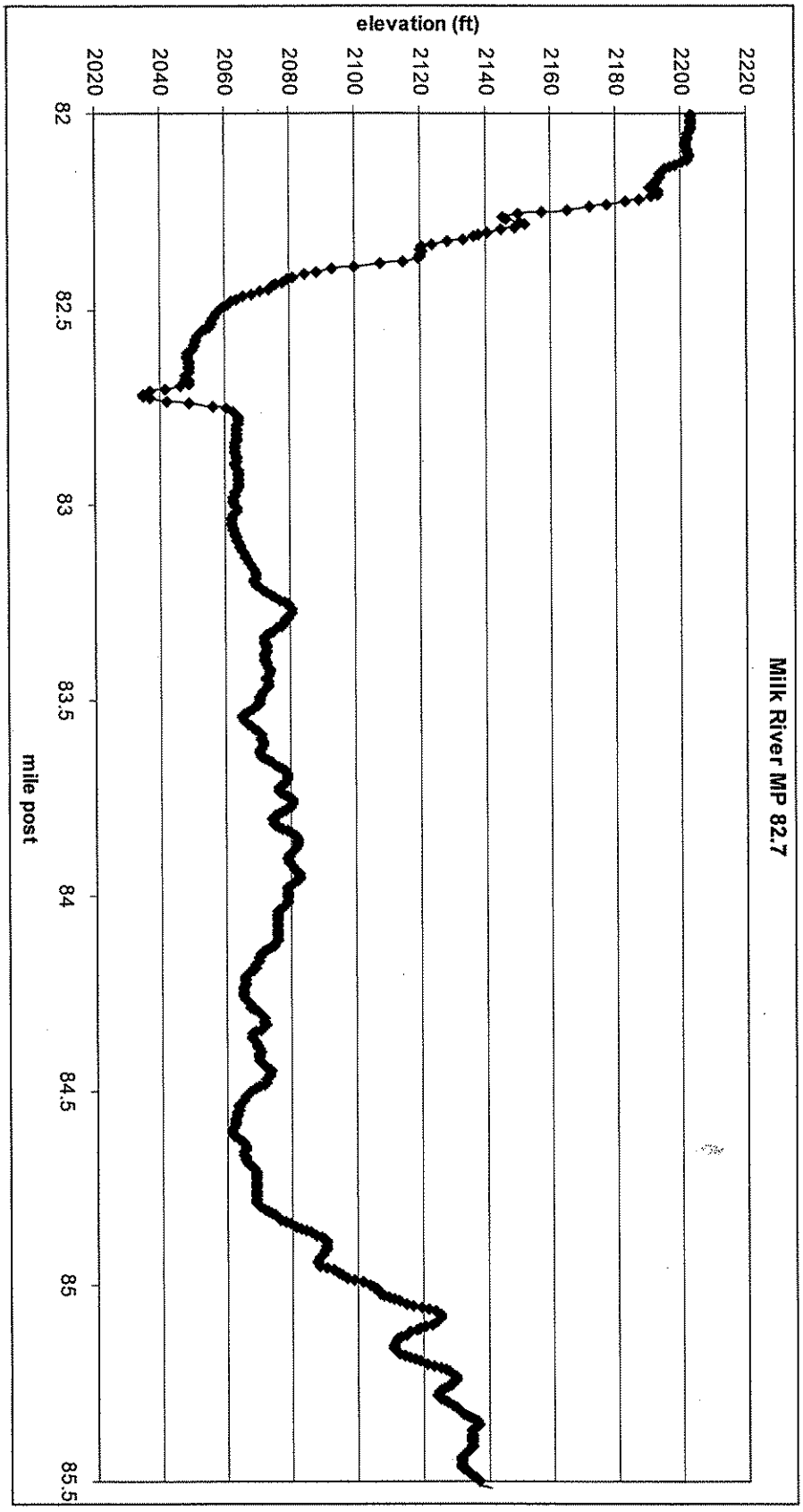
CHANNEL DISTURBANCE/PERTERBATIONS	
Natural NA	Artificial
Beaver dams NA	In-stream structures NA
Debris flow NA	
	Flow Diversion NA
Landslides NA	
	Debris NA
Woody debris NA	
Other:	Other:

PHOTO CHECKLIST		
Site Overview	☒	349-353 panaramic starting from us →ds
Channel US Showing Both Banks	☒	347
Channel DS Showing Both Banks	☒	346
Channel Bed Surface Alluvium	☒	335 336
Channel Bed Sub-Surface Alluvium	☒	NA
Bar Alluvium	☒	NA
Bars Overview	☒	NA
Islands Overview	☒	NA
Left Bank Alluvium	☒	no access
Left Bank Toe Detail	☒	"
Left Bank Top of Bank Detail	☒	"
Left Bank Overview	☒	X 337
Left Floodplain Alluvium	☒	No access
Left Floodplain Overview	☒	348
Left Floodplain Landforms	☒	NA
Right Bank Alluvium	☒	341
Right Bank Toe Detail	☒	339
Right Bank Top of Bank Detail	☒	340
Right Bank Overview	☒	338
Right Floodplain Alluvium	☒	344
Right Floodplain Overview	☒	345 (looking upstream)
Right Floodplain Landforms	☒	NA
Infrastructure	☒	NA
Disturbance/Instability	☒	NA

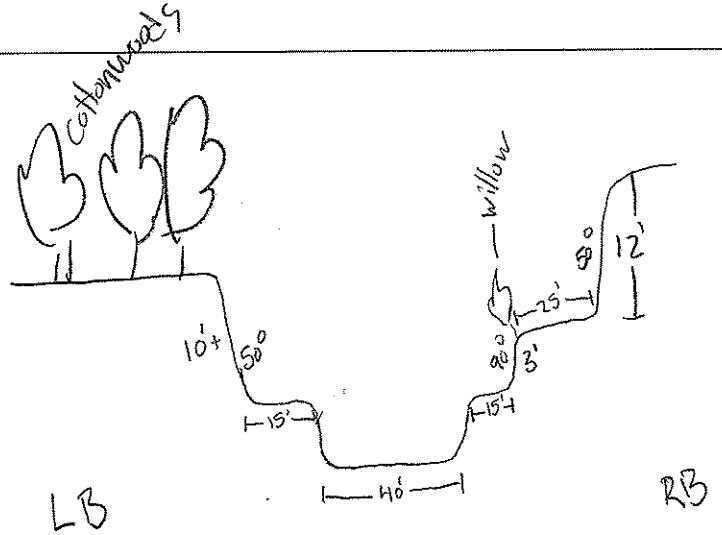
PHOTO LOG		
Photo ID	View Direction	Description
342	upstream	rt bank bankfull floodplain bf/fp boundary left side bank
343	perp to ch.	rt bank bankfull bank undercutting
344		

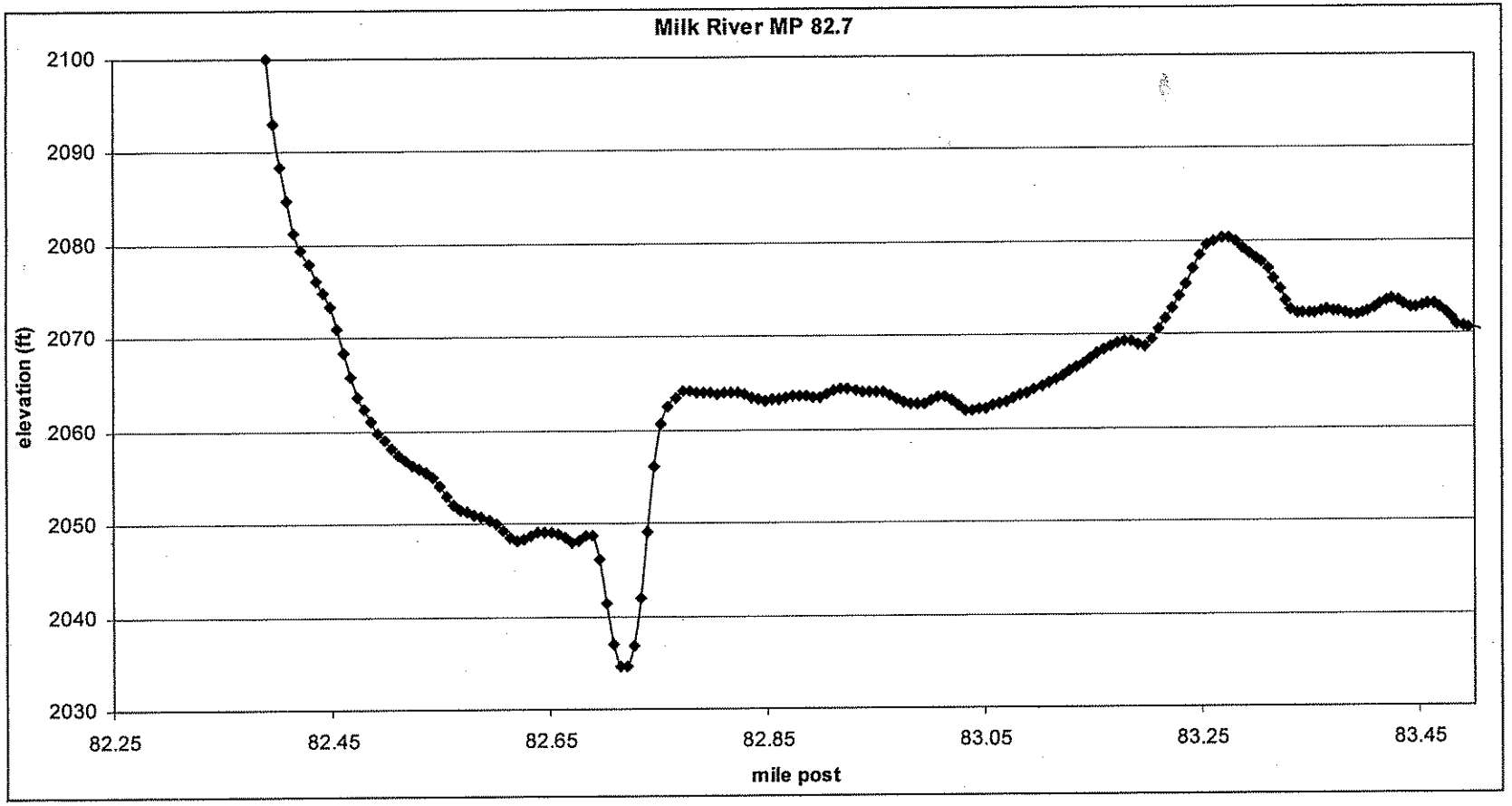
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



CHANNEL CROSS-SECTION SKETCH





*notes -- channel cross-section derived from 30 / 10 meter USGS DEM

PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA

Site	Milk River	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression*	22,324	–	–	–	–	–	–	–	–	–
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: Bulletn 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

Gradient: <.001

width	min	max	mean	std dev
	84	104	95	8

meander wavelength (ft): 3343

meander amplitude (ft): 1266

Sinuosity: 2.80

radius of curvature (ft)	Upstream (ft) distance from crossing	Upstream (ft) radius of curvature	Downstream (ft) distance from crossing	Downstream (ft) radius of curvature
	1765	3178	2175	3920
	15137	11037	7278	2929
	21140	6586	8836	2644
	26145	8492	11244	4349

Valley

Gradient: <0.01

width	min	max	mean	std dev
	2624	3019	2785	148

describe geology (lithology, erodibility):

Alluvium of modern channels and flood plain.

Bedrock: Shale

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:

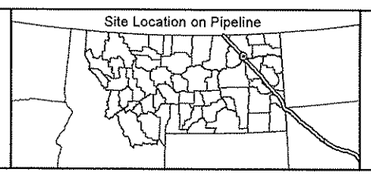
Oxbow or man made pond (US 0.25 mi river right); Oxbow or man made pond (DS 0.82mi river right, near SHighway 117)

Channel form (braided, anabranching, single thread):	
Single thread	
Channel confinement at crossing (W_v / W_c): 90.98	channel cut-offs: none
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
Incised, the floodplain surrounding the channel has a higher elevation than the channel	
Unique features, exceptions, etc	
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):	
DS 0.26 mi; US 0.34 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. Road (River right 0.15 mi, per. and river left 0.26 mi par.) 2. Railroad (River left 0.26 mi, par.) 3. Residence (river right 0.15,). DS: 2. Bridge (1.33 mi)	
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):	
None	

Perennial Stream Crossings
Intermittent Stream Crossings
Proposed Pipeline Route
1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Milk River - MILE POST 82.7
2005 NAIP Aerial

ENTRIX

200 1st Ave W Ste 500
Seattle, WA 98119

ph (206) 269-0104
fx (206) 269-0098

www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 100 200 400 Feet

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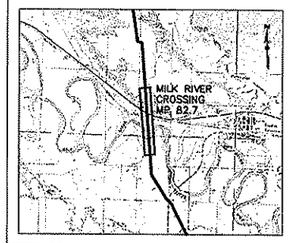
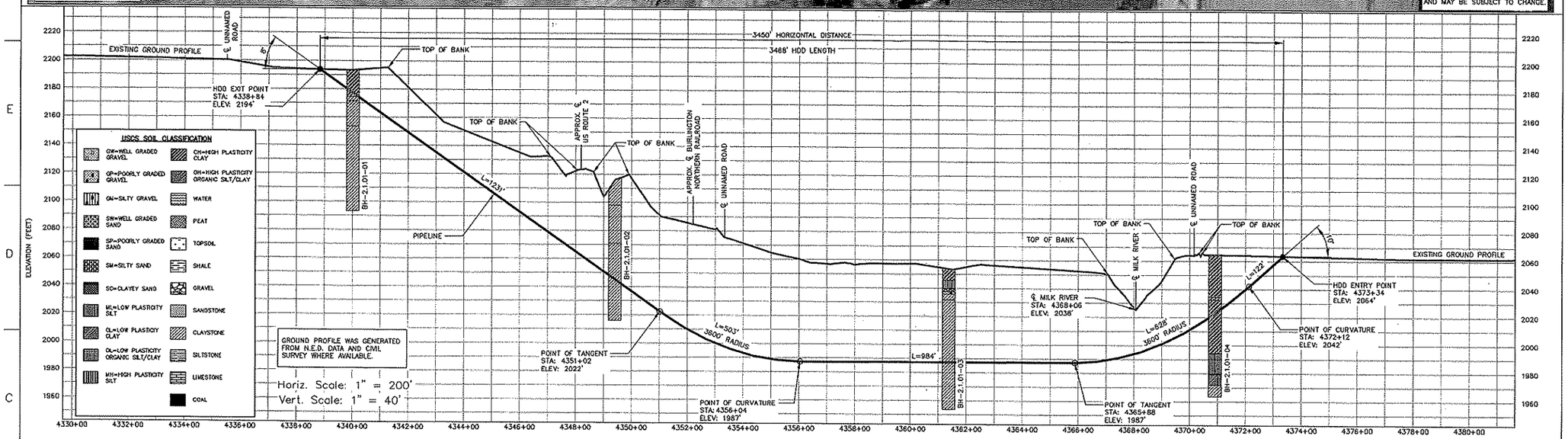
File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd





USCS SOIL CLASSIFICATION

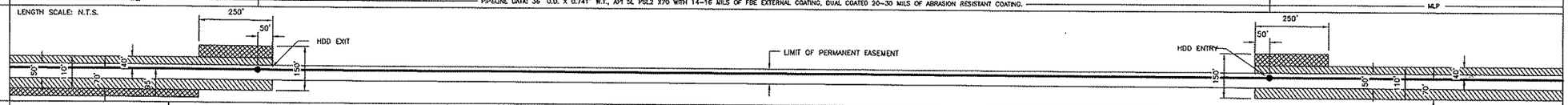
GW=WELL GRADED GRAVEL	CH=HIGH PLASTICITY CLAY
GP=POORLY GRADED GRAVEL	OH=HIGH PLASTICITY ORGANIC SILT/CLAY
GM=SILTY GRAVEL	WATER
SW=WELL GRADED SAND	PEAT
SP=POORLY GRADED SAND	TOPSOL
SM=SILTY SAND	SHALE
SC=CLAYEY SAND	GRAVEL
ML=LOW PLASTICITY SILT	SANDSTONE
CL=LOW PLASTICITY CLAY	CLAYSTONE
OL=LOW PLASTICITY ORGANIC SILT/CLAY	SILTSTONE
MH=HIGH PLASTICITY SILT	LIMESTONE
	COAL

GROUND PROFILE WAS GENERATED FROM N.E.D. DATA AND CIVIL SURVEY WHERE AVAILABLE.

Horiz. Scale: 1" = 200'
Vert. Scale: 1" = 40'

CROSSING INFORMATION (ESTIMATED STATIONS)	4335+52 ℄ UNNAMED ROAD	4338+84 HDD EXIT POINT	4340+00 BH-2.1.01-01	4341+28 TOP OF BANK	4347+12 TOP OF BANK	4348+05 TOP OF BANK	4348+20 APPROX. ℄ US ROUTE 2	4348+64 TOP OF BANK	4349+41 BH-2.1.01-02	4349+80 TOP OF BANK	4351+02 PT OF TANGENT	4352+20 APPROX. ℄ BURLINGTON NORTHERN RAILROAD	4353+33 ℄ UNNAMED ROAD	4356+04 PT OF CURVATURE	4361+38 BH-2.1.01-03	4365+88 PT OF TANGENT	4367+07 TOP OF BANK	4368+06 ℄ MILK RIVER	4369+47 TOP OF BANK	4370+15 ℄ UNNAMED ROAD	4370+33 TOP OF BANK	4370+43 TOP OF BANK	4370+91 BH-2.1.01-04	4372+12 PT OF CURVATURE	4373+34 HDD ENTRY POINT
PIPELINE DATA	MLP	PIPELINE DATA: 36" O.D. X 0.741" W.T., API 5L PSL2 X70 WITH 14-16 MILS OF FBE EXTERNAL COATING, DUAL COATED 20-30 MILS OF ABRASION RESISTANT COATING.																							MLP

LENGTH SCALE: N.T.S.



ENVIRONMENTAL MITIGATION/RECLAMATION	
	TOPSOIL SALVAGE METHOD
	STREAMS
	WETLANDS
	TIMING CONSRAINTS
	MILEPOST
	MONITORING
	RECLAMATION
	SPECIAL CONSIDERATIONS

TO BE DETERMINED

INSTALLATION NOTES

1) ACCESS: ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY FROM PUBLIC OR APPROVED PRIVATE ROADS.
2) VEHICLE AND EQUIPMENT ACCESS CROSSING MAY BE INSTALLED IF APPROVED BY THE ENVIRONMENTAL INSPECTOR.
3) WORK SPACE: WORK SPACE LIMITS ARE DEPICTED. CLEARING WILL BE RESTRICTED TO THE WORK SPACES INDICATED AT THE ENTRY AND EXIT POINTS AND PULLBACK MAKE-UP AREA ALONG THE RIGHT-OF-WAY. CLEARING BETWEEN THE ENTRY AND EXIT POINTS IS LIMITED TO THE MINIMUM AMOUNT NECESSARY TO STRING LOCATION WIRES AND INSTALL PUMPS AND PIPING TO OBTAIN WATER (WHERE APPROVED).
4) WATER SOURCE: DRILL WATER AND PRE-INSTALLATION HYDROSTATIC TEST WATER SHALL BE OBTAINED FROM AN APPROVED SOURCE. THE CONTRACTOR SHALL SCREEN THE INTAKE HOSE TO PREVENT THE ENTRAINMENT OF FISH OR DEBRIS AND IN ACCORDANCE WITH THE CONSTRUCTION MITIGATION AND RECLAMATION PLAN (CMRP) AND PROJECT REQUIREMENTS. THE HOSE SHALL BE KEPT OFF THE BOTTOM OF THE WATER BODY.
5) HYDROSTATIC TEST: PRE-INSTALLATION HYDROSTATIC TEST SHALL BE CONDUCTED IN ACCORDANCE WITH PERMIT REQUIREMENTS. THE CONTRACTOR SHALL DISCHARGE HYDROSTATIC TEST WATER IN ACCORDANCE WITH PROJECT PERMITS. DISCHARGES WILL BE BACK TO THE WATER SOURCE UNLESS OTHERWISE DIRECTED BY THE ENVIRONMENTAL INSPECTOR. DISCHARGES SHALL NOT CAUSE EROSION OR SEDIMENTATION, TO REDUCE THE VELOCITY OF THE DISCHARGE, THE CONTRACTOR SHALL UTILIZE AN ENERGY-DISSIPATING DEVICE AS DESCRIBED IN THE CMRP.
6) SPILL-PREVENTION: ALL PUMPS SHALL BE SET IN SECONDARY CONTAINMENT AND IN ACCORDANCE WITH THE SPILL PREVENTION CONTROL AND COUNTERMEASURE PLAN (SPCC). EQUIPMENT AND PUMPS OPERATING WITHIN 100 FEET OF ANY WATER BODY OR WETLAND SHALL BE OPERATED AND REFUELED IN ACCORDANCE WITH THE SPCC PLAN. EQUIPMENT REFUELING AND STORAGE OF HAZARDOUS MATERIALS, FUELS, ETC. SHALL BE CONDUCTED AT LEAST 100 FEET FROM WATER BODIES AND WETLANDS. EACH CONSTRUCTION CREW SHALL HAVE ON HAND SUFFICIENT TOOLS AND MATERIALS TO STOP LEAKS AND SUPPLIES OF ABSORBENT AND BARRIER MATERIALS TO ALLOW RAPID CONTAINMENT AND RECOVERY OF SPILLED MATERIALS.
7) EROSION AND SEDIMENT CONTROL: CONTRACTOR SHALL SUPPLY, INSTALL AND MAINTAIN SEDIMENT CONTROL STRUCTURES IN ACCORDANCE WITH CONTRACT DOCUMENTS. CONTRACTOR SHALL INSTALL ADDITIONAL EROSION CONTROL STRUCTURES AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR.
8) TOPSOIL SHALL BE STRIPPED AS REQUIRED BY PROJECT SPECIFICATIONS.
9) PRIOR TO PIPE PULLBACK, CONTRACTOR'S ACTUAL DRILL PROFILE SHALL BE SUBMITTED TO KEYSTONE FOR APPROVAL.
10) INSTALLATION: THE PIPE SECTION FOR THE DRILLED CROSSING SHALL BE MADE UP WITHIN THE RIGHT-OF-WAY AT THE DRILL EXIT POINT AS SHOWN. CONTRACTOR SHALL ASSESS THE NEED FOR AND SUPPLY APPROPRIATE BALLAST DURING PULLBACK.
11) MUD DISPOSAL: CONTRACTOR SHALL DISPOSE OF EXCESS DRILLING MUD AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS. UNDER NO CIRCUMSTANCES SHALL DRILLING FLUID BE DISPOSED OF IN WATER BODIES OR WETLANDS. ANY DRILLING MUD WHICH INADVERTENTLY EXITS AT POINTS OTHER THAN THE ENTRY AND EXIT POINTS SHALL BE CONTAINED AND COLLECTED TO THE EXTENT PRACTICAL AND DISPOSED OF AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS.
12) CLEANUP/STABILIZATION/RESTORATION: ALL DISTURBED AREAS SHALL BE RETURNED TO THE ORIGINAL CONTOURS. DISTURBED AREAS SHALL BE SEEDED AS SPECIFIED IN PROJECT DOCUMENTS.
13) NOMINAL WORKING SPACE DIMENSIONS ARE SHOWN. LARGER AREAS MAY BE REQUIRED IN IRREGULAR TERRAIN. UPDATED DIMENSIONS MAY BE PROVIDED AFTER LOCAL TOPOGRAPHICAL SURVEYS ARE PERFORMED.

LEGEND

- POINT OF INTERSECTION (P.I.)
- ENTRY OR EXIT POINT
- GEOTECHNICAL BOREHOLE
- POWERPOLE
- MLP: MAINLINE PIPE
- PIPELINE
- FOREIGN PIPELINE
- EDGE OF WATER
- PRIVATE ACCESS SHOO FLY ROAD
- COUNTY BOUNDARY
- WATER LEVEL
- USACOE CONSTRUCTION REFERENCE POINT
- WETLANDS
- PERMANENT EASEMENT
- TEMPORARY EASEMENT
- EXTRA WORKSPACE

REFERENCE DRAWINGS

DRAWING No	TITLE

REVISION

REV No	DATE	DESCRIPTION	APPROVAL: PROJECT CODE	DRAFTER	DRAFTING CHECKER	DESIGNER	DESIGN CHECKER	PROJECT MANAGER	COMPANY
3	07.06.09	ISSUED FOR SUPPLEMENTAL U.S. DEPT. OF STATE FILING (02.15.09 CL)	THES0050388XS	JB	AH	FP	FP	RG	TROW
2	04.21.09	ISSUED FOR REVIEW (02.15.09 CL)	THES0050388XS	AH	AH	FP	FP	RG	TROW
1	12.08.08	ISSUED FOR REVIEW (12.1.08 CL)	THES0050388X	JB	AH	HF	RB	RG	TROW
0	11.19.08	ISSUED FOR UNITED STATES DEPARTMENT OF STATE (07.31.08 CL)	THES0050388X	JB	JP	FP	RB	RG	TROW

PROFESSIONAL ENGINEER/RPT | PERMIT/ ENG. APPROVAL | DATE

PRELIMINARY

REV. NO.	DATE	PERMIT NUMBER:

CADD DRAWING: DO NOT MAKE MANUAL REVISIONS

TROW ENGINEERING CONSULTANTS INC. | ConocoPhillips | TransCanada In business to deliver

VALLEY SECTION

FIA #	CHAINAGE:	DISCIPLINE #
4360	MP 82.7	03

MILK RIVER HDD INSTALLATION
KEYSTONE XL PROJECT
VALLEY COUNTY, MONTANA

SCALE	DRAWING No	REV
AS SHOWN	4360-03-ML-03-001	3

TIME---DESIGNFILE

TC_UD_BR.DWG 22x34

PLOTTED SIZE: ANSI D (22x34)

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Missouri River MP 89			Surveyors	Eriksson
GPS	WP:	N:	E:	Date/Time	8/7/09 2:00 pm
Flow Condition	check gauge				
General Site Characteristics / Comments	Crossing at apex of meander on flow regulated Missouri R. downstream of Ft. Peck Dam. Big perennial river with high banks and mature cottonwood forests on floodplains.				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	silt		
	D_{50}	1/5		
	D_{84}	1.5 mm		
	% sand	95		
	SOIL CLASS SYMBOL	SP		
Bed (sub-surface)	D_{16}			
	D_{50}			
	D_{84}	NA		
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}			
	D_{84}	NA cobbles		
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	clay
	D_{50}	NA	D_{50}	1/10 mm
	D_{84}	NA	D_{84}	1 mm
	% sand		% sand	65
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	SC
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}	NA	D_{84}	
	% sand		% sand	
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	

Comments:

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 25'			Bank Height (ft) 12'		
Bank Slope (°) 80-75°			Bank Slope (°) > 70°		
Woody Cover (%) 0			Woody Cover (%) 75		
Dominant Species —			Dominant Species Salix		
Root Depth (ft) 1.5' Observed (Y) N			Root Depth (ft) ? Observed Y / (N)		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y /(N)	Potential (Y)/ N	Gradual Migration	Present Y / (N)	Potential Y /(N)
Slumping	Present (Y)/ N	Potential (Y)/ N	Slumping	Present Y /(N)	Potential (Y)/ N
Landsliding	Present Y /(N)	Potential Y /(N)	Landsliding	Present Y / (N)	Potential Y / (N)
Other:	Present Y /(N)	Potential Y /(N)	Other:	Present Y / (N)	Potential Y /(N)
Notes:			Notes:		
			No access, observed		
			from left bank		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity		Soil Maturity	
Natural Levees (Y/(N))		Natural Levees (Y/N)	
Description:		Description	
		No Access	
Artificial Levees (Y/(N))		Artificial Levees (Y/N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft)	
Woody Riparian Plant Density (L,M,H) —		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species —		Dominant Woody Species	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/N)	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/N)	
Notes:		Notes: Mature Cottonwood forest	
Farmed Field			

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 1100'	Bridges (Y/N)
Bankfull Depth (ft) ~~Feet~~ 12'+ depth to thalweg	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) bank	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) ~1000'	
	Roads (Y/N)
Incision Evidence NA	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence NA	dam upstream regulating all flows
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) ?	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes: both lateral and instream bars	Notes:

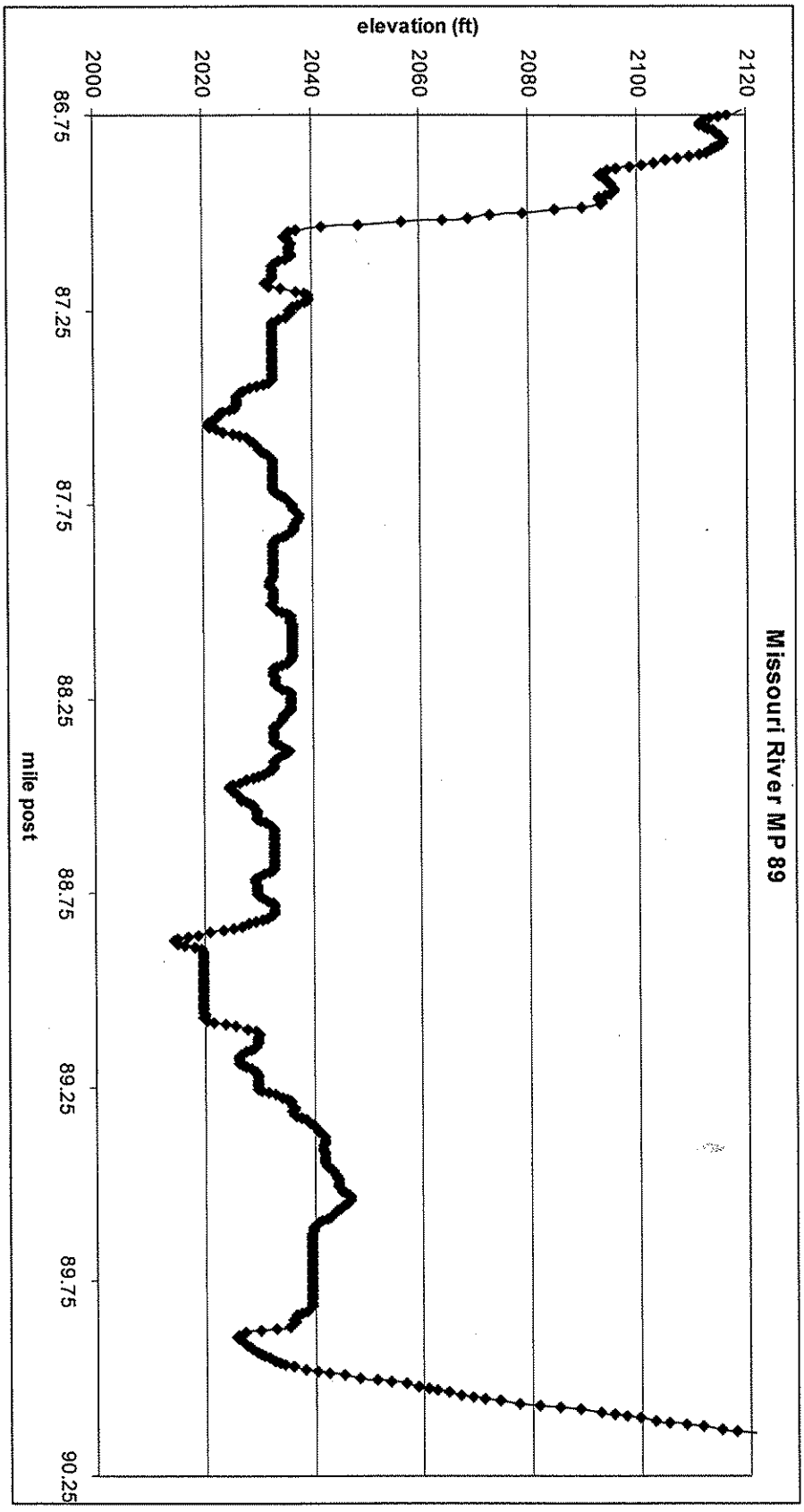
CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams —	In-stream structures dam upstream
Debris flow —	
	Flow Diversion multiple for irrigation
Landslides —	pumps
	Debris —
Woody debris —	
Other: —	Other: —

PHOTO CHECKLIST		
Site Overview	☑	370 - 374 panaramic
Channel US Showing Both Banks	☑	359-361 panaramic
Channel DS Showing Both Banks	☑	362-363 panaramic
Channel Bed Surface Alluvium	☒	358
Channel Bed Sub-Surface Alluvium	☑	NA
Bar Alluvium	☒	NA
Bars Overview	☒	364, 365
Islands Overview	☑	364, 365 (instream bars)
Left Bank Alluvium	☑	357
Left Bank Toe Detail	☑	354
Left Bank Top of Bank Detail	☑	356
Left Bank Overview	☑	355
Left Floodplain Alluvium	☐	—
Left Floodplain Overview	☐	~~367-369 panaramic~~ 376
Left Floodplain Landforms	☑	—
Right Bank Alluvium	☒	—
Right Bank Toe Detail	☒	—
Right Bank Top of Bank Detail	☒	—
Right Bank Overview	☒	367-369 panaramic
Right Floodplain Alluvium	☒	—
Right Floodplain Overview	☒	367-369 panaramic
Right Floodplain Landforms	☒	—
Infrastructure	☒	—
Disturbance/Instability	☒	—

PHOTO LOG		
Photo ID	View Direction	Description
366	upstream	dam
375		lb FP

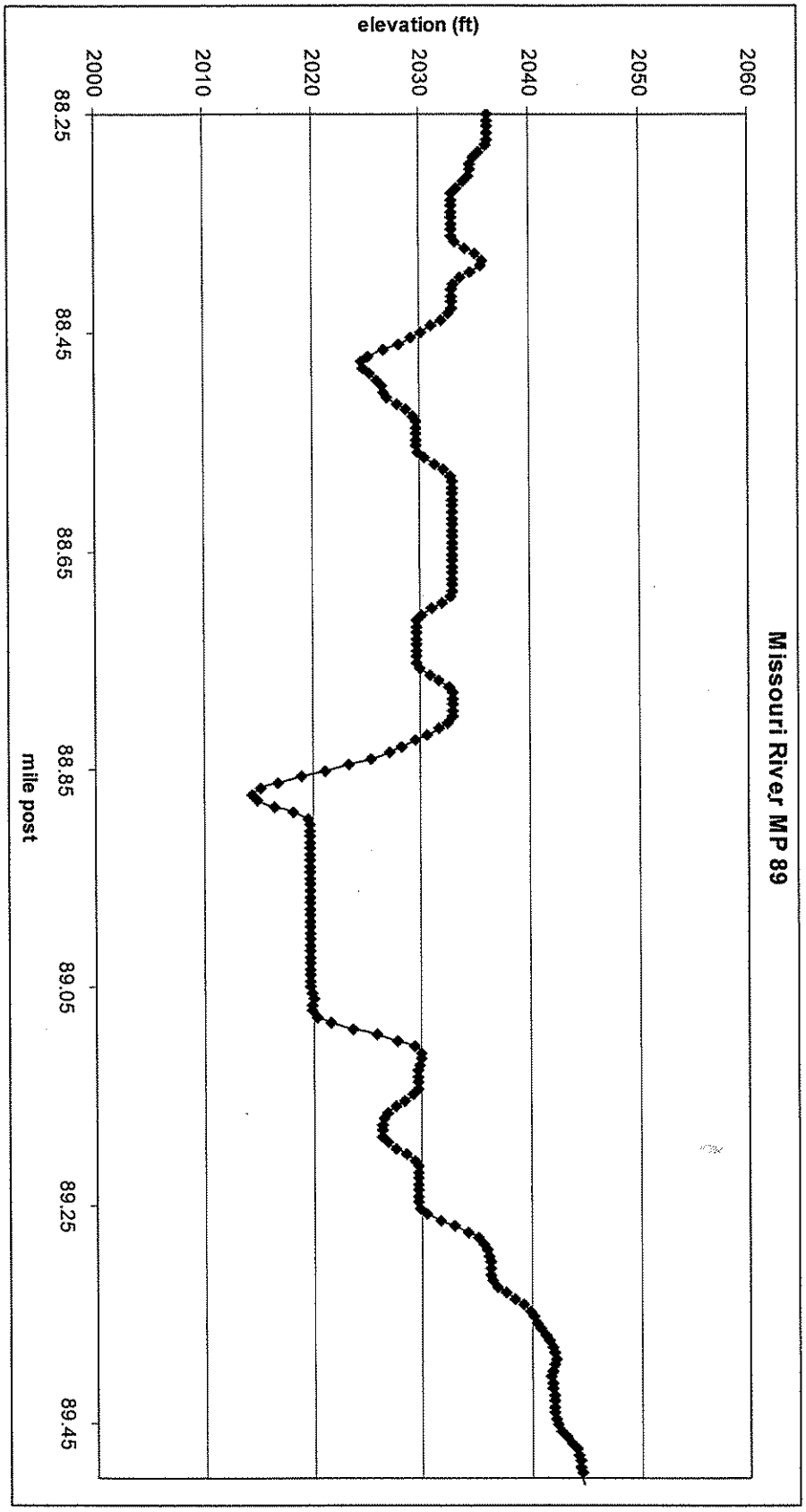
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA

Site	Missouri River	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression *	57,565	--	--	--						
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 for watershed 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

Gradient 0.02

width	min	max	mean	std dev
	656	987	811	147

meander wavelength (ft): 15,009

meander amplitude (ft): 5352

Sinuosity: 1.35

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	1765	22045	21140	13366
	15137	14996	26145	8754
			2175	9358

Valley

Gradient 0.03

width	min	max	mean	std dev
	3289	4380	3780	358

describe geology (lithology, erodibility):

Alluvium of modern channels and flood plains

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:

US River Right 0.85 mi due south

Channel form (braided, anabranching, single thread):	channel cut-offs: None
Single Thread	
Channel confinement at crossing (W_v / W_c): 13.17	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
Incised:The flood plain elevation is higher than the channel.	
Unique features, exceptions, etc:	
There is sediment deposition or an avulsion near the site. US there are two depositional features (islands) which appear to have vegetation: 0.44 mi from crossing, river right 0.00 mi from crossing. The influence of confluence with Milk River (0.30 mi DS) could be causing sediment desposition.	
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. Dam 9.3 mi @ Ft. Peck 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.)	
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):	
None	

1320000 17460000 1316000 1312000

17460000

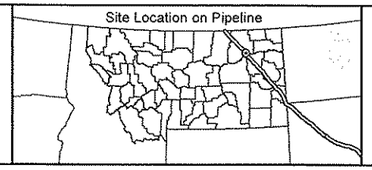
17464000

1320000 1316000 1312000

- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Missouri River - MILE POST 89.0
2005 NAIP Aerial

ENTRIX

200 1st Ave W Ste 500
Seattle, WA 98119

ph (206) 269-0104
fx (206) 269-0098

www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

S W E N

0 300 600 1,200 Feet

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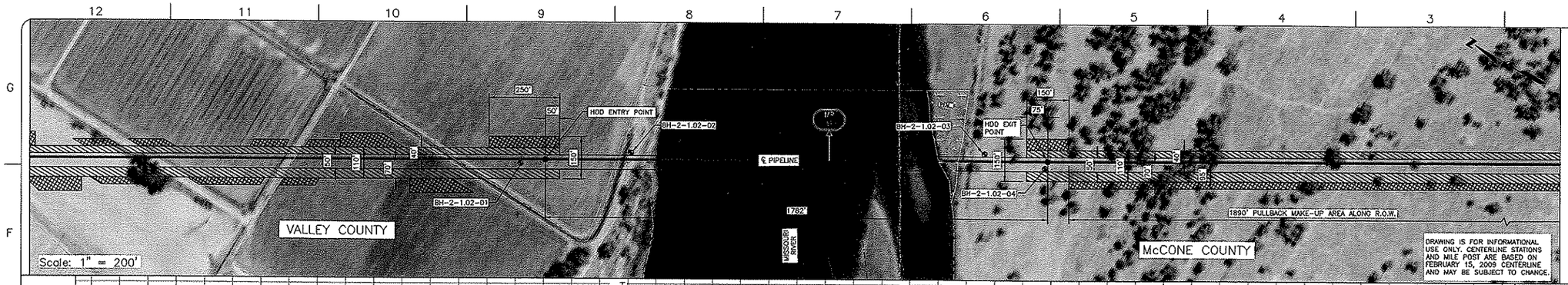
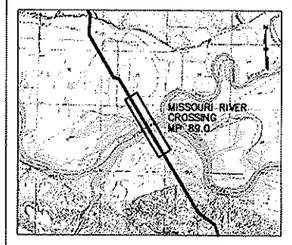
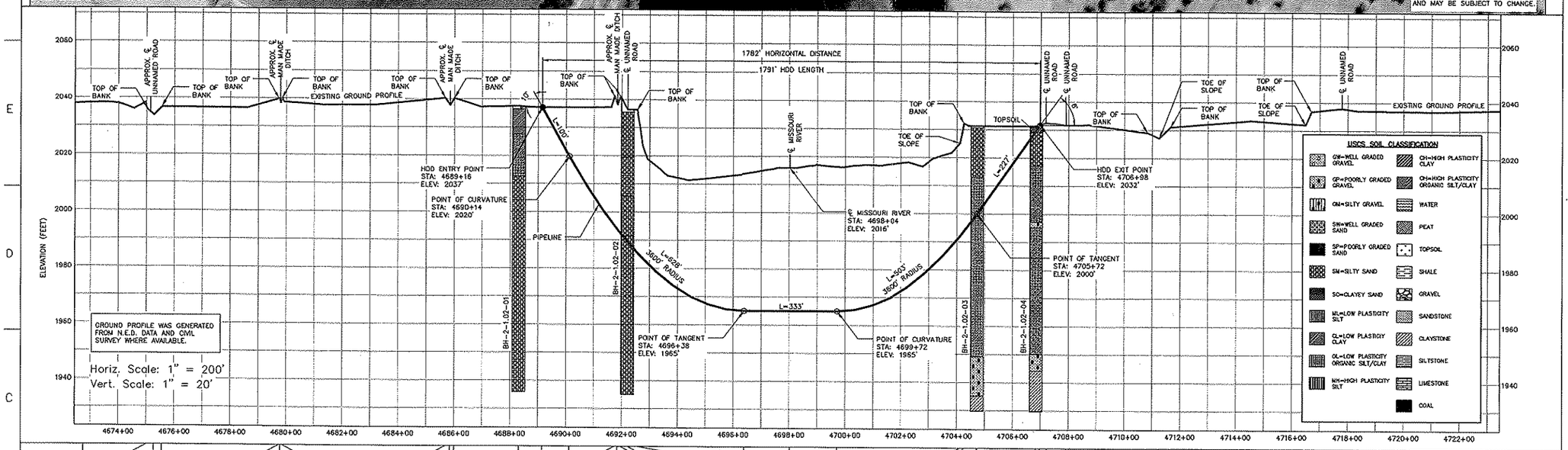
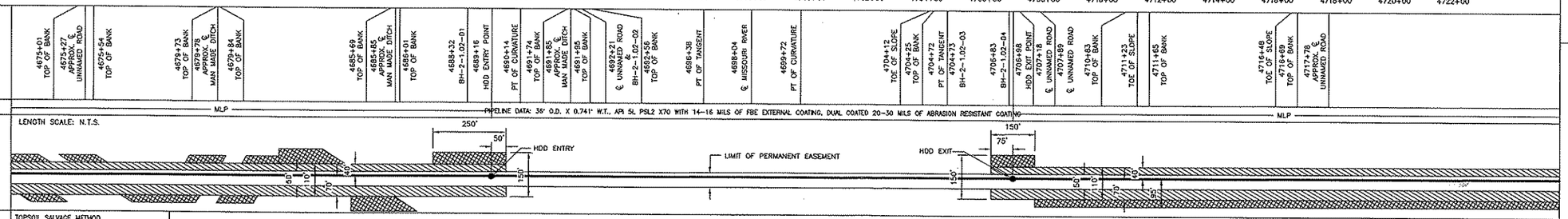
File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd









INSTALLATION NOTES

1) ACCESS ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY FROM PUBLIC OR APPROVED PRIVATE ROADS.
2) VEHICLE AND EQUIPMENT ACCESS CROSSING MAY BE INSTALLED IF APPROVED BY THE ENVIRONMENTAL INSPECTOR.
3) WORK SPACE: WORK SPACE LIMITS ARE DEPICTED. CLEARING WILL BE RESTRICTED TO THE WORK SPACES INDICATED AT THE ENTRY AND EXIT POINTS AND PULLBACK MAKE-UP AREA ALONG THE RIGHT-OF-WAY. CLEARING BETWEEN THE ENTRY AND EXIT POINTS IS LIMITED TO THE MINIMUM AMOUNT NECESSARY TO STRING LOCATION WIRES AND INSTALL PUMPS AND PIPING TO OBTAIN WATER (WHERE APPROVED).
4) WATER SOURCE: DRILL WATER AND PRE-INSTALLATION HYDROSTATIC TEST WATER SHALL BE OBTAINED FROM AN APPROVED SOURCE. THE CONTRACTOR SHALL SCREEN THE INTAKE HOSE TO PREVENT THE ENTRAINMENT OF FISH OR DEBRIS AND IN ACCORDANCE WITH THE CONSTRUCTION MITIGATION AND RECLAMATION PLAN (CMRP) AND PROJECT REQUIREMENTS. THE HOSE SHALL BE KEPT OFF THE BOTTOM OF THE WATER BODY.
5) HYDROSTATIC TEST: PRE-INSTALLATION HYDROSTATIC TEST SHALL BE CONDUCTED IN ACCORDANCE WITH PERMIT REQUIREMENTS. THE CONTRACTOR SHALL DISCHARGE HYDROSTATIC TEST WATER IN ACCORDANCE WITH PROJECT PERMITS. DISCHARGES WILL BE BACK TO THE WATER SOURCE UNLESS OTHERWISE DIRECTED BY THE ENVIRONMENTAL INSPECTOR. DISCHARGES SHALL NOT CAUSE EROSION OR SEDIMENTATION. TO REDUCE THE VELOCITY OF THE DISCHARGE, THE CONTRACTOR SHALL UTILIZE AN ENERGY-DISSIPATING DEVICE AS DESCRIBED IN THE CMRP.
6) SPILL-PREVENTION: ALL PUMPS SHALL BE SET IN SECONDARY CONTAINMENT AND IN ACCORDANCE WITH THE SPILL PREVENTION CONTROL AND COUNTERMEASURE PLAN (SPCC). EQUIPMENT AND PUMPS OPERATING WITHIN 100 FEET OF ANY WATER BODY OR WETLAND SHALL BE OPERATED AND REFUELED IN ACCORDANCE WITH THE SPCC PLAN. EQUIPMENT REFUELING AND STORAGE OF HAZARDOUS MATERIALS, FUELS, ETC. SHALL BE CONDUCTED AT LEAST 100 FEET FROM WATER BODIES AND WETLANDS. EACH CONSTRUCTION CREW SHALL HAVE ON HAND SUFFICIENT TOOLS AND MATERIALS TO STOP LEAKS AND SUPPLIES OF ABSORBENT AND BARRIER MATERIALS TO ALLOW RAPID CONTAINMENT AND RECOVERY OF SPILLED MATERIALS.
7) EROSION AND SEDIMENT CONTROL: CONTRACTOR SHALL SUPPLY, INSTALL AND MAINTAIN SEDIMENT CONTROL STRUCTURES IN ACCORDANCE WITH CONTRACT DOCUMENTS. CONTRACTOR SHALL INSTALL ADDITIONAL EROSION CONTROL STRUCTURES AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR.
8) TOPSOIL SHALL BE STRIPPED AS REQUIRED BY PROJECT SPECIFICATIONS.
9) PRIOR TO PIPE PULLBACK, CONTRACTOR'S ACTUAL DRILL PROFILE SHALL BE SUBMITTED TO KEYSTONE FOR APPROVAL.
10) INSTALLATION: THE PIPE SECTION FOR THE DRILLED CROSSING SHALL BE MADE UP WITHIN THE RIGHT-OF-WAY AT THE DRILL EXIT POINT AS SHOWN. CONTRACTOR SHALL ASSESS THE NEED FOR AND SUPPLY APPROPRIATE BALLAST DURING PULLBACK.
11) MUD DISPOSAL: CONTRACTOR SHALL DISPOSE OF EXCESS DRILLING MUD AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS. UNDER NO CIRCUMSTANCES SHALL DRILLING FLUID BE DISPOSED OF IN WATER BODIES OR WETLANDS. ANY DRILLING MUD WHICH INADVERTENTLY EXITS AT POINTS OTHER THAN THE ENTRY AND EXIT POINTS SHALL BE CONTAINED AND COLLECTED TO THE EXTENT PRACTICAL AND DISPOSED OF AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS.
12) CLEANUP/STABILIZATION/RESTORATION: ALL DISTURBED AREAS SHALL BE RETURNED TO THE ORIGINAL CONTOURS. DISTURBED AREAS SHALL BE SEEDED AS SPECIFIED IN PROJECT DOCUMENTS.
13) NOMINAL WORKING SPACE DIMENSIONS ARE SHOWN. LARGER AREAS MAY BE REQUIRED IN IRREGULAR TERRAIN. UPDATED DIMENSIONS MAY BE PROVIDED AFTER LOCAL TOPOGRAPHICAL SURVEYS ARE PERFORMED.

LEGEND

- POINT OF INTERSECTION (P.I.)
- ENTRY OR EXIT POINT
- GEOTECHNICAL BOREHOLE
- POWERPOLE
- MLP: MAINLINE PIPE
- PIPELINE
- FOREIGN PIPELINE
- EDGE OF WATER
- PRIVATE ACCESS SHOO FLY ROAD
- COUNTY BOUNDARY
- WATER LEVEL
- USACOE CONSTRUCTION REFERENCE POINT
- WETLANDS
- PERMANENT EASEMENT
- TEMPORARY EASEMENT
- EXTRA WORKSPACE

REFERENCE DRAWINGS

DRAWING No	TITLE

REVISION

REV No	DATE	DESCRIPTION	PROJECT CODE	DRAFTER	DRAFTING CHECKER	DESIGNER	DESIGN CHECKER	PROJECT MANAGER	COMPANY
3	07.06.09	ISSUED FOR SUPPLEMENTAL U.S. DEPT. OF STATE FILING (02.15.09 CL)	THES0050388XS	JB	AH	HF	FP	RG	TROW
2	04.21.09	ISSUED FOR REVIEW (02.15.09 CL)	THES0050388XS	AH	AH	HF	FP	RG	TROW
1	12.08.08	ISSUED FOR REVIEW (12.1.08 CL)	THES0050388X	JB	AH	HF	RB	RG	TROW
0	11.19.08	ISSUED FOR UNITED STATES DEPARTMENT OF STATE (07.31.08 CL)	THES0050388X	JB	JP	HF	RB	RG	TROW

PROFESSIONAL ENGINEER/RPT | PERMIT/ ENG. APPROVAL | DATE

PRELIMINARY

REV. NO. | DATE | PERMIT NUMBER:

Trow ENGINEERING CONSULTANTS INC. | ConocoPhillips | TransCanada In business to deliver

VALLEY SECTION

FIA # 4360 | CHAINAGE: MP 89.0 | DISCIPLINE # 03

MISSOURI RIVER HDD INSTALLATION
KEYSTONE XL PROJECT
VALLEY & McCONE COUNTY, MONTANA

SCALE AS SHOWN | DRAWING No 4360-03-ML-03-002 | REV 3

TC_UD_6R.DWG 22X34

CADD DRAWING: DO NOT MAKE MANUAL REVISIONS

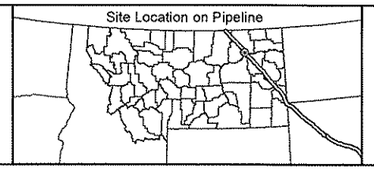
PLOTTED SIZE: ANSI D (22x34)

TIME: DESIGNFILE

- Intermittent Stream Crossings
- Perennial Stream Crossings
- SteeleCitySegmentMP
- Proposed Pipeline Route

Aerials: USGS EarthExplorer
http://edcsns17.cr.usgs.gov/EarthExplorer/

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Missouri River - MILE POST 89.0
1975 Historic Aerial

ENTRIX

200 1st Ave W Ste 500
Seattle, WA 98119

ph (206) 269-0104
fx (206) 269-0098

www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	West Fork Lost Creek MP 93.8			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/7/09
Flow Condition	No Flow - Dry				
General Site Characteristics / Comments	moderately steep, grass lined channel, locally planar bed, stable bed + banks, well vegetated, laterally confined by hillslopes that form both banks				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	Grass		
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bed (sub-surface)	D_{16}			
	D_{50}	<5% small rnd. gravel		
	D_{84}			
	% sand	<2		
	SOIL CLASS SYMBOL	CL		
Bars	D_{16}	NA	NA	
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	<5	% sand	<5
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}	NA	D_{16}	NA
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand		% sand	
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	

Comments: Sunburst Clay Loam soil 130

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)		
		GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)		
		GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)		
		SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)		
		SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 7 30			Bank Height (ft) 715		
Bank Slope (°) lower 1.5' 90°, hillslope 30°			Bank Slope (°) 20		
Woody Cover (%) <10			Woody Cover (%) <5		
Dominant Species See photos			Dominant Species See photos		
Root Depth (ft) grass ~1' trees ? Observed (Y) N Trees NO			Root Depth (ft) grass ~1' trees ? Observed (Y) N Trees NO		
Undercutting (Y/N) Very minor and isolated <0.3'			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / (N)	Potential Y / (N)	Gradual Migration	Present Y / N	Potential Y / N
Slumping	Present (Y) / N	Potential (Y) / N	Slumping	Present Y / (N)	Potential Y / (N)
Landsliding	Present Y / (N)	Potential Y / (N)	Landsliding	Present Y / (N)	Potential Y / (N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: Slumping induced by cattle trampling - stable (mostly), well vegetated banks			Notes: stable, well vegetated banks		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity NA - NO LFP		Soil Maturity NA - NO RFP	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft) <10 on hillslope		Woody Riparian Buffer Width (ft) <10 on hillslope	
Woody Riparian Plant Density ((L),M,H)		Woody Riparian Plant Density ((L),M,H)	
Dominant Woody Species see photo		Dominant Woody Species see photo	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes:		Notes:	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 10 -15 on average	Bridges (Y/N)
Bankfull Depth (ft) ~ 2-3	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) break in slope of bank profile	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) grass lined channel	
	Roads (Y/N)
Incision Evidence NO	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence NO	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) NO pools	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS cattle trampling of some banks & low flow channel	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other: small reservoir several hundred feet downstream - doesn't affect site at X-ing	Other:

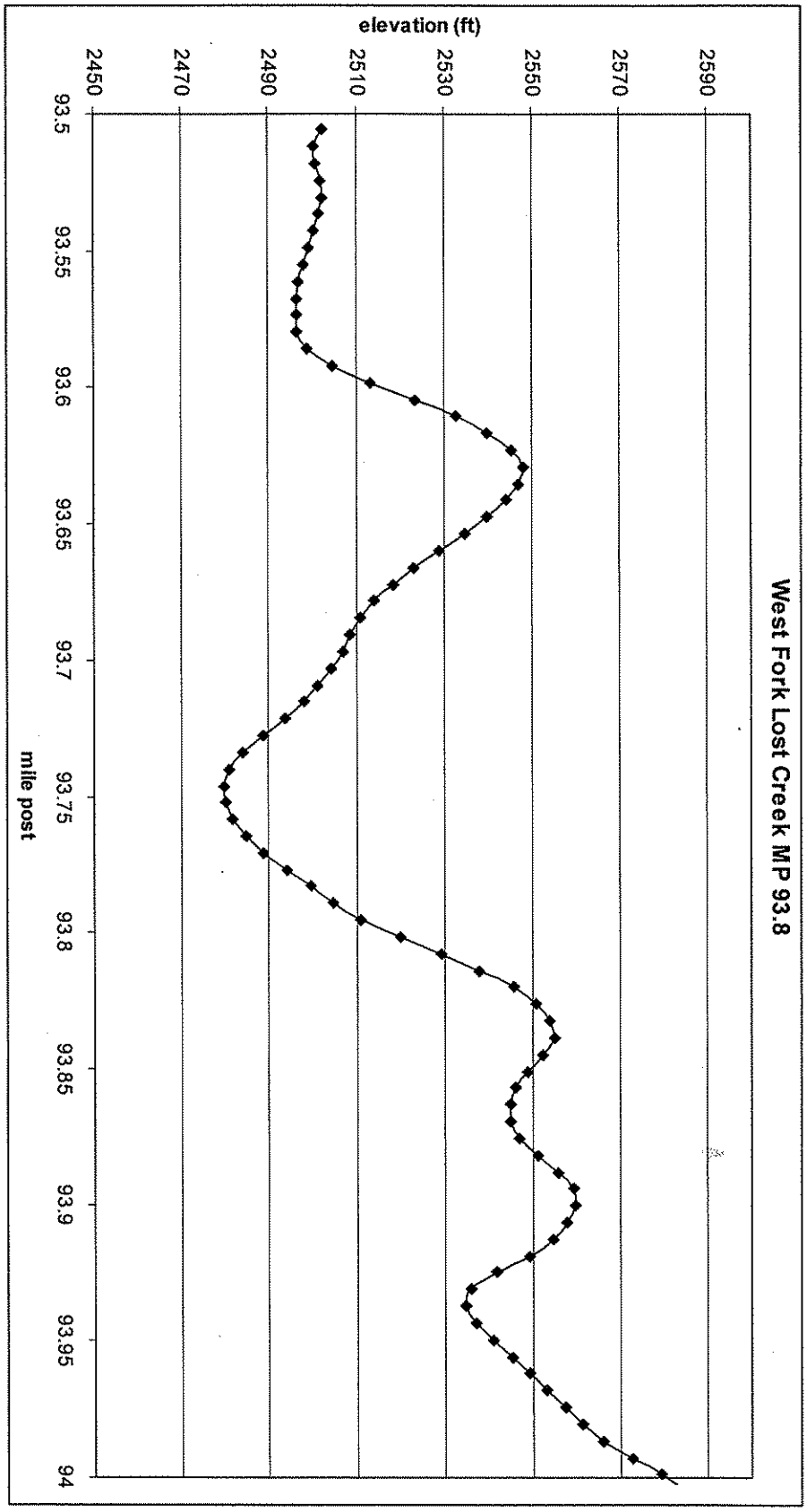
PHOTO CHECKLIST		
Site Overview	☒	US 31, 32, 33, 34, 35 US54, DS55
Channel US Showing Both Banks	☒	36, 37, 38
Channel DS Showing Both Banks	☒	39, 40, 41
Channel Bed Surface Alluvium	☒	42
Channel Bed Sub-Surface Alluvium	☒	43
Bar Alluvium	☒	N/A
Bars Overview	☒	N/A
Islands Overview	☒	N/A
Left Bank Alluvium	☒	44
Left Bank Toe Detail	☒	45
Left Bank Top of Bank Detail	☒	46
Left Bank Overview	☒	47
Left Floodplain Alluvium	☒	N/A
Left Floodplain Overview	☒	N/A
Left Floodplain Landforms	☒	N/A
Right Bank Alluvium	☒	48
Right Bank Toe Detail	☒	49
Right Bank Top of Bank Detail	☒	50
Right Bank Overview	☒	51
Right Floodplain Alluvium	☒	N/A
Right Floodplain Overview	☒	N/A
Right Floodplain Landforms	☒	N/A
Infrastructure	☒	N/A
Disturbance/Instability	☒	52 Cattle trail on L Bank

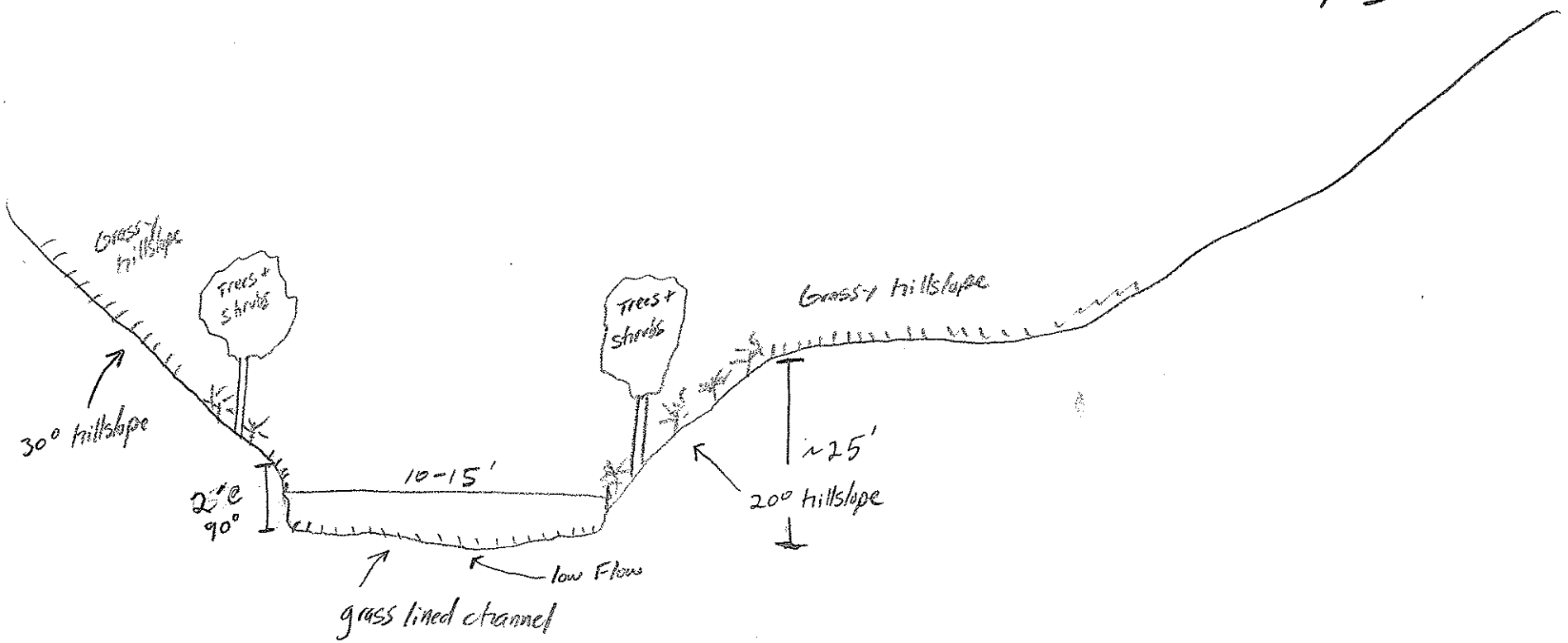
PHOTO LOG		
Photo ID	View Direction	Description
56-60		Dominant tree + shrub species - same for Trib. to West Fork Lost Creek

53 - Video

VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM

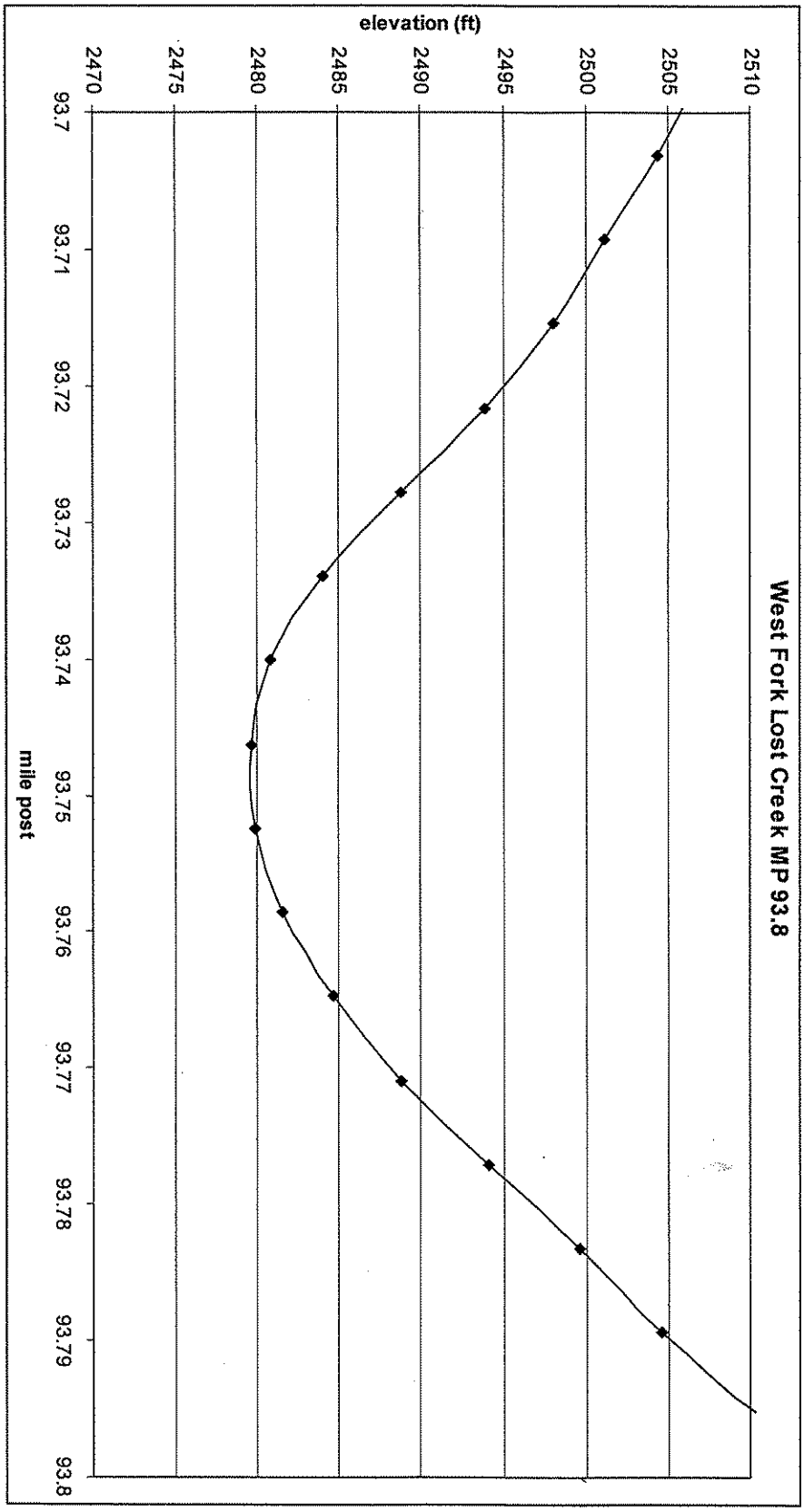




- Stable, well vegetated channel confined by hillslopes

CHANNEL CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



West Fork Lost Creek

Questions:

What is the likelihood the project will impact turbidity at the site?

No - dry channel

What is the potential impact on incision and erosion?

None

Will the project activate historical instability?

NO

What actions or alternatives can mitigate project effects?

Reconstruct stable hillslopes + revg

Are there any cumulative effects of pipeline?

NO

General Notes:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA

Site	West Fork Lost Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression	0.39	–	–	–	131	488	873	1478	1,994	2,095
No Gage Station Data Available	–	–	–	–						

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: 2.07

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

meander wavelength (ft) 210

meander amplitude (ft) 107

Sinuosity: 0.47

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	1059	323	174	53
	886	270	259	79
	676	206		
	508	155		
	361	110		
	31	9.6		

Channel form (braided, anabranching, single thread):

Single thread

Channel confinement at crossing (W_v / W_c): 9.24

Valley

Gradient: 3.7

width	min	max	mean	std dev
	224	257	238	13

describe geology (lithology, erodibility):

Fine-med. Grained sandstone in upper part.

Interbedded sandstone, siltstone and black shale Thickness (98-148ft)

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

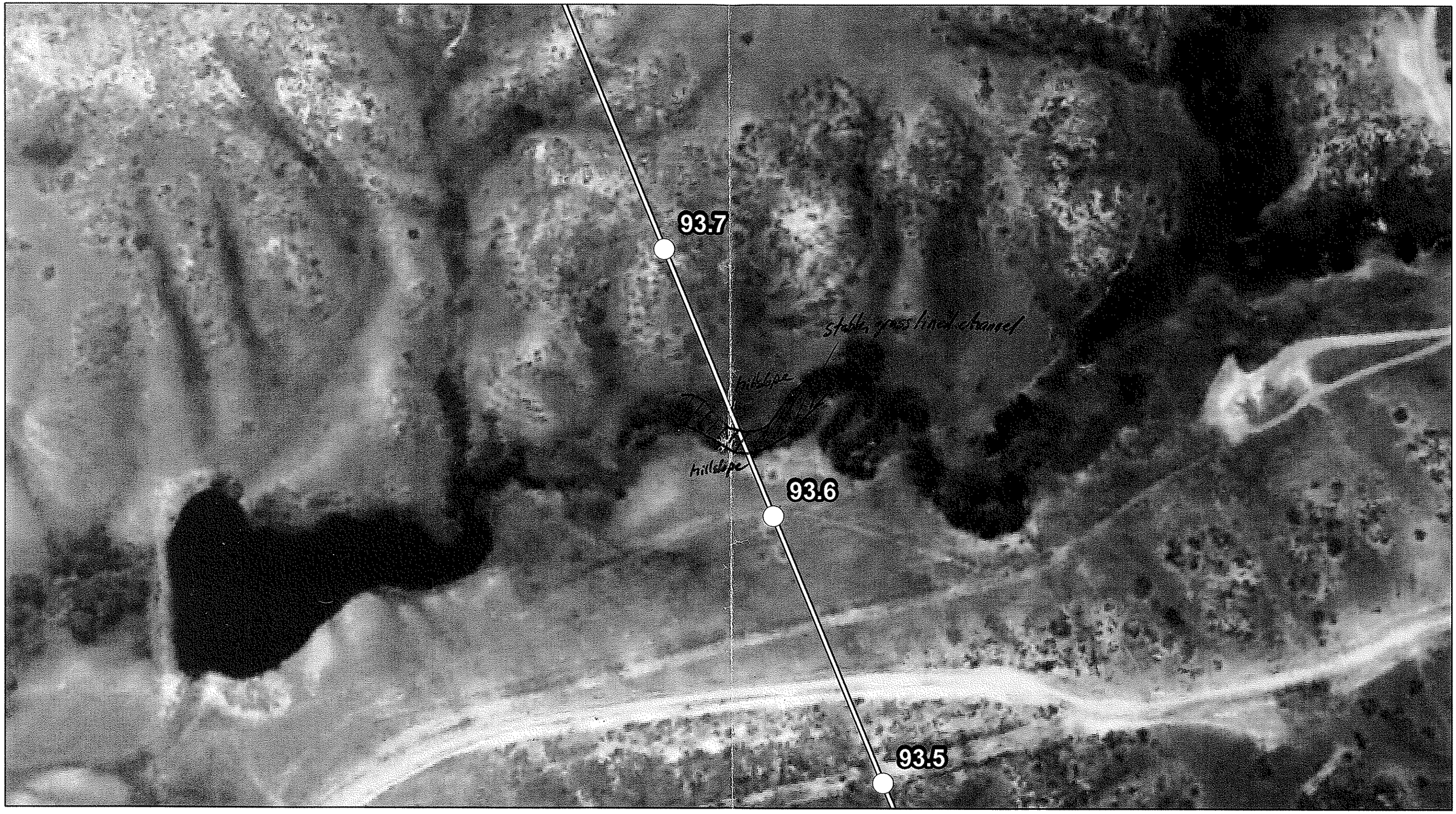
oxbows: None

channel cut-offs: None visible.

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
There appears to be a man made levee 0.25 mi DS. Backwater conditions 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?):
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 (0.1mi Par.) 2. Electric Lines (0.50 mi Perp.) DS: Levee with pond (0.25 mi, in channel)
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

PLANVIEW MAP

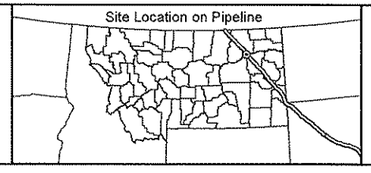
*notes – image background date:



- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

West Fork Lost Creek - MILE POST 93.8
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 75 150 300 Feet

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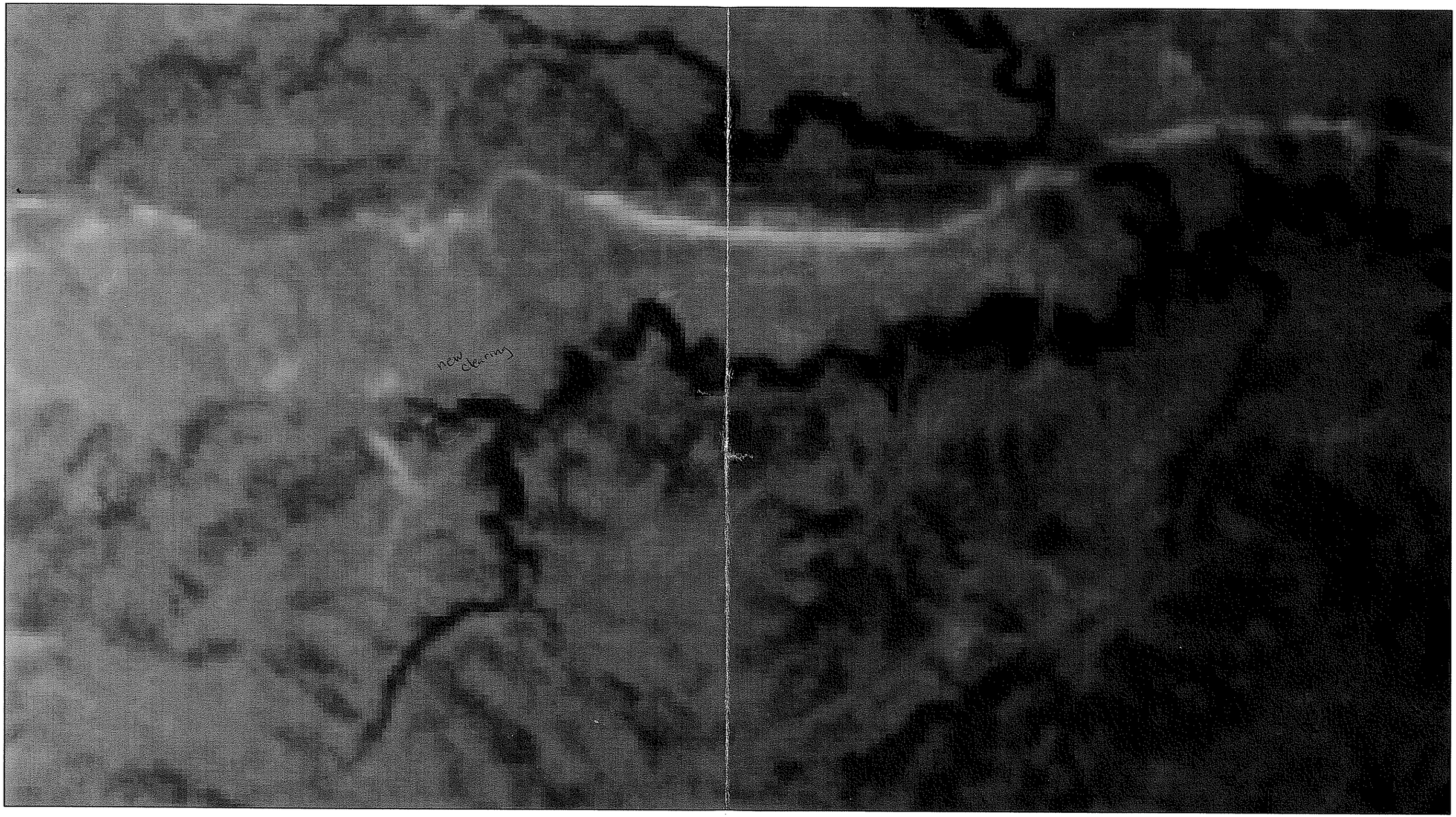
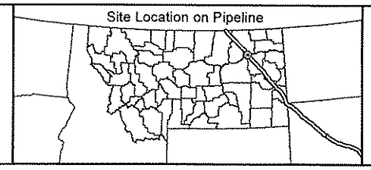
File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd



- Intermittent Stream Crossings
- Perennial Stream Crossings
- SteeleCitySegmentMP
- Proposed Pipeline Route

Aerials: USGS EarthExplorer
http://edcsns17.cr.usgs.gov/EarthExplorer/

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

West Fork Lost Creek - MILE POST 93.8
1975 Historic Aerial

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Trib. West Fork Lost Creek MP 94.6			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/7/09
Flow Condition	No Flow - Dry				
General Site Characteristics / Comments	moderately steep, planar bed grass lined channel confined by valley walls - no room for lateral movement, no evidence of recent				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}			
	D_{50}	Grass		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bed (sub-surface)	D_{16}			
	D_{50}			
	D_{84}			
	% sand	<5		
	SOIL CLASS SYMBOL	ML		
Bars	D_{16}	NA		
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	20	% sand	20
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	20	% sand	20
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML

Comments: Sunburst clay loam soil 130

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
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	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
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SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 12 to > 50'			Bank Height (ft) 12 to > 50		
Bank Slope (°) 40			Bank Slope (°) 20 - 40		
Woody Cover (%) 40			Woody Cover (%) 40		
Dominant Species see photo			Dominant Species see photo		
Root Depth (ft) grass ~1' trees ? Observed (Y) / N Trees no			Root Depth (ft) grass ~1' trees ? Observed (Y) / N Trees no		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y /(N)	Potential Y /(N)	Gradual Migration	Present Y /(N)	Potential Y /(N)
Slumping	Present Y /(N)	Potential Y /(N)	Slumping	Present Y /(N)	Potential Y /(N)
Landsliding	Present Y /(N)	Potential Y /(N)	Landsliding	Present Y /(N)	Potential Y /(N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: Stable vegetated banks			Notes: ←		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity low		Soil Maturity low	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft) 20 - 30' on hillslope		Woody Riparian Buffer Width (ft) 20 - 30' on hillslope	
Woody Riparian Plant Density (L/(M)/H)		Woody Riparian Plant Density (L/(M)/H)	
Dominant Woody Species see photos		Dominant Woody Species see photos	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes:		Notes:	

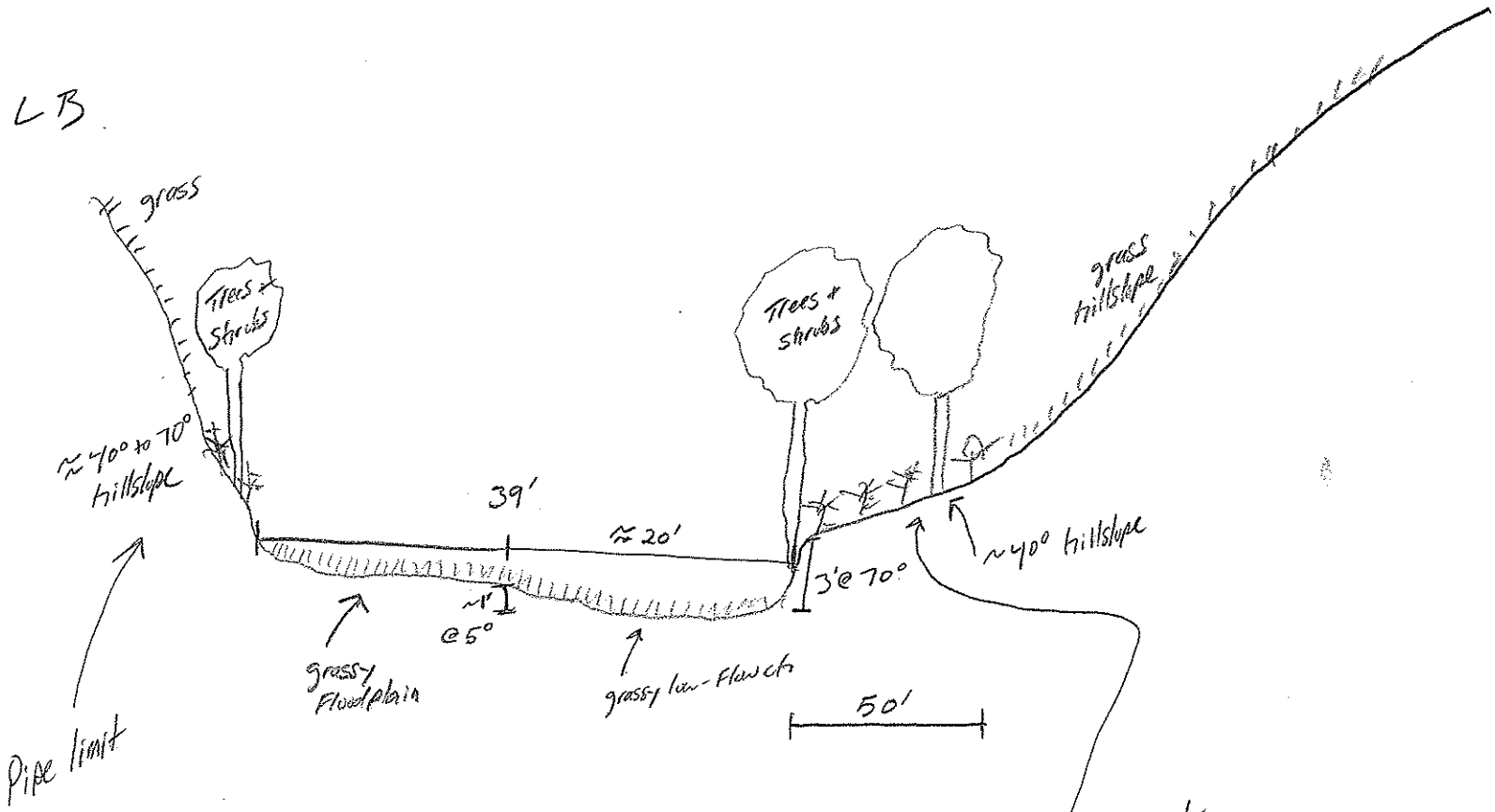
CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 15-25	Bridges (Y/N)
Bankfull Depth (ft) 1	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) Small inset floodplains	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) entire channel is vegetated	
	Roads (Y/N)
Incision Evidence NONE	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence None	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) No pools	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS None - cattle footprints along low-flow	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

PHOTO CHECKLIST		
Site Overview	☒	U/S 1,2,3,4,5,6,7,8
Channel US Showing Both Banks	☒	9,10,11
Channel DS Showing Both Banks	☒	12,13,14
Channel Bed Surface Alluvium	☒	15
Channel Bed Sub-Surface Alluvium	☒	16
Bar Alluvium	☒	N/A
Bars Overview	☒	N/A
Islands Overview	☒	N/A
Left Bank Alluvium	☒	17
Left Bank Toe Detail	☒	18
Left Bank Top of Bank Detail	☒	19
Left Bank Overview	☒	20
Left Floodplain Alluvium	☒	21
Left Floodplain Overview	☒	22
Left Floodplain Landforms	☒	N/A
Right Bank Alluvium	☒	23
Right Bank Toe Detail	☒	24
Right Bank Top of Bank Detail	☒	25
Right Bank Overview	☒	26
Right Floodplain Alluvium	☒	21
Right Floodplain Overview	☒	27
Right Floodplain Landforms	☒	N/A
Infrastructure	☒	N/A
Disturbance/Instability	☒	N/A

PHOTO LOG		
Photo ID	View Direction	Description
29	U/S	overview
30	D/S	overview

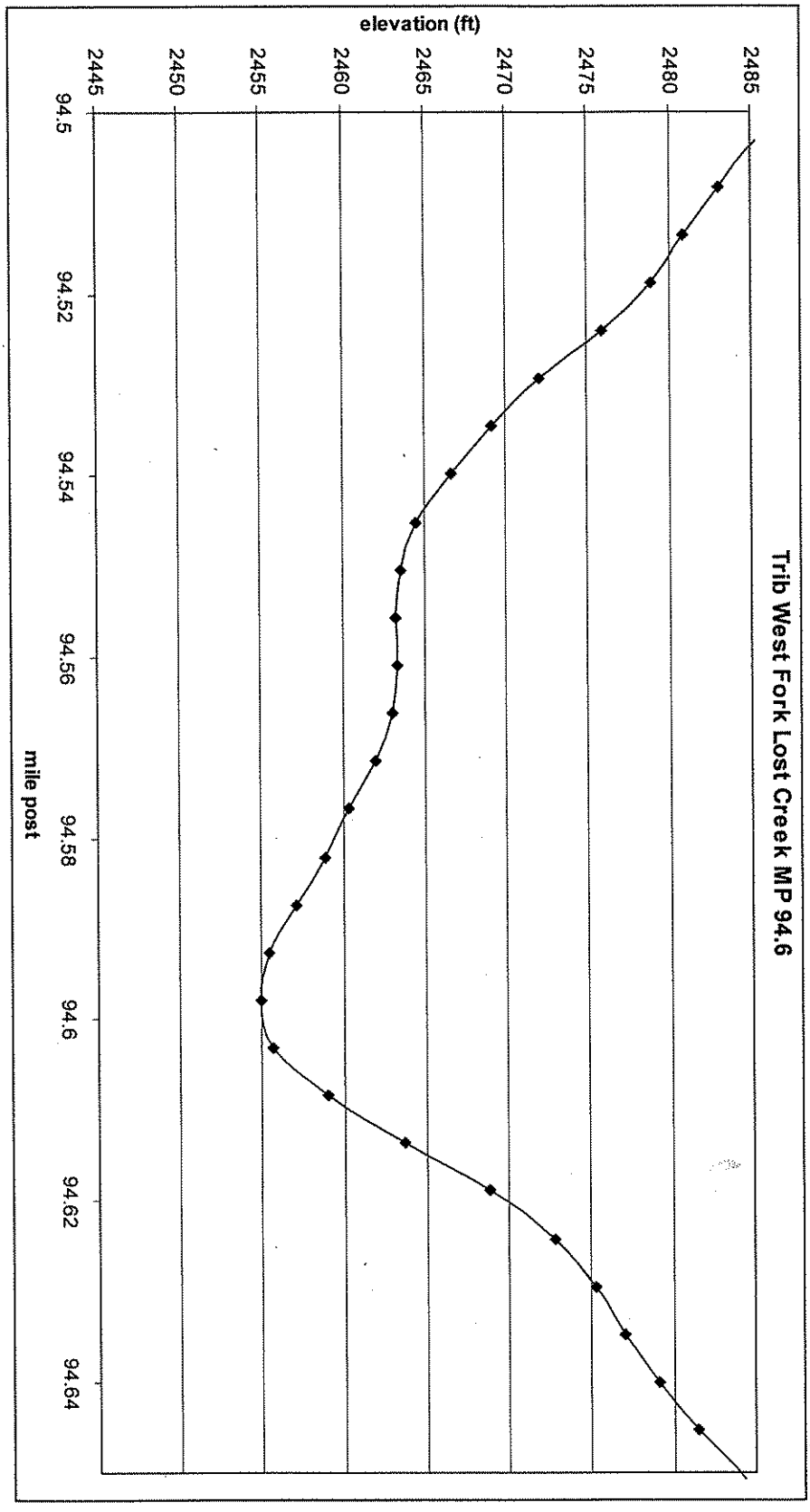
28- Video



Stable, grass lined channel confined in valley

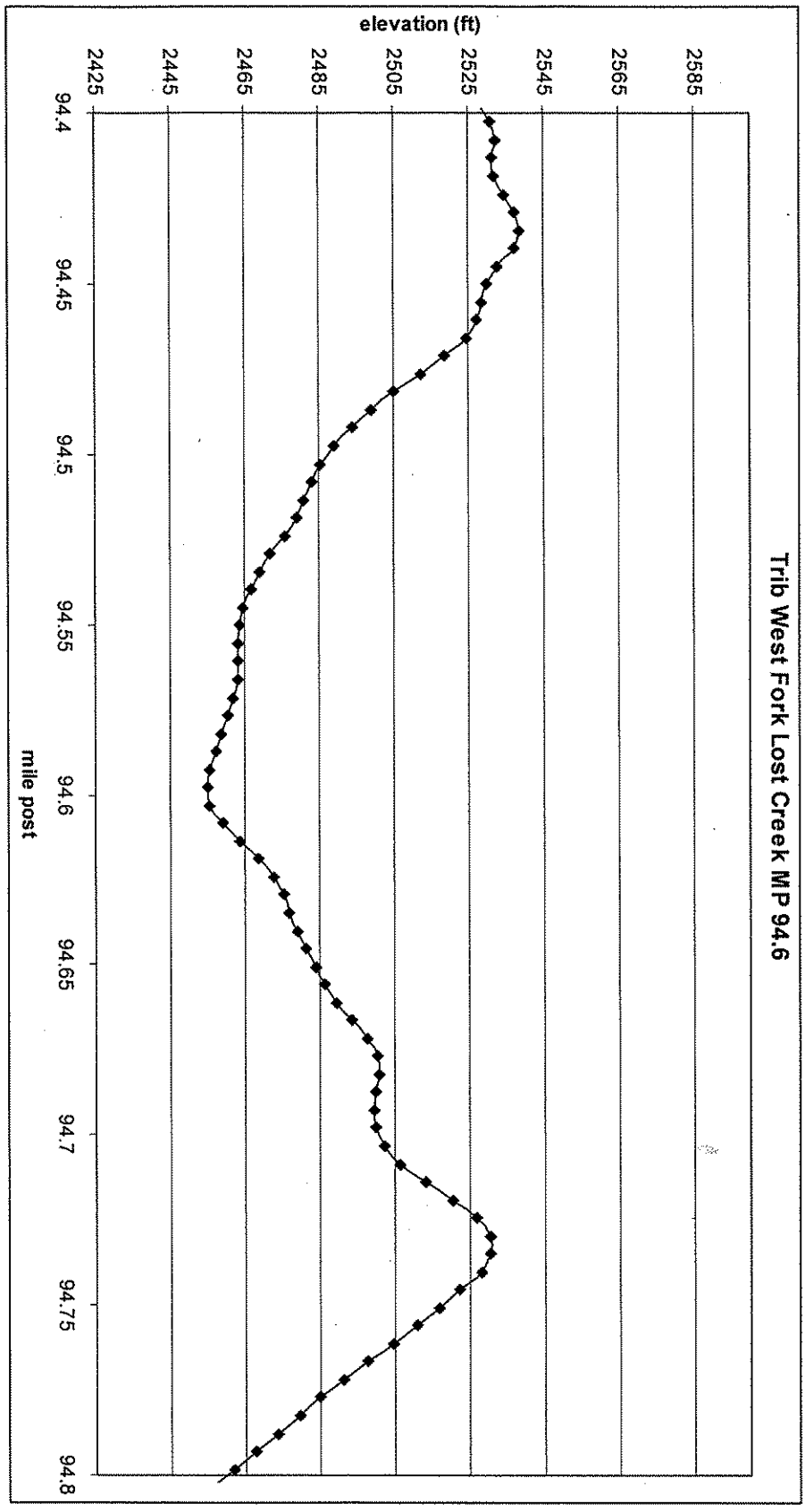
CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

Trib. to West Fork Lost Creek

Questions:

What is the likelihood the project will impact turbidity at the site?

None Dry channel

What is the potential impact on incision and erosion?

None

Will the project activate historical instability?

NO

What actions or alternatives can mitigate project effects?

Reconstruct stable, revegetated banks

Are there any cumulative effects of pipeline?

NO

General Notes:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA

Site	Trib to West Fork Lost Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression	0.39	--	--	--	131	487	871	1,474	1,990	2,091
No Gage Station Data Available	--	--	--	--						

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:: 2.9

Width *Vegetation prevented an accurate channel measurement	min	max	mean	std dev
	34	47	39	5

meander wavelength (ft): 420

meander amplitude (ft) 111

Sinuosity 1.23

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	640	305	93	283
	410	196	227	180
			441	319
			731	200
			1302	270
			1588	159

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 4.21

Valley

Gradient:: 3.6

	min	max	mean	std dev
width	37	62	47	8

describe geology (lithology, erodibility):

Fine-med.-grained sandstone in upper part.

Interbedded sandstone, siltstone and black shale in lower part. Thickness 98-148ft

Floodplain

FEMA National Database N

if yes, describe widths below

Width (ft)	min	max	mean	std dev

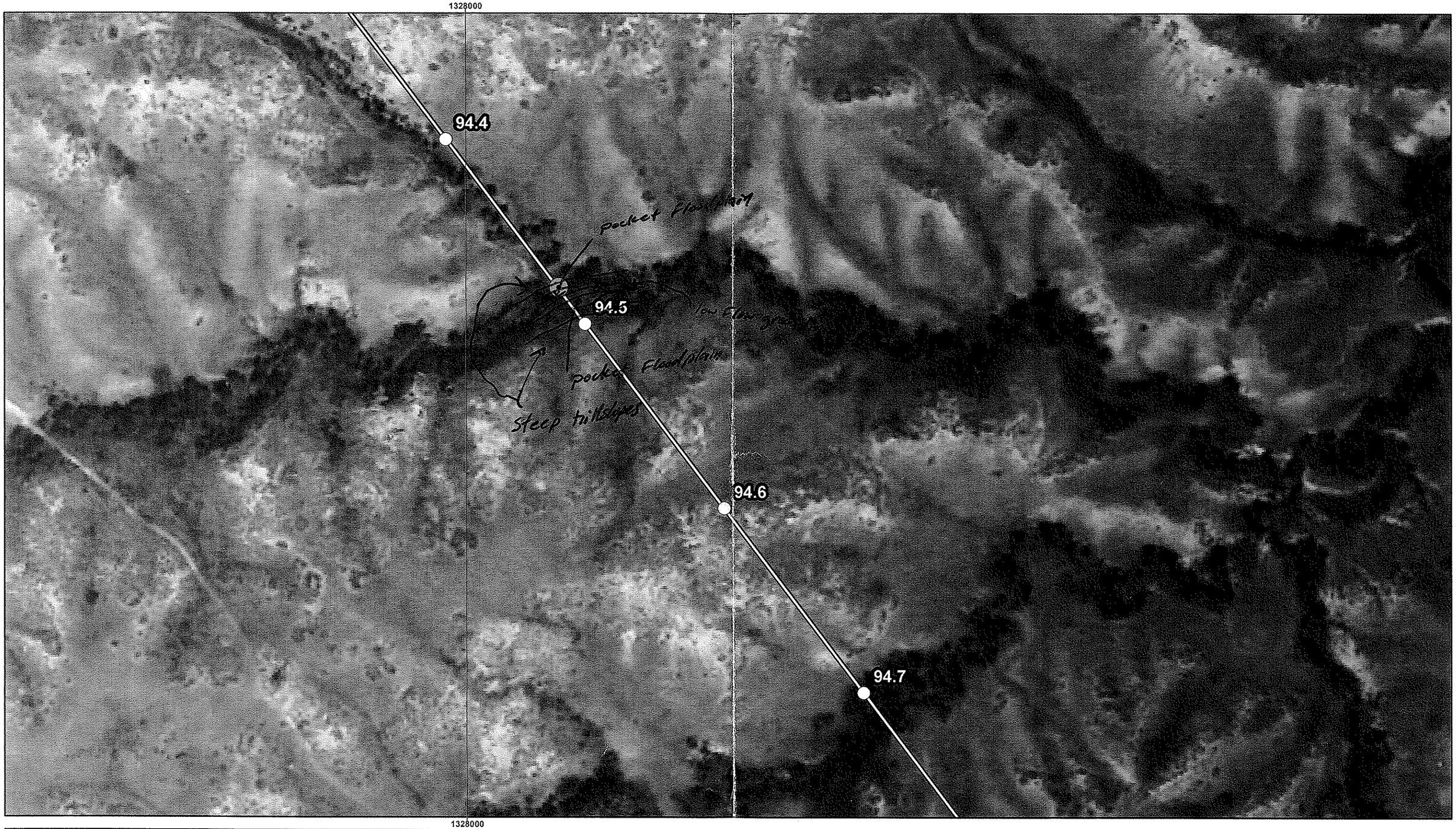
Describe abundance and location(s) of:

scroll bars: None

oxbows: None

channel cut-offs: None

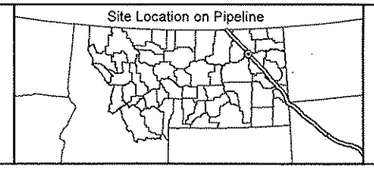
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
The floodplain elevation is greater than the channel.
Unique features, exceptions, etc
There is a straightened section of channel 0.25 mi US of crossing (at the stream crossing with the electricity lines), possible incision location.
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
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. Electricity lines (0.25 mi, perp.) 2. Road/culvert (0.90 mi, perp.)
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):



- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Trib. to West Fork Lost Creek
MILE POST 94.6 - 2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
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Coordinate System: NAD 1983 UTM Zone 13 feet

N W E S

0 100 200 400 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	East Fork Prairie Elk Creek MP 127.6			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/7/09
Flow Condition	No Flow - Dry				
General Site Characteristics / Comments	low gradient, single thread, meandering				
- See pipeline 8/7/09 re-route drawn on map					

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	Grassy channel		
	D_{50}	silt 41" thick		
	D_{84}			
	% sand	< 2		
	SOIL CLASS SYMBOL	ML		
Bed (sub-surface)	D_{16}			
	D_{50}	clay		
	D_{84}			
	% sand	0		
	SOIL CLASS SYMBOL	OH		
Bars	D_{16}	NA - all grassy		
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}	VFS	D_{50}	clay/silt
	D_{84}		D_{84}	
	% sand	>90	% sand	>10
	SOIL CLASS SYMBOL	SP	SOIL CLASS SYMBOL	ML
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}	VFS	D_{50}	Sandy silt
	D_{84}		D_{84}	
	% sand	>50	% sand	<50
	SOIL CLASS SYMBOL	SM	SOIL CLASS SYMBOL	ML/M

Comments: Alona Silt Loam, saline 6

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) Point bar w/ no distinct bank			Bank Height (ft) 30' @ 15° upper 5' @ 40°-90°		
Bank Slope (°) 5-10			Bank Slope (°) 〃 〃 〃 〃		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species grass			Dominant Species grass		
Root Depth (ft) <1' Observed (Y)/ N			Root Depth (ft) <1' Observed (Y) N		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y /(N)	Potential (Y) N	Gradual Migration	Present (Y) N	Potential (Y) N
Slumping	Present Y /(N)	Potential Y /(N)	Slumping	Present (Y) N	Potential (Y) N
Landsliding	Present Y /(N)	Potential Y (N)	Landsliding	Present Y /(N)	Potential Y (N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: LB is a densely grass vegetated point bar / floodplain that transitions up into the terrace and hillslope			Notes: RB is outer cut bank, sandy unconsolidated material w/ evidence of slumping + potential for lateral migration * Check planform of historic aerials		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity none		Soil Maturity none	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species		Dominant Woody Species	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes:		Notes: RFP is likely infrequently inundated - likely a terrace	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 64	Bridges (Y/N)
Bankfull Depth (ft) 8	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) topography	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) entire ch. is vegetated	
w/ sedges	Roads (Y/N)
Incision Evidence NO	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence NO	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) NO appreciable pools observed	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS None	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

PHOTO CHECKLIST		
Site Overview	☒	US-DS 61, 62, 63, 64, 65
Channel US Showing Both Banks	☒	66, 67, 68
Channel DS Showing Both Banks	☒	69, 70, 71
Channel Bed Surface Alluvium	☒	79
Channel Bed Sub-Surface Alluvium	☒	80, 81
Bar Alluvium	☒	N/A
Bars Overview	☒	N/A
Islands Overview	☒	N/A
Left Bank Alluvium	☒	82
Left Bank Toe Detail	☒	83
Left Bank Top of Bank Detail	☒	84
Left Bank Overview	☒	85
Left Floodplain Alluvium	☒	86
Left Floodplain Overview	☒	US-DS 87, 88, 89
Left Floodplain Landforms	☒	N/A
Right Bank Alluvium	☒	75
Right Bank Toe Detail	☒	76
Right Bank Top of Bank Detail	☒	77
Right Bank Overview	☒	78
Right Floodplain Alluvium	☒	72
Right Floodplain Overview	☒	73, 74
Right Floodplain Landforms	☒	N/A
Infrastructure	☒	N/A
Disturbance/Instability	☒	N/A

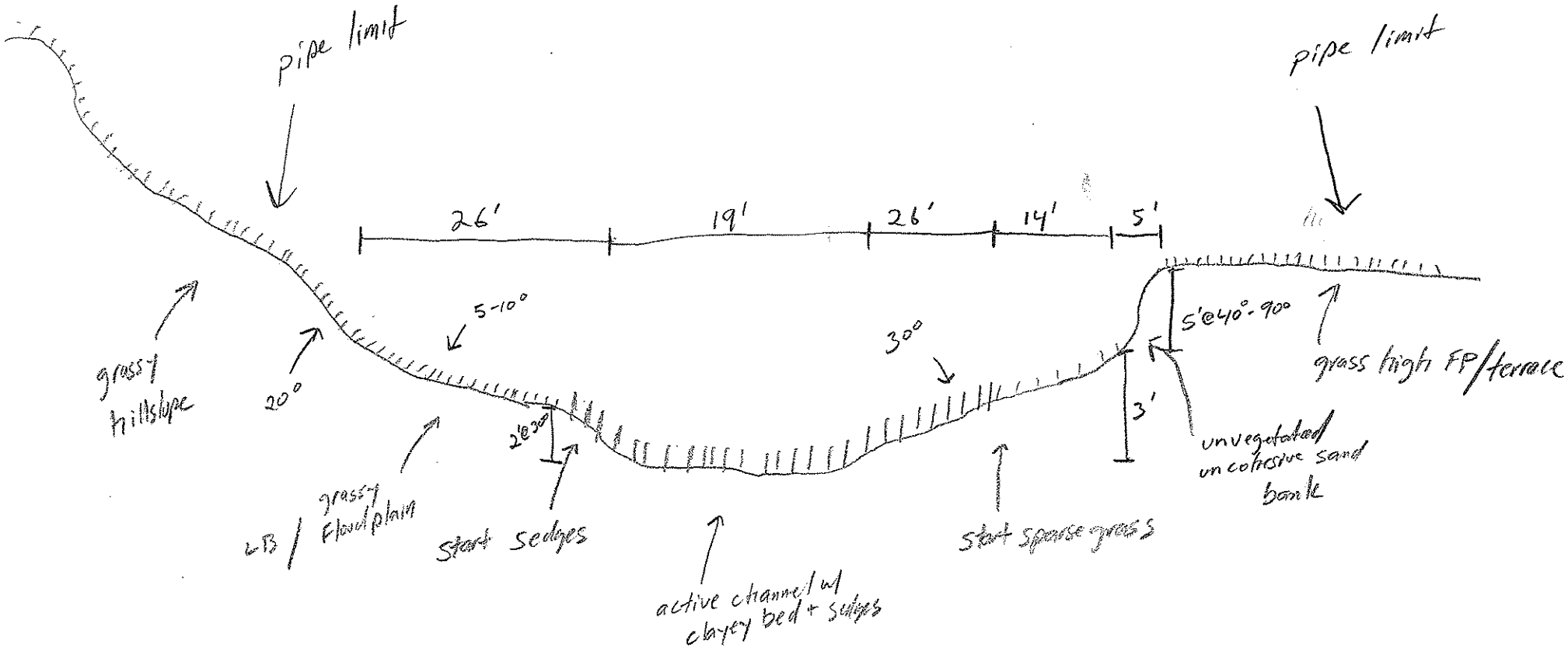
PHOTO LOG		
Photo ID	View Direction	Description

90 - Video

91 - 93 overview DS, US, US

LB

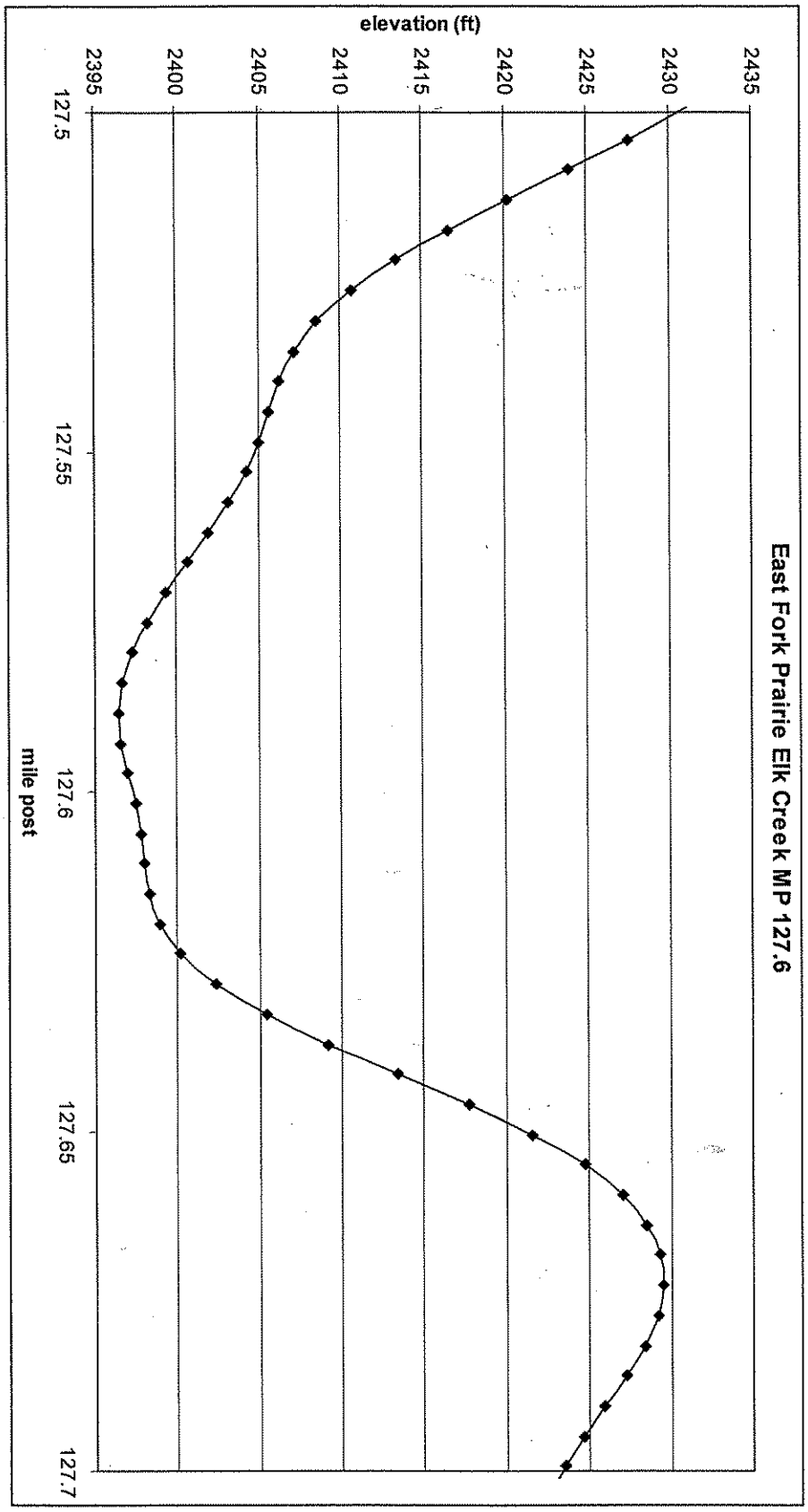
RB



* analyze historic aerials for planform change - planform migration appears low in Field; most banks are dense grass + sedge

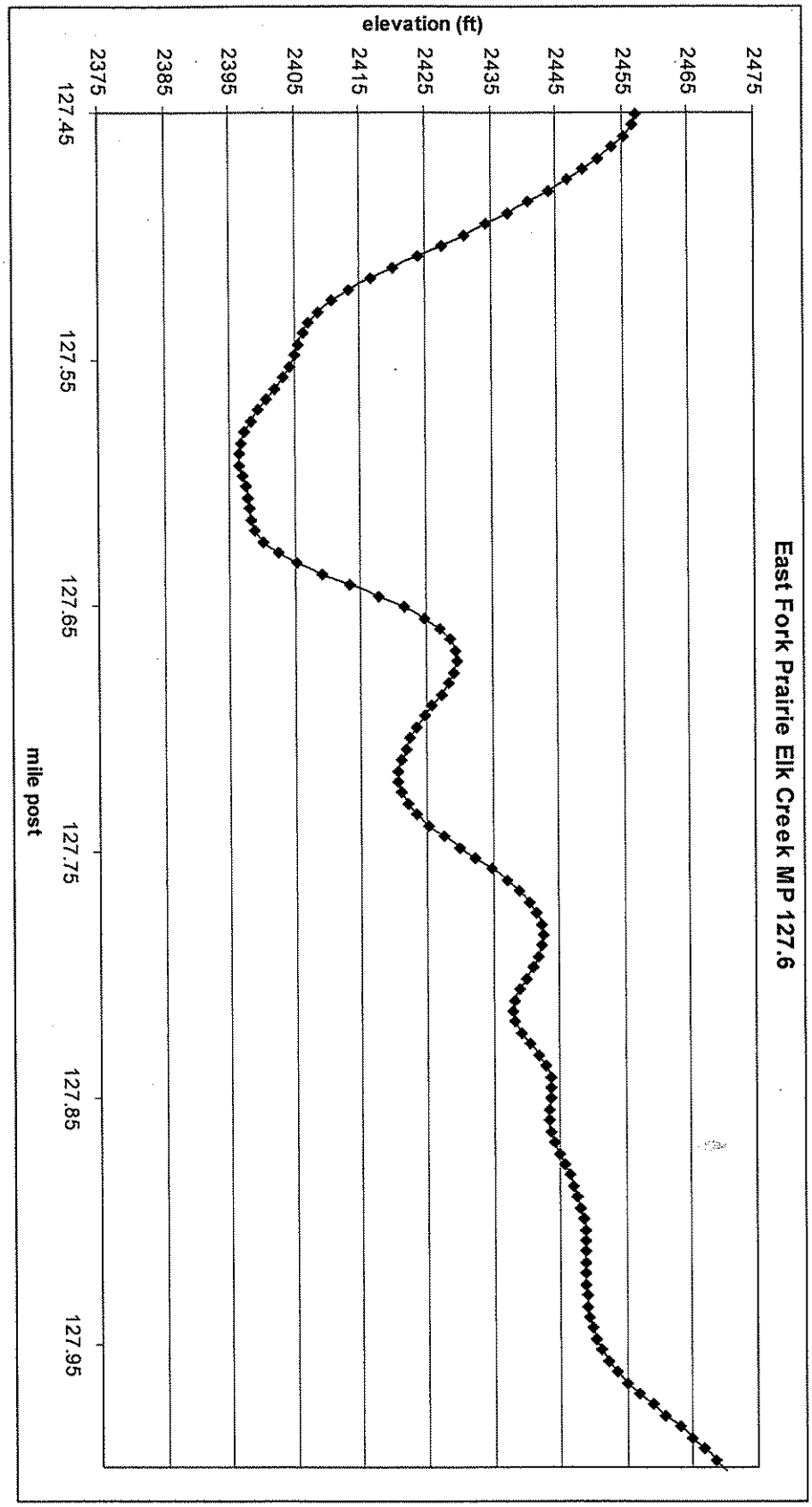
CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA

Site	East Fork Prairie Elk Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression	20.39	--	--	--	1,161	3,985	6,854	10,711	13,891	14,596
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

Gradient: <0.1

Width (ft)	min	max	mean	std dev
	12	60	26	16

meander wavelength (ft) 869

meander amplitude (ft) 594

Sinuosity 2.08

radius of curvature (ft)	Upstream (ft) distance from crossing	Upstream (ft) radius of curvature	Downstream (ft) distance from crossing	Downstream (ft) radius of curvature
	256	682	567	827
	1254	754	1194	708
	1969	417	1988	663
	2779	1171	2762	977
	3897	577	567	827
	256	682		

Channel form (braided, anabranching, single thread): single

Channel confinement at crossing (W_v / W_c): 11.59

Valley

Gradient: 0.4

Width (ft)	min	max	mean	std dev
	367	830	538	167

describe geology (lithology, erodibility):

Alluvium of modern channels and flood plains.

Sandstone, sandy and silty shale and coal. Thickness 984ft.

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:

US 0.50 mi, a side channel is present

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, <0.1 mi, another stream enters this creek
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
Small disturbances: US 0.30 mi, DS 0.15 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 (0.80 mi, river left) 2. road crossing (no bridge or culvert) 0.50 mi, perp.)
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

Questions:

What is the likelihood the project will impact turbidity at the site?

What is the potential impact on incision and erosion?

Will the project activate historical instability?

What actions or alternatives can mitigate project effects?

Are there any cumulative effects of pipeline?

General Notes:

17308000

17308000

127.4

127.5

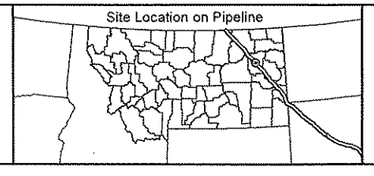
127.6

Flow

Perennial Stream Crossings
Intermittent Stream Crossings
Proposed Pipeline Route
1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

East Fork Prairie Elk Creek
MILE POST 127.6 - 2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 50 100 200 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

17312000

1440000

17308000

1440000

17312000

127.7

127.6

127.5

127.4

127.3

127.2

127.1

127

126.9

126.8

1436000

1436000

17308000

Perennial Stream Crossings

Intermittent Stream Crossings

Proposed Pipeline Route

1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline

KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

East Fork Prairie Elk Creek
MILE POST 127.6 - 2005 NAIP Aerial

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0 150 300 600 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Redwater River			Surveyors	BB, ME
GPS	WP:	N:	E:	Date/Time	7/16/09 15:30
Flow Condition	low flow, muddy water				

General Site Characteristics / Comments

low gradient meandering channel with variable channel width

- pipe X-ing depth under channel should be maintained until beyond LB floodplain and into terrace

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}			
	D_{50}	4mm		
	D_{84}			
	% sand	30-40		
	SOIL CLASS SYMBOL		GM (w/ organics)	
Bed (sub-surface)	D_{16}			
	D_{50}			
	D_{84}	N	A	
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}			
	D_{84}	N	A	
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}	silt	D_{50}	0.06
	D_{84}	<1% clay	D_{84}	<1% clay
	% sand	50	% sand	50
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}	0.08	D_{50}	0.08
	D_{84}		D_{84}	
	% sand	40	% sand	40
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML

Comments: Right Bank basal layer D50 ~ 30mm

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	
	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 2.3'			Bank Height (ft) 15-17		
Bank Slope (°) vertical 90°			Bank Slope (°) lower 2' 90°, mid 30°, upper 2' 90		
Woody Cover (%) 0			Woody Cover (%) 0 (some sages)		
Dominant Species grass/sedges			Dominant Species grasses		
Root Depth (ft) 2'+	Observed Y / N		Root Depth (ft) 2+	Observed Y / N	
Undercutting (Y/N) 1'±			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / N	Potential Y / N	Gradual Migration	Present Y / N	Potential Y / N
Slumping	Present Y / N	Potential Y / N	Slumping	Present Y / N	Potential Y / N
Landsliding	Present Y / N	Potential Y / N	Landsliding	Present Y / N	Potential Y / N
Other: rotational bank failure	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes:			Notes: gravel + cobble mixed with sand on lower level bank - possible lag deposit - not an armour layer - potential for very slow migration into step + high outer bank		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity young/immature no organic		Soil Maturity NA	
Natural Levees (Y/N)		Natural Levees (Y/N)	
Description:		Description Terrace	
Artificial Levees (Y/N)		Artificial Levees (Y/N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/N)	Relic/Abandoned (Y/N) potentially	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Riparian Buffer Width (ft) 0		Riparian Buffer Width (ft) 0	
Riparian Plant Density (L,M,H) 0		Riparian Plant Density (L,M,H)	
Dominant Species NA		Dominant Species grasses	
Crevasse Splays (Y/N)		Crevasse Splays (Y/N)	
Crevasse Channels (Y/N)		Crevasse Channels (Y/N)	
Notes: hummocky low floodplain and 3 ft' higher terrace w/ more sage plants		Notes:	

update to woody

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 85' to low bank, 164' to high bank	Bridges (Y/N)
Bankfull Depth (ft) ~4'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) topography - alluvial flat	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 75' @ X-ing	
	Roads (Y/N)
Incision Evidence nothing recent	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence NO	
Bars (Y/N) only minor sand + gravel bars @	
trib. confluence US	
Vegetated Islands (Y/N) dominant vegetated floodplain	
features resembling islands constructed low flow channel	
Pool Depths (ft) unknown - flat water, possibly	
slow bed channel	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams just US of trib confluence	In-stream structures
US of X-ing	
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

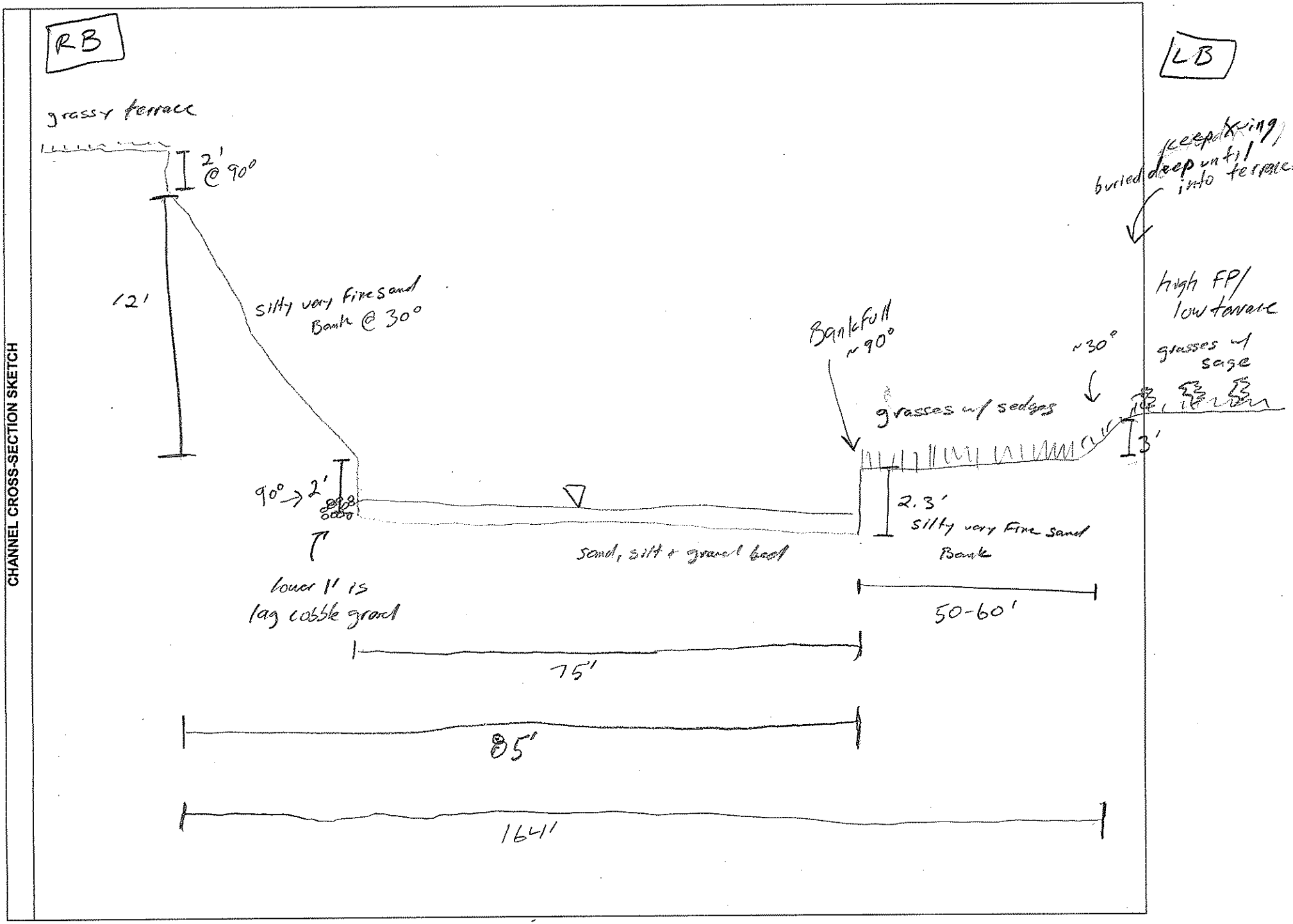
MANDATORY PHOTO CHECKLIST				
Photo		*Photo ID*	*View Direction*	*Description*
Site Overview	☒	76-80	starts US ends DS	
Channel US Showing Both Banks	☒	74		
Channel DS Showing Both Banks	☒	75		
Channel Bed Surface Alluvium	☒	56		
Channel Bed Sub-Surface Alluvium	☒	NA		
Bar Alluvium	☒	NA		
Bars Overview	☒	NA		
Islands Overview	☒	NA		
Left Bank Alluvium	☒	57		
Left Bank Toe Detail	☒	61/62		
Left Bank Top of Bank Detail	☒	63		
Left Bank Overview	☒	64,73		
Left Floodplain Alluvium	☒	58,		
Left Floodplain Overview	☒	59,60	60 = downstream	
Left Floodplain Landforms	☒	see overview (hummocky terrain)		
Right Bank Alluvium	☒	~~54~~ 69		
Right Bank Toe Detail	☐	~~61~~/~~62~~	68,69	channel lag @ base, Finer material above lag
Right Bank Top of Bank Detail	☒	71		
Right Bank Overview	☒	65,72	(72 is DS)	
Right Floodplain Alluvium	☐	NA		Right is terrace
Right Floodplain Overview	☐	NA		
Right Floodplain Landforms	☐	NA		
Infrastructure	☐	NA		
Disturbance/Instability	☐	NA		

SUPPLEMENTAL PHOTOS		
Photo ID	*View Direction*	*Description*
54	US	beaver dam on main ch. just US tributary (dry) + X-ing
55	US	unnamed tributary from confluence w/ Redwater River
66		overview video from top RB
67		" " mid RB
70	RB	slumping

* Note: Banks are reversed

Redwater River

CHANNEL CROSS-SECTION SKETCH



VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM

PLANVIEW MAP

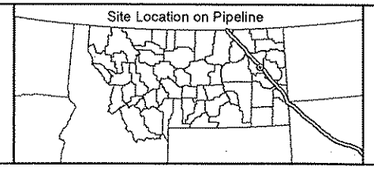
*notes – image background date:

Legend

- Intermittent Stream Crossings
- Perennial Stream Crossings
- Proposed Pipeline Route
- 1,000 ft Profile Interval

Base Photo: 2005 U.S. Farm Services Agency
National Agricultural Imagery Program (NAIP)

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

REDWATER RIVER - MILE POST 146.6
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

N W E S

0 500 1,000 2,000 Feet

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File: \\Sacramento-nas\Data\SHARED\Belby\Keystone Pipeline\gis\map\mxd\Keystone XS field map landscape tabloid.mxd

1496000 1500000 1504000 1508000 1512000

17240000 17236000 17232000

1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000

BM 2910

SEWAGE DISPOSAL

Legend

- Intermittent Stream Crossings
- Perennial Stream Crossings
- Proposed Pipeline Route
- 1,000 ft Profile Interval

USGS 1:24:000 Quadrangles:
http://nris.mt.gov/nsdi/drgpages/quadsid.html

Site Location on Pipeline

KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

REDWATER RIVER - MILE POST 146.6
USGS 1:24000 Quadrangles

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0 500 1,000 2,000 Feet

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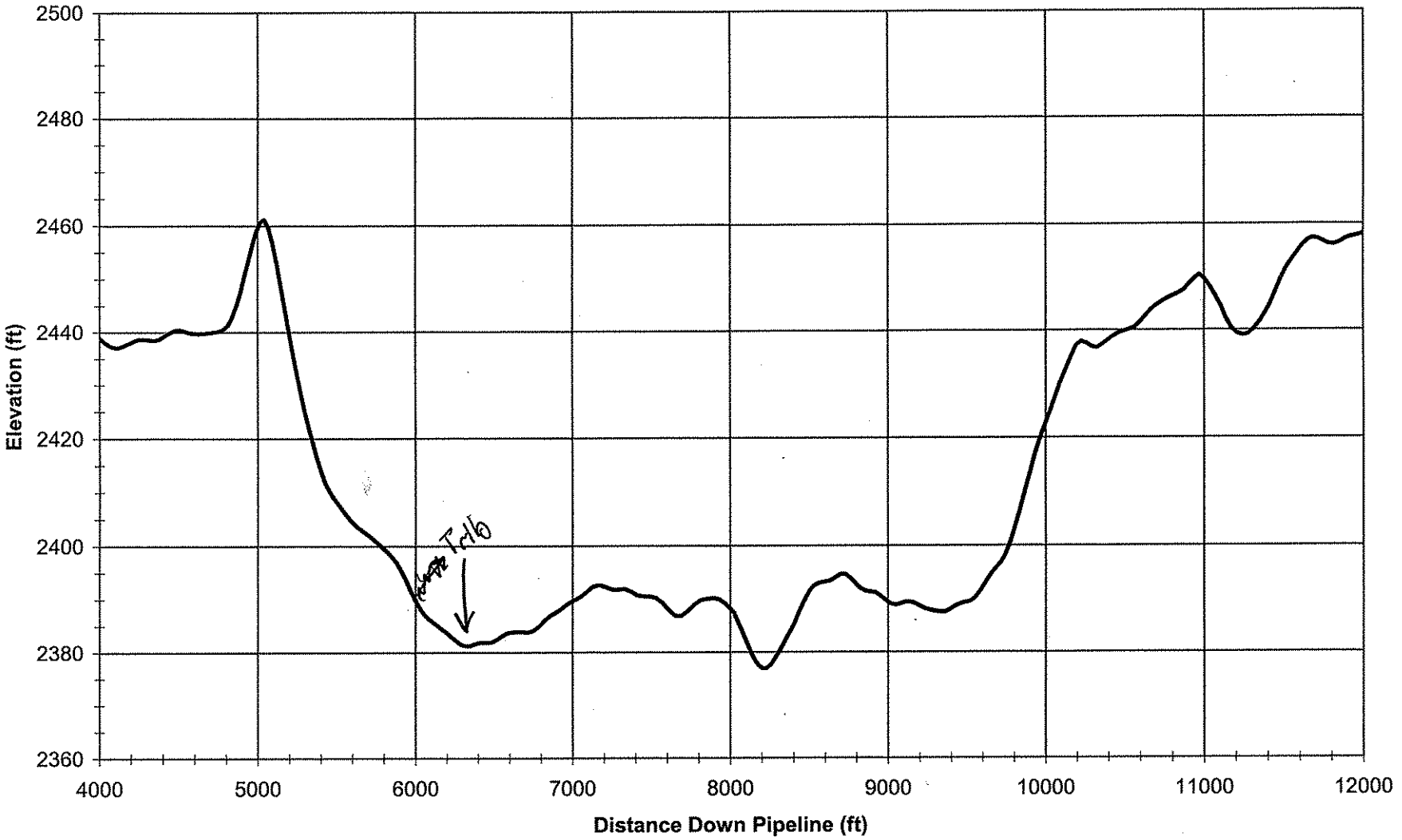
Redwater River - Proposed Keystone XL Pipeline Alignment Elevation Profile



KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Buffalo Springs Creek MP 153.3			Surveyors	Ericsson
GPS	WP:	N:	E:	Date/Time	8/8/2009 9:30AM
Flow Condition	no flow				

General Site Characteristics / Comments: Re-route location: crossing is now 300' or so upstream of railroad bridge crossing immediately upstream of 200 highway crossing. Site is within 450' wide valley single thread channel with low and high floodplains with high flow side channels. Widely scattered willows

* only access is a row along rr track

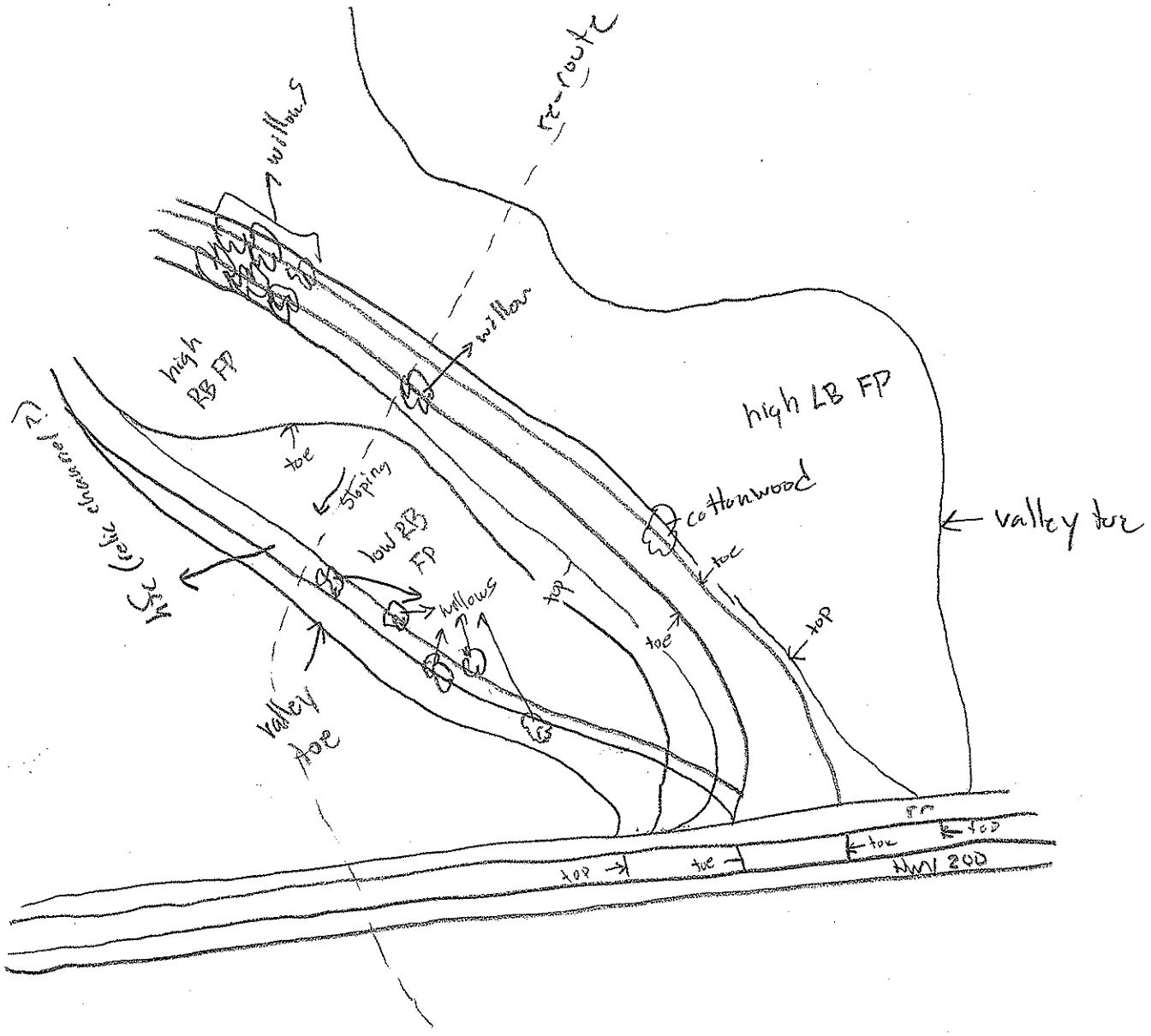
ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	1/2 mm		
	D_{50}	0.75 cm		
	D_{84}	1.9 cm		
	% sand	20		
	SOIL CLASS SYMBOL	GW		
Bed (sub-surface)	D_{16}			
	D_{50}	N/A		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}	N/A		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	1/12 mm
	D_{50}	N/A	D_{50}	1/8 mm
	D_{84}	N/A	D_{84}	1/4 mm
	% sand		% sand	100
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	SP
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}	1/10 mm	D_{16}	silt
	D_{50}	1/4 mm	D_{50}	1/8 mm
	D_{84}	1.3 cm	D_{84}	1/4 mm
	% sand	95	% sand	95-90%
	SOIL CLASS SYMBOL	SP	SOIL CLASS SYMBOL	SP

Comments: right bank sediment looks similar to left bank

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils



re-route
willows
willow
high RB FP
high LB FP
toe
sloping
low RB FP
cottonwood
valley toe
toe
top
willows
top
toe
valley toe
top
toe
toe
top
NW 200

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 6'-8'			Bank Height (ft) 4'-6'		
Bank Slope (°) 55			Bank Slope (°) 35		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species —			Dominant Species —		
Root Depth (ft) 1'-1.5' Observed (Y) N			Root Depth (ft) 1'-1.5' Observed Y / (N)		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / (N)	Potential (Y) / N	Gradual Migration	Present Y / (N)	Potential (Y) / N
Slumping	Present Y / (N)	Potential (Y) / N	Slumping	Present Y / (N)	Potential (Y) / N
Landsliding	Present Y / (N)	Potential Y / (N)	Landsliding	Present Y / (N)	Potential Y / (N)
Other:	Present Y / (N)	Potential Y / (N)	Other:	Present Y / (N)	Potential Y / (N)
Notes: measurement taken @ downstream site (same as @ crossing upstream)			Notes: measurement from observation downstream looking upstream		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity Young little to no dark surface		Soil Maturity	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/N)
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/N)	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) —	
Woody Riparian Plant Density (L,M,H) very low		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species 1 cottonwood tree on lb		Dominant Woody Species Salix	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes: 50yr FP		Notes: high FP = 25 yr low FP / side channel = 2-5 yr	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 50-60 ft	Bridges (Y/N) 2
Bankfull Depth (ft) 3'	Distance from Crossing (ft) 300' U.S. / D.S.
Bankfull Indicator(s) high banks	Associated Instability (Y/N) scour @ bridge
	Pier Scour Present (Y/N) If yes, depth: 1'-2'
Unvegetated Channel Width (ft) 0 covered w/ grasses	
	Roads (Y/N) bridge 200 hwy
Incision Evidence 1-2' scour pools at downstream	(RR, LB, US, DS) 300'
bridges w/ gravel/cobble substrate	
	Other Infrastructure N/A
Aggradation Evidence NA	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) 1-2' downstream of crossings	
Channel in Low Elevation of Valley Floor (Y/N)	
Notes: check aerial to see if rt FP side channel connects to thalweg upstream of bridge	Notes: only rip rap on rr bridge is on u.s. side of lb. HWY 200 bridge has riprap on both banks

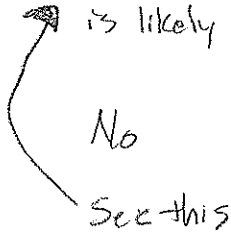
CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams N/A	In-stream structures NA
Debris flow NA	
	Flow Diversion NA
Landslides NA	
	Debris some lwd racked onto rr bridge
Woody debris see →	supports
Other:	Other: bridges (see above)

PHOTO CHECKLIST		
Site Overview	☒	188-192 looking upstream @ crossing from rr (pan)
Channel US Showing Both Banks	☒	no access @ crossing 194-195 panoramic looking upstream
Channel DS Showing Both Banks	☒	no access " 196-198 pan looking d.s. @ irr @ crossing bridge
Channel Bed Surface Alluvium	☒	193
Channel Bed Sub-Surface Alluvium	☒	NA
Bar Alluvium	☒	~~NOT BARS~~
Bars Overview	☒	~~200-203~~ pan looking u.s. @ crossing from rr (pan) 201-204
Islands Overview	☒	
Left Bank Alluvium	☒	206 209 - looking u.s. from lf fp @ rr
Left Bank Toe Detail	☒	~~204~~ 205
Left Bank Top of Bank Detail	☒	~~199~~ 200
Left Bank Overview	☒	~~198~~ 199
Left Floodplain Alluvium	☒	~~209~~ 207
Left Floodplain Overview	☒	208
Left Floodplain Landforms	☒	NA
Right Bank Alluvium	☐	—
Right Bank Toe Detail	☐	—
Right Bank Top of Bank Detail	☐	—
Right Bank Overview	☐	—
Right Floodplain Alluvium	☒	212
Right Floodplain Overview	☒	210
Right Floodplain Landforms	☐	
Infrastructure	☒	211 hwy 200 bridge w 2' boulder riprap
Disturbance/Instability	☐	

PHOTO LOG		
Photo ID	View Direction	Description
~~8~~ 213	downstream	racked lwd on rr bridge

Fine sand banks (easily erodable), potential for turbid release during first flow after construction. However bed/banks, and floodplain are very similar (easily erodable) and any sediment on new channel bed would be the same as if not crossed.

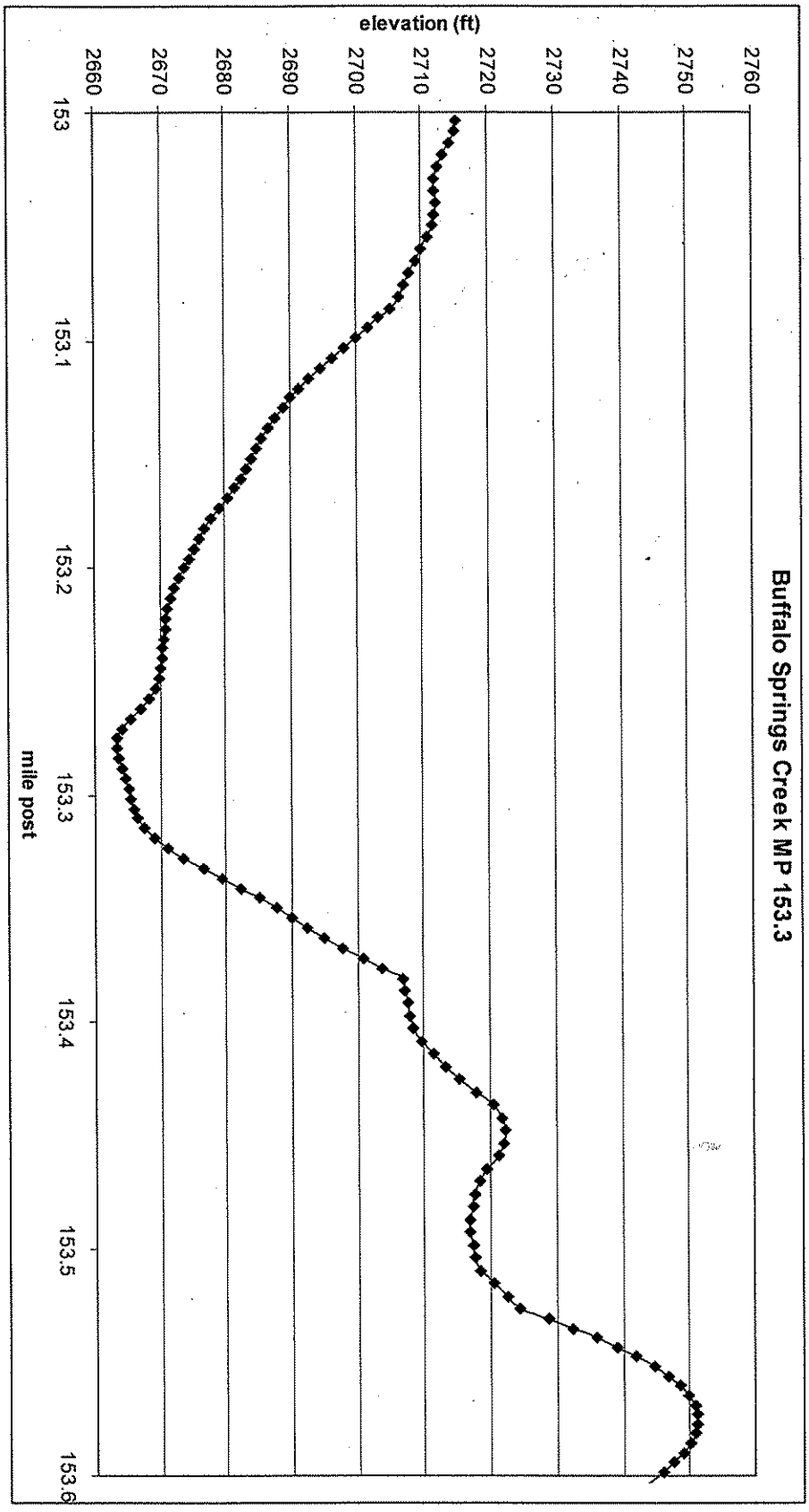
Ensure thalweg is cobble/gravel, else headcut incision upstream is likely in these erodable materials



Minimal habitat lost (few salix), short term turbid release expected but not much above expected background.

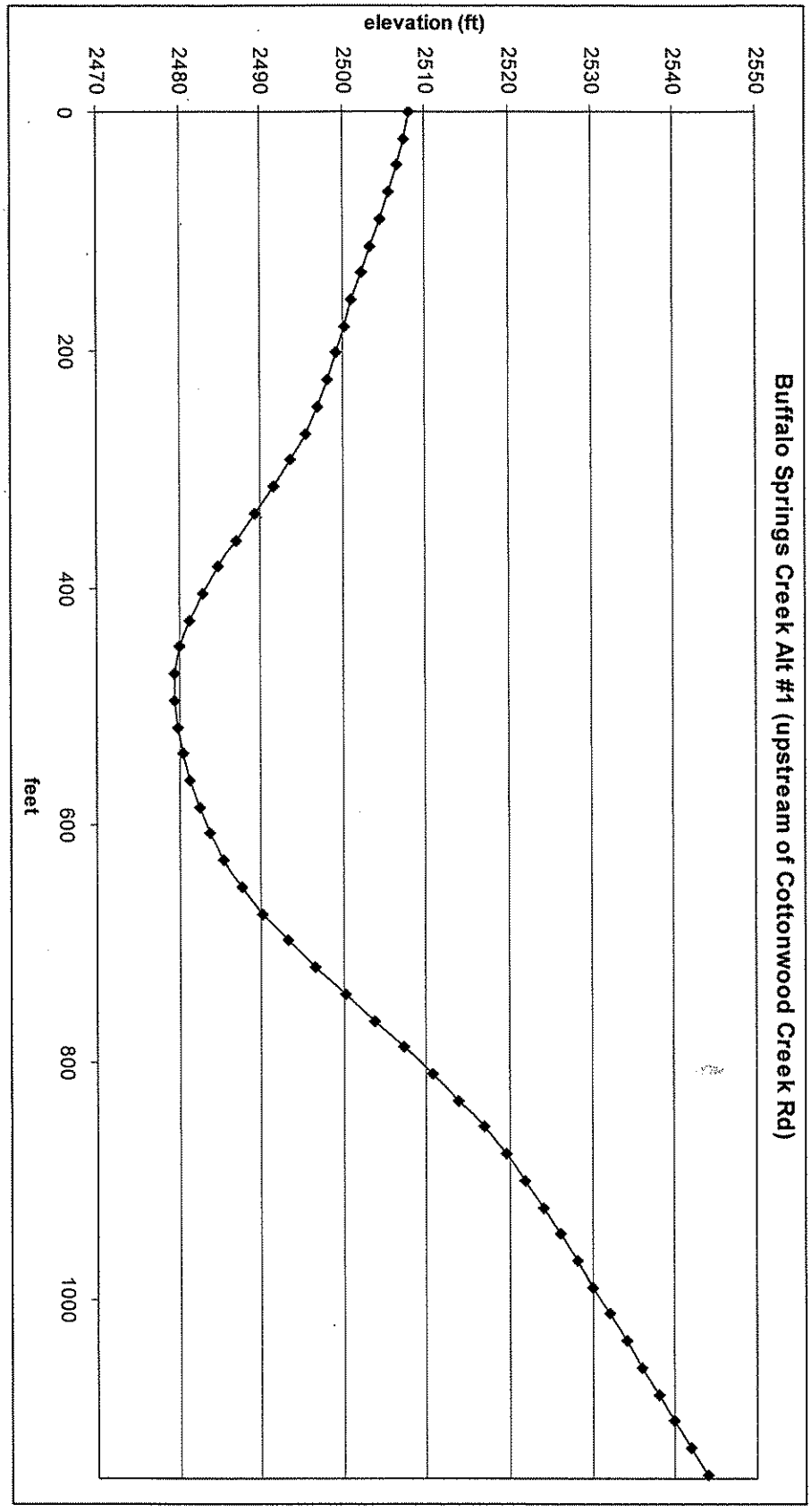
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



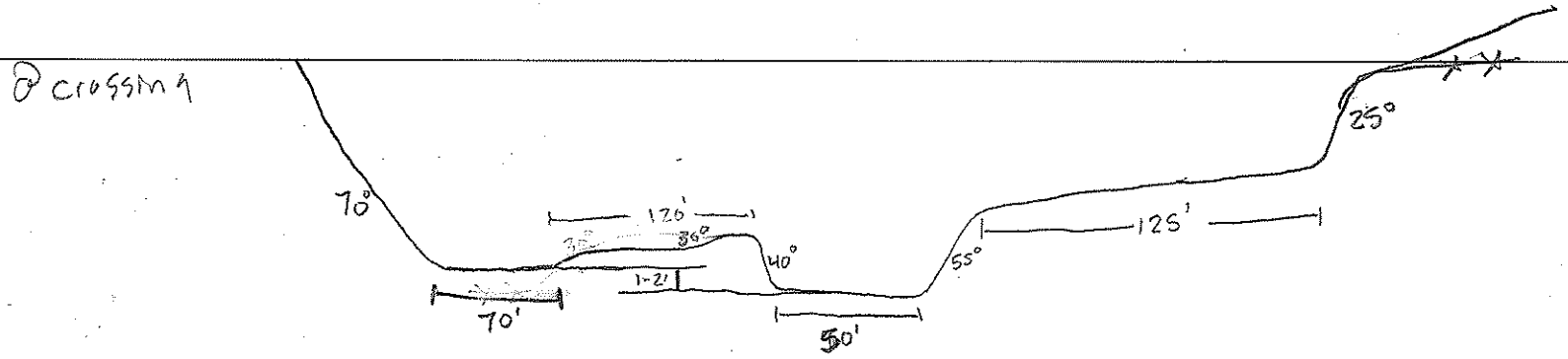
ALT #1 VALLEY CROSS-SECTION SKETCH

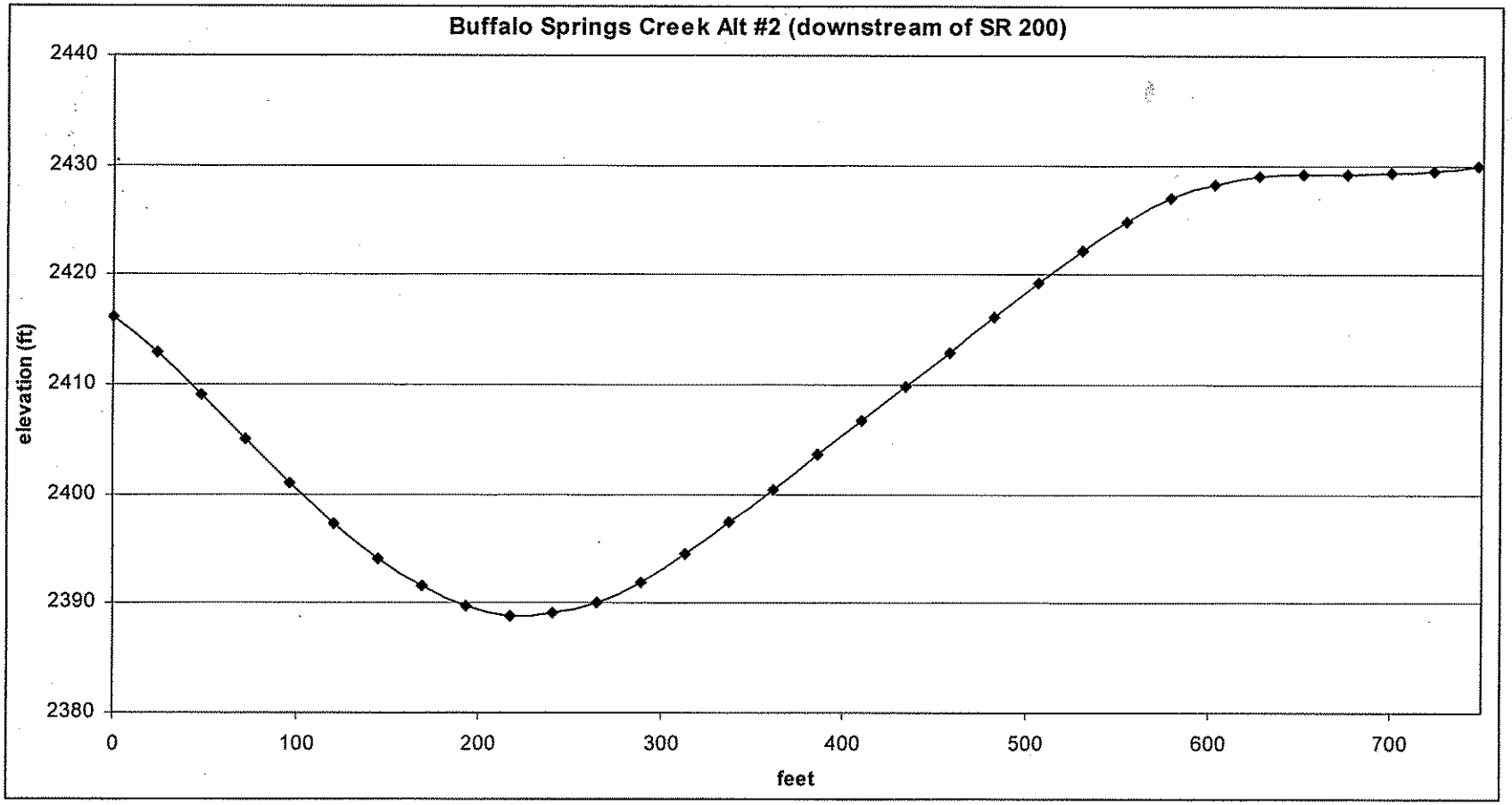
*notes – valley cross-section derived from 30 / 10 meter USGS DEM



ALT #2 VALLEY CROSS-SECTION SKETCH

*notes -- valley cross-section derived from 30 / 10 meter USGS DEM





KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA

Site	Buffalo Springs Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing Regional Regression	5.14	--	--	--	441	1,549	2,713	4,403	5,835	6,200
No Gage Station Data Available										

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: 0.10

Width (ft)	min	max	mean	std dev
	16	26	22	4

meander wavelength (ft) 403

meander amplitude (ft) 169

Sinuosity 1.56

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	456	561	108	247
	794	830	476	272
	1269	269	718	193
			1020	216

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 19.80

Valley

Gradient: 0.20

width	min	max	mean	std dev
	322	636	457	100

describe geology (lithology, erodibility):

Alluvium of modern channels and flood plains.

Sandstone, sandy and silty shale and coal. Thickness 984 ft

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:

US Oxbow or man made pond (0.37 mi river right near farm); DS Oxbow (0.35 mi, river right in field)

channel cut-offs:

US 1. Relic Channel (0.80 mi river left, along embankment) 2. Relic Channel (0.00-0.20 mi, river right along valley wall)

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
The channel appears to be incised because the floodplain elevation is greater than the channel's water surface elevation.
Unique features, exceptions, etc
There is a sediment depositional feature <0.1mi US of the crossing.
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
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/farm (0.40 mi, river right)
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Berry Clk, MT			Surveyors	BD, ME
GPS	WP:	N:	E:	Date/Time	7/15/09 17:00
Flow Condition	very slow trickle - possibly not perennial				

General Site Characteristics / Comments

Non-perennial meandering channel cut down through Fort Union Formation sedimentary rock

* mainline pipe buried depth 5' below thalweg across floodplain (see XS sketch)

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	< 5% clay		
	D_{50}			
	D_{84}			
	% sand	0		
	SOIL CLASS SYMBOL	ML		
Bed (sub-surface)	D_{16}			
	D_{50}	NA		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}	NA		
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand		% sand	
	SOIL CLASS SYMBOL	SP ~15% silt	SOIL CLASS SYMBOL	SP <5% silt
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN NA	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand		% sand	
	SOIL CLASS SYMBOL	<1% sand CH 35% clay	SOIL CLASS SYMBOL	

Comments: not a well defined floodplain - likely flooded every year - yet alluvium different than low-flow thalweg - much more clay on FP, unusually dry

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)		
		GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)		
		GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)		
		SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)		
		SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 10-12'			Bank Height (ft) 10-12'		
Bank Slope (°) 30° 2 toe			Bank Slope (°) 45		
30° 2 top					
Woody Cover (%) 35			Woody Cover (%) 70		
Dominant Species Ash?			Dominant Species see photos		
Root Depth (ft) Observed Y/(N) species dependent grasses ~1ft, trees ~4', sage ~2'			Root Depth (ft) Observed Y/(N) see LB notes		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure NO			Bank Failure		
Gradual Migration	Present Y/(N)	Potential Y/(N)	Gradual Migration	Present Y/(N)	Potential Y/(N)
Slumping	Present Y/(N)	Potential Y/(N)	Slumping	Present Y/(N)	Potential Y/(N)
Landsliding	Present Y/(N)	Potential (Y/N)	Landsliding	Present Y/(N)	Potential (Y/N)
Other:	Present Y/(N)	Potential Y/(N)	Other:	Present Y/(N)	Potential Y/(N)
Notes: low potential for migration of incised ch. w/ 10' or > banks. Low landslide potential @ x-ings, but higher ~200' bs @ unvegetated steep, high bank			Notes: see LB notes		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity NA		Soil Maturity weak - aggrading	
Natural Levees (Y/N)		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Riparian Buffer Width (ft)		Riparian Buffer Width (ft) 20'	
Riparian Plant Density (L,M,H)		Riparian Plant Density (L,M,H)	
Dominant Species		Dominant Species see photo notes	
Crevasse Splays (Y/N)		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/N)		Crevasse Channels (Y/(N))	
Notes:		Notes: Floodplain is actually inside of Right Bank - removed	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) ~78	Bridges (Y/(N))
Bankfull Depth (ft) ~1.5-2' for low floodplain, 12' for high FP	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) topography, alluvium, + veg.	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) NA - grass channel	
	Roads (Y/N)
Incision Evidence NO - geologic scale incision	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence no	
Bars (Y/(N)) NO-	
Vegetated Islands (Y/(N))	
Pool Depths (ft) NA - planar ch. w/ no flow	
to measure any potential pools	
Channel In Low Elevation of Valley Floor ((Y)/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS NO	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

MANDATORY PHOTO CHECKLIST				
Photo		*Photo ID*	*View Direction*	*Description*
Site Overview	☒	Video RMOU0036		360° panorama
Channel US Showing Both Banks	☒	28, 29		
Channel DS Showing Both Banks	☒	30, 31		
Channel Bed Surface Alluvium	☒	32		
Channel Bed Sub-Surface Alluvium	☐	NA		
Bar Alluvium	☐	NA		
Bars Overview	☐	NA		
Islands Overview	☐	NA		
Left Bank Alluvium	☒	25		
Left Bank Toe Detail	☒	24		Sand banks
Left Bank Top of Bank Detail	☒	26		Sand
Left Bank Overview	☒	43		
Left Floodplain Alluvium	☒	NA		
Left Floodplain Overview	☒	NA		
Left Floodplain Landforms	☒	NA		
Right Bank Alluvium	☒	44		
Right Bank Toe Detail	☒	45		
Right Bank Top of Bank Detail	☒	46		
Right Bank Overview	☒	27		
Right Floodplain Alluvium	☐	33		
Right Floodplain Overview	☐	34, 35		
Right Floodplain Landforms	☐	NA		
Infrastructure	☐	NA		
Disturbance/Instability	☐	NA		

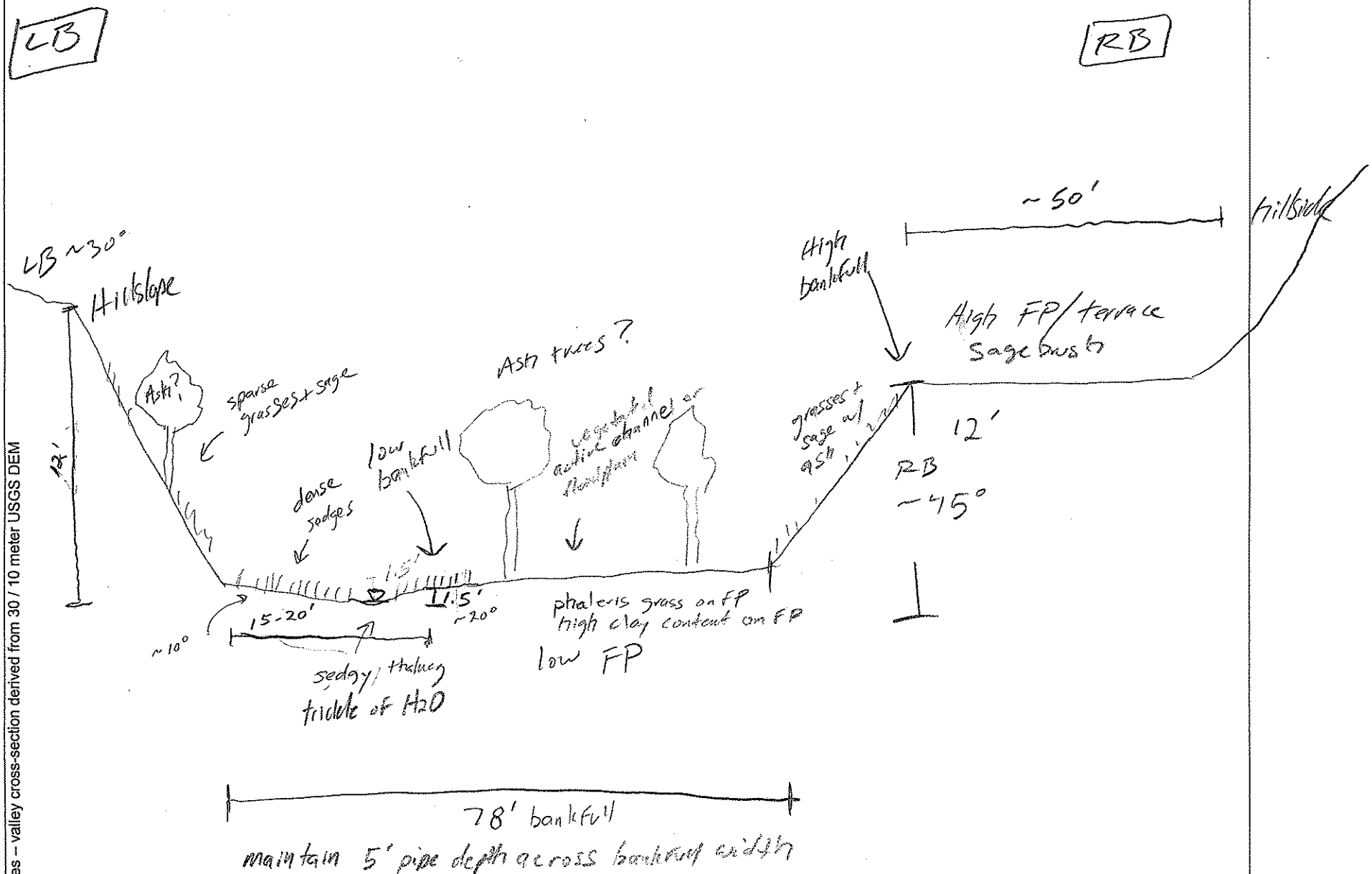
SUPPLEMENTAL PHOTOS		
Photo ID	*View Direction*	*Description*
37-39		left bank dominant spp leaf close-up, tree overview
41, 42		Right bank dominant spp leaf + tree
47		DS view from upon LB ~ 100' US X-ings
48		across ch " "
49		US " "
50		US from RB floodplain
51		" "

Video RMOU0023 - taken on Right top terrace

Berry Creek

VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM

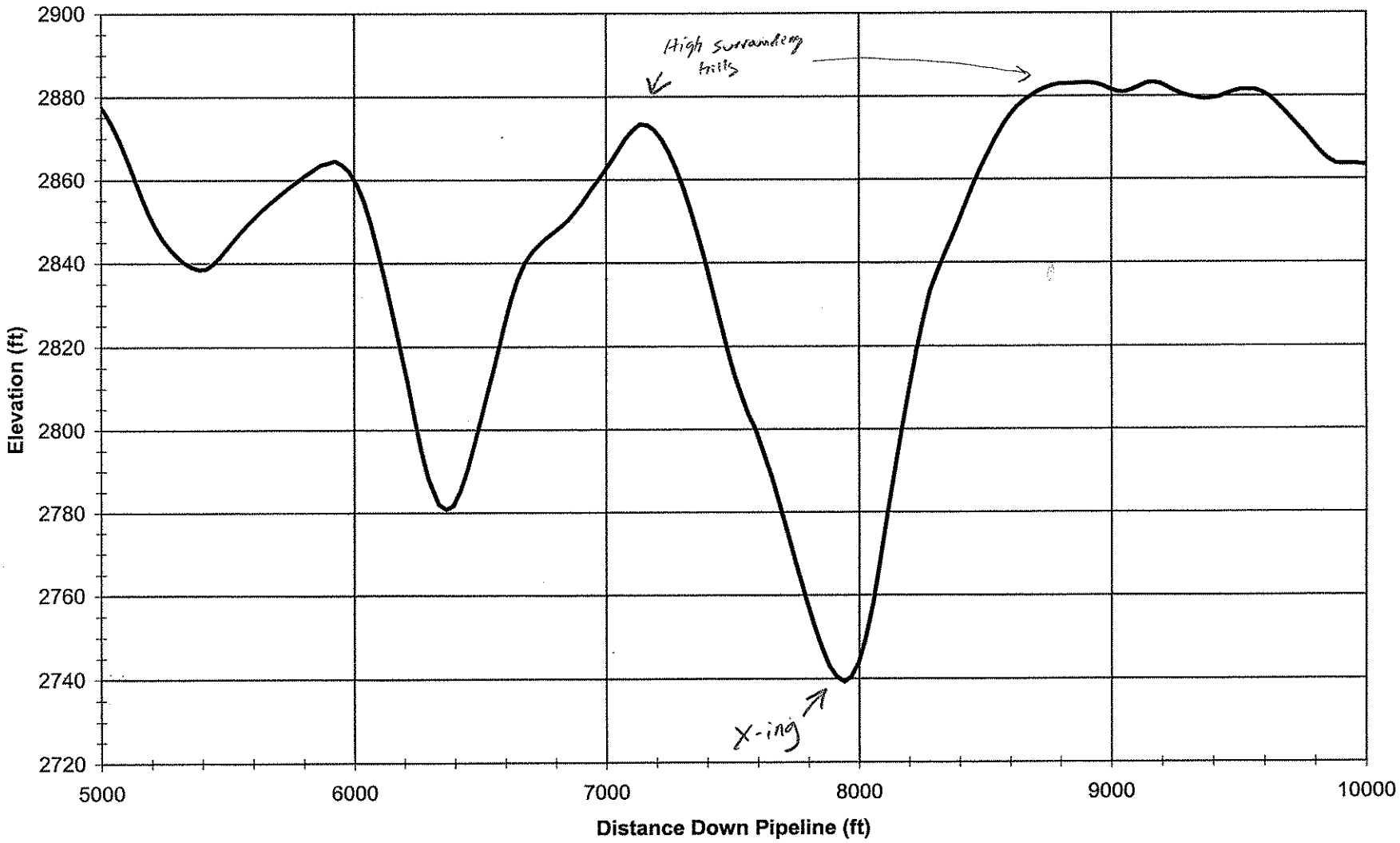


CHANNEL CROSS-SECTION SKETCH

PLANVIEW MAP

*notes – image background date:

Berry Creek - Proposed Keystone XL Pipeline Alignment Elevation Profile



1548000

1552000

17192000

17192000

3000

4000

5000

6000

7000

8000

9000

10000

11000

RB floodplain

RB

1548000

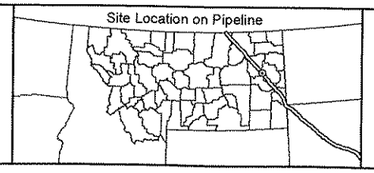
1552000

Legend

- Intermittent Stream Crossings
- Perennial Stream Crossings
- Proposed Pipeline Route
- 1,000 ft Profile Interval

Base Photo: 2005 U.S. Farm Services Agency National Agricultural Imagery Program (NAIP)

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS GEOMORPHOLOGY ASSESSMENT

BERRY CREEK - MILE POST 159.2 2005 NAIP Aerial

ENTRIX

200 1st Ave W Ste 500
Seattle, WA 98119

ph (206) 269-0104
fx (206) 269-0098

www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

N W E S

0 300 600 1,200 Feet

File: \\Sacramento-nas\Data\SHARED\Belby\Keystone Pipeline\gis\map\mxd\Keystone XS field map landscape tabloid.mxd

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KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Clear Creek, MT			Surveyors	BB, ME
GPS	WP:	N:	E:	Date/Time	7/15/09 14:30
Flow Condition	low to stagnant - not perennial - channel dry @ fenceline DS				

General Site Characteristics / Comments

- low gradient meandering channel, X-ing on a mowed bend, in middle of pasture. Channel width at X-ing is appreciably wider than US or DS
- channel is dotted w/ cattle tanks * maintain 5' buried pipe depth ≥ 15' beyond bankfull
- channel is dredged to maintain spring, year-round and for agricultural water supply (per landowner) spoilsave stockpiled into left bank berm

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}			
	D_{50}	silt		
	D_{84}			
	% sand	<1%		
	SOIL CLASS SYMBOL	OL		
Bed (sub-surface)	D_{16}			
	D_{50}	NA		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
NA Bars	D_{16}			
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}	silt	D_{50}	silt
	D_{84}		D_{84}	
	% sand	<1	% sand	<1
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}	silt	D_{50}	silt
	D_{84}		D_{84}	
	% sand	<1	% sand	<1
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	

Comments: very few pebbles ~22mm Dmax in L.B.

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)		
		GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)		
		GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)		
		SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)		
		SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 6			Bank Height (ft) 3.5'		
Bank Slope (°) low bank 20°, upper 1.5' bank is 90°			Bank Slope (°) 17 * double check w/ site photo		
Woody Cover (%) None			Woody Cover (%) 0		
Dominant Species grasses - dense cover			Dominant Species grasses on bank, emergent marsh base		
Root Depth (ft) 1.6 Observed (Y) / N			Root Depth (ft) 1.6 Observed Y / (N)		
Undercutting (Y)N toe not deeply undercut, but slumping indicates prior undercutting			Undercutting (Y)(N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / N	Potential (Y) / N	Gradual Migration	Present Y / N	Potential Y / (N)
Slumping	Present (Y) / N	Potential Y / N	Slumping	Present Y / N	Potential Y / (N)
Landsliding	Present Y / (N)	Potential Y / (N)	Landsliding	Present Y / N	Potential Y / (N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / (N)
Notes: could be migrating, no evidence of. Ran on p13, Reaumer, silt could be colonized quickly w/ cattails + grass			Notes:		
dredging undermining bank slopes/oversteepening and contributing to aggic datron					

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity weak, low organics		Soil Maturity ~~weak~~, weak, low organics	
Natural Levees (Y)(N)		Natural Levees (Y)(N)	
Description:		Description	
Artificial Levees (Y)(N) dredge spoil material		Artificial Levees (Y)(N) ~~dredge spoil material~~	
Description: ~~bumped X-ing may be spoil~~ ~~material according to Landowner~~		Description:	
Side Channels		Side Channels	
Perennial (Y)(N)	Ephemeral (Y)(N)	Perennial (Y)(N)	Ephemeral (Y)(N)
Intermittent (Y)(N)	Relic/Abandoned (Y)(N)	Intermittent (Y)(N)	Relic/Abandoned (Y)(N)
Wine observation around			
Riparian Buffer Width (ft) 0-15' mostly grass to TOB, mowed up to TOB		Riparian Buffer Width (ft) 0-15 grass on bank emergent marsh at base	
Riparian Plant Density (L,M,H) grasses		Riparian Plant Density (L,M,H) emergent marsh	
Dominant Species grasses		Dominant Species grasses / typha	
Crevasse Splays (Y)(N)		Crevasse Splays (Y)(N)	
Crevasse Channels (Y)(N)		Crevasse Channels (Y)(N)	
Notes: high grassy bank w/ slumping evident		Notes:	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 25 m	Bridges (Y/N)
Bankfull Depth (ft) 5'	Distance from Crossing (ft) ~~U.S. / D.S.~~
Bankfull Indicator(s) topo	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 14m	
	Roads (Y/N)
Incision Evidence ~~natural~~ ~~down~~ maintained	(RB) LB, US, DS) rb has small dirt access rd.
channel dredging	upstream
	Other Infrastructure
Aggradation Evidence siltation requiring dredging	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) NA	
Channel in Low Elevation of Valley Floor (Y/N)	
Notes: completely dry at fence boundary	Notes:
East of crossing	

CHANNEL DISTURBANCE/PERTERBATIONS	
Natural NA	Artificial dredging / maintenance
Beaver dams NA	In-stream structures NA
Debris flow NA	
	Flow Diversion NA
Landslides NA	
	Debris NA
Woody debris NA	
Other: natural spring in channel @ crossing that is dredged out periodically, spoils left on right bank. Upstream the channel has dry reaches between spring reaches	Other: Landowner communication: "This channel has not moved in 50 yrs"

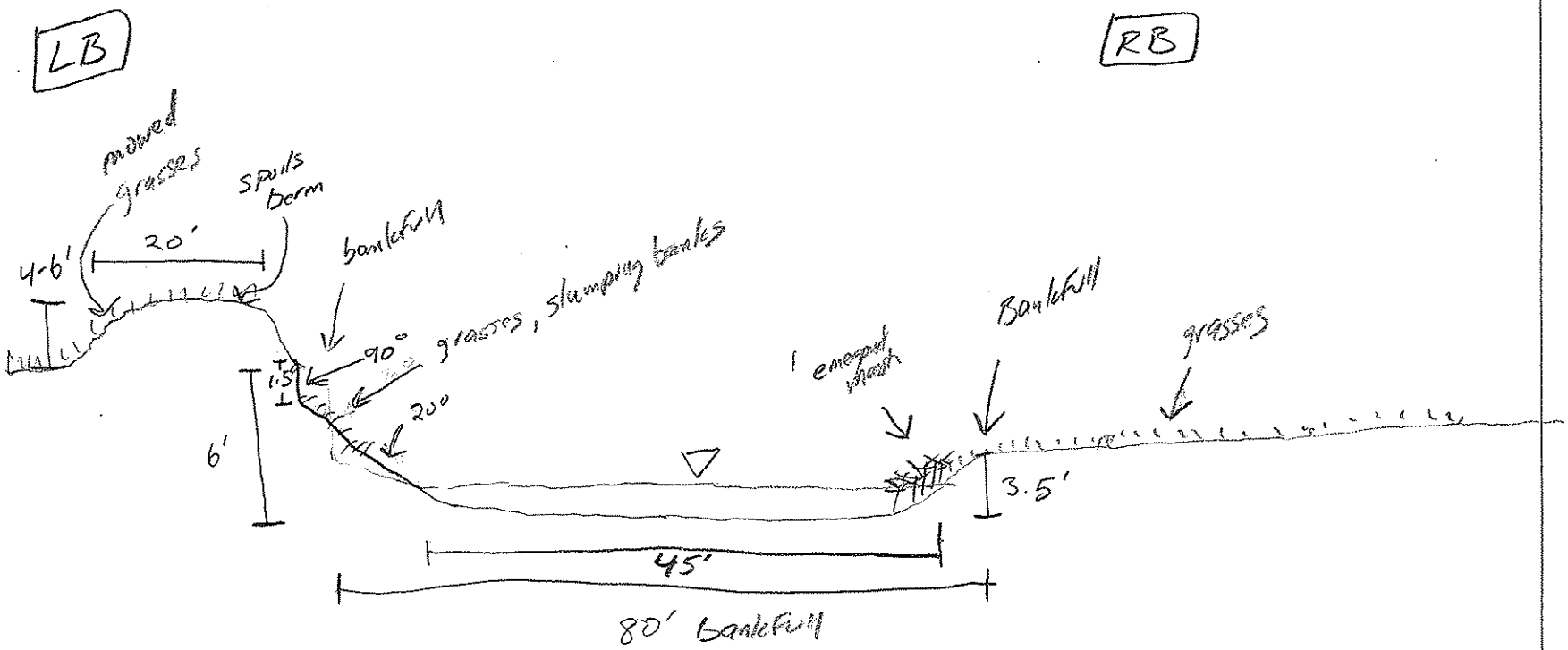
MANDATORY PHOTO CHECKLIST				
Photo		*Photo ID*	*View Direction*	*Description*
Site Overview	☐			
Channel US Showing Both Banks	☒	~~19~~ 20		
Channel DS Showing Both Banks	☒	~~20~~ 19		
Channel Bed Surface Alluvium	☐			
Channel Bed Sub-Surface Alluvium	☐	NA		
Bar Alluvium	☐	NA		
Bars Overview	☐	NA		
Islands Overview	☐	NA		
Left Bank Alluvium	☒	16		
Left Bank Toe Detail	☒	15		
Left Bank Top of Bank Detail	☒	14		
Left Bank Overview	☒	8		
Left Floodplain Alluvium	☒	~~3~~	~~do~~	
Left Floodplain Overview	☒	~~5~~		
Left Floodplain Landforms	☒	~~NA~~		
Right Bank Alluvium	☒	~~3~~	NA	
Right Bank Toe Detail	☒	~~5~~ 10		
Right Bank Top of Bank Detail	☒	~~NA~~ 9		
Right Bank Overview	☒	13		
Right Floodplain Alluvium	☒	3+4		
Right Floodplain Overview	☒	5+6+7		
Right Floodplain Landforms	☒	NA		
Infrastructure	☐	NA		
Disturbance/Instability	☐	see slumping below		

SUPPLEMENTAL PHOTOS		
Photo ID	*View Direction*	*Description*
11	~~dry~~	dry channel downstream
12		dry channel downstream
17		slumping on left bank
18		slumping on left bank

Took 2 videos showing site

Clear Creek

CHANNEL CROSS-SECTION SKETCH



maintain 5' bankfull depth ≥ 15' beyond bankfull

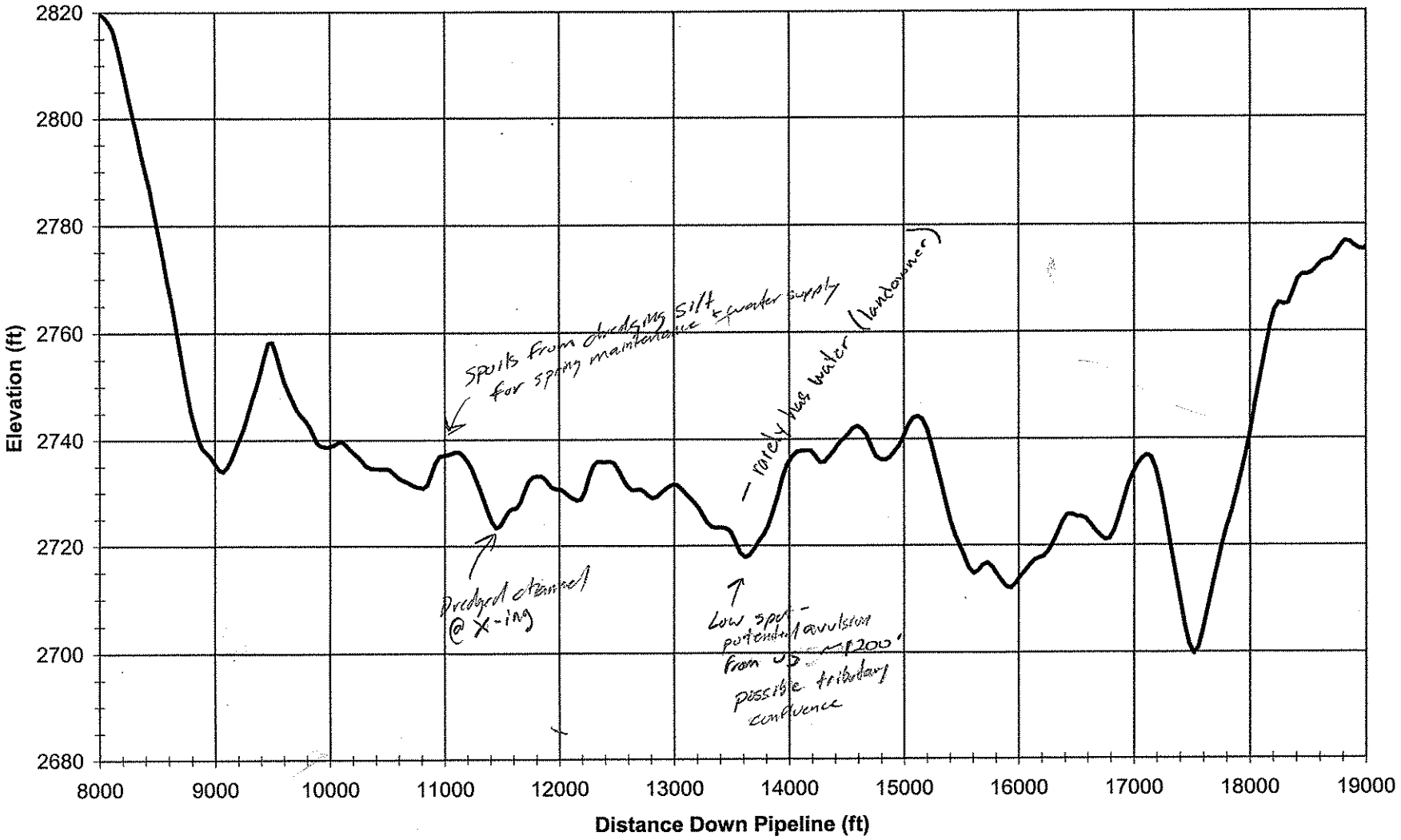
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM

PLANVIEW MAP

*notes – image background date:

Clear Creek - Proposed Keystone XL Pipeline Alignment Elevation Profile



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

CLEAR CREEK - MILE POST 175.2
NRCS SSURGO Soils

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

N W E S

0 300 600 1,200 Feet

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KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Yellowstone River - Side Channel			Surveyors	BB, ME
GPS	WP:	N:	E:	Date/Time	7/17/09
Flow Condition	low flow, muddy water				

General Site Characteristics / Comments

slightly meandering side channel
John - drill for HDD supposed to begin 25' beyond fenceline @ side channel
- bedrock exposure on left bank and in channel bed
- channel migration and scour potential should not threaten HDD X-ing as proposed / explained by John

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}			
	D_{50}		Fine sand	
	D_{84}			
	% sand		> 75	
	SOIL CLASS SYMBOL		GM w/ bedrock, boulder + cobble	
Bed (sub-surface)	D_{16}			
	D_{50}		likely coarser than	
	D_{84}		sfc - bedrock + boulders	
	% sand			
	SOIL CLASS SYMBOL		GM	
Bars	D_{16}			
	D_{50}		0.1	
	D_{84}			
	% sand		80	
	SOIL CLASS SYMBOL		SM	
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}	very Fine sand	D_{50}	0.1
	D_{84}		D_{84}	
	% sand	80	% sand	80
	SOIL CLASS SYMBOL	SM	SOIL CLASS SYMBOL	rest = mostly silt 5% clay SM
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	N/A
	D_{50}	very Fine sand	D_{50}	terrace
	D_{84}		D_{84}	
	% sand	80	% sand	
	SOIL CLASS SYMBOL	SM	SOIL CLASS SYMBOL	

Comments: Note LB also has bedrock exposures and coarse cobble + gravel alluvium on upper half

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	
	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 30			Bank Height (ft) 15		
Bank Slope (°) lower 5' ~ 80-90°, 20' @ 45°, 30-40' @ 20°			Bank Slope (°) 10-15		
Woody Cover (%) < 5			Woody Cover (%) < 2 (sage)		
Dominant Species herbaceous lone cottonwood			Dominant Species herbaceous annual		
Root Depth (ft) 2+ Observed Y / N			Root Depth (ft) 2+ Observed Y (N)		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure Bedrock			Bank Failure NO		
Gradual Migration	Present Y /(N)	Potential Y /(N)	Gradual Migration	Present Y (N)	Potential Y (N)
Slumping	Present (Y) / N minor	Potential (Y) / N	Slumping	Present Y (N)	Potential Y (N)
Landsliding	Present Y /(N)	Potential Y /(N)	Landsliding	Present Y (N)	Potential Y (N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: bedrock outcrop on LB - has large gravel + cobble material overlying it bedrock - very fine sandstone bedrock			Notes: Both banks are stable, cohesive w/ dense root structure		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity N/A Terrace @ road		Soil Maturity no organic - undeveloped soil	
Natural Levees (Y/N)		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels no side channels to the side channel site	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Riparian Buffer Width (ft)		Riparian Buffer Width (ft) 0	
Riparian Plant Density (L,M,H)		Riparian Plant Density (L,M,H)	
Dominant Species		Dominant Species Herbaceous	
Crevasse Splays (Y/N)		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/N)		Crevasse Channels (Y/(N))	
Notes:		Notes: water stains on base of cottonwoods on island - not observed - undulating micro-topography on island	

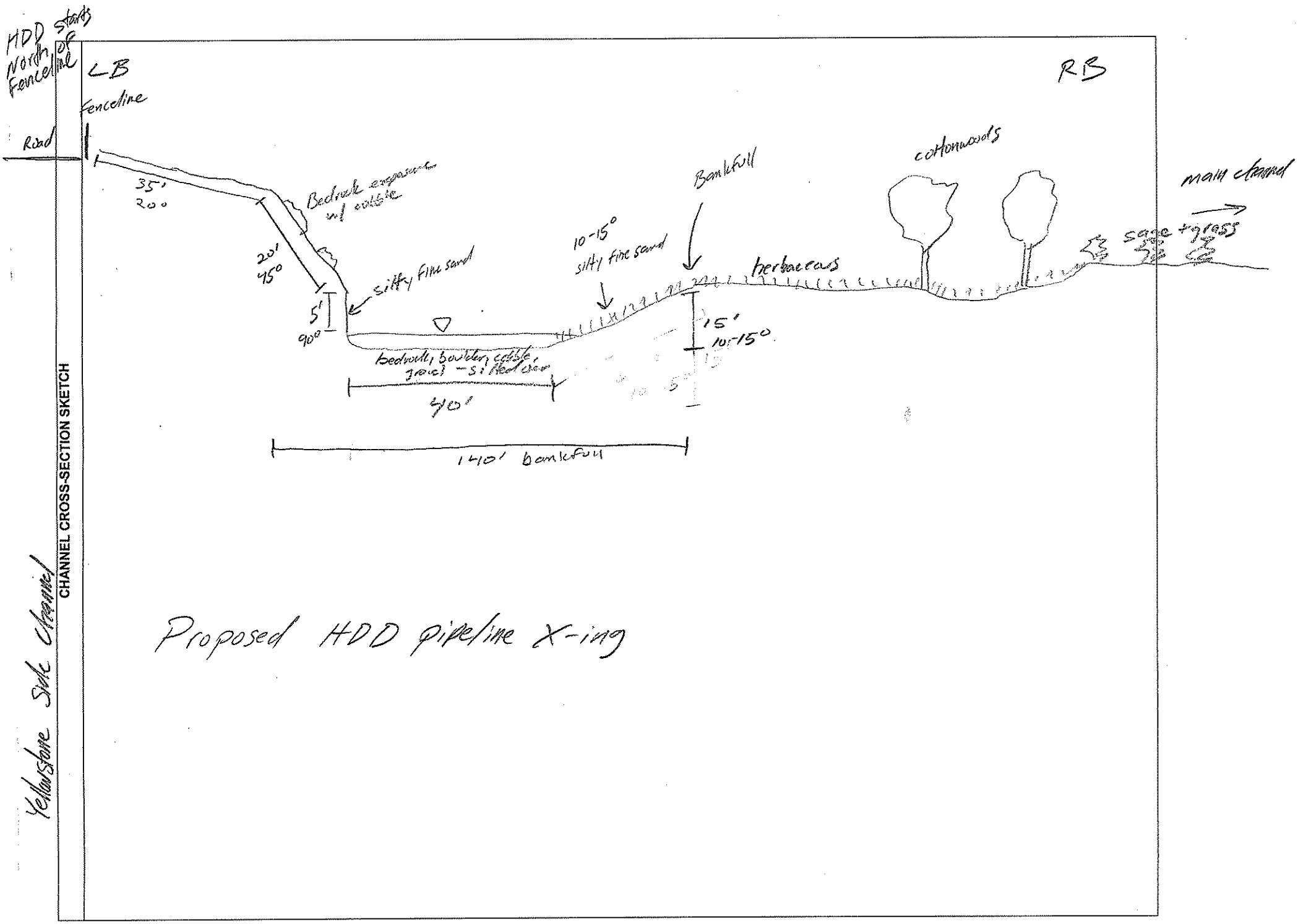
CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 141	Bridges (Y/N)
Bankfull Depth (ft) 20	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) Alluvial Flat	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 40	
	Roads (Y/N) road on LB terrace
Incision Evidence NO	(RR, LB, US, DS)
	Other Infrastructure NO
Aggradation Evidence NO	
Bars (Y/N) larger silty point-bar US, small (20'×5')	
grassy alternating bars throughout	
Vegetated Islands (Y/N) right floodplain is the	
vegetated island	
Pool Depths (ft) not observed - flat water	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes: Channel bed mostly silt, but has bedrock	Notes:
exposures, some boulders + cobbles	

CHANNEL DISTURBANCE/PERTERBATIONS none	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

MANDATORY PHOTO CHECKLIST				
Photo		*Photo ID*	*View Direction*	*Description*
Site Overview	☒	17-18	start DS	
Channel US Showing Both Banks	☒	9		
Channel DS Showing Both Banks	☒	10		
Channel Bed Surface Alluvium	☒	11, 14-16		11 silty bed, 14-16 bedrock + cobble bed
Channel Bed Sub-Surface Alluvium	☒	11		sub-sfc similar to photos for surface
Bar Alluvium	☒	11		
Bars Overview	☒	12		US of X-ing site
Islands Overview	☐			
Left Bank Alluvium	☒	13		see picture 11 for silty bed
Left Bank Toe Detail	☒	5		
Left Bank Top of Bank Detail	☒	8		
Left Bank Overview	☒	21		
Left Floodplain Alluvium	☐	NA		see picture 11 for silty bed
Left Floodplain Overview	☐	NA		
Left Floodplain Landforms	☐	NA		
Right Bank Alluvium	☒	22		
Right Bank Toe Detail	☒	6		
Right Bank Top of Bank Detail	☒	23		
Right Bank Overview	☒	7		
Right Floodplain Alluvium	☒	22		
Right Floodplain Overview	☒	18		
Right Floodplain Landforms	☒	24, 25		micro topography on island
Infrastructure	☐	NA		Road up on terrace
Disturbance/Instability	☐	NA		

SUPPLEMENTAL PHOTOS		
Photo ID	*View Direction*	*Description*
1	LB	bedrock outcrop
2-4	LB	coarse alluvium
26-27, 28		transition from Right Floodplain up higher to drier terrace

video 19 - site overview from LB @ X-ing
video 29 - island overview from boundary of RB FP + terrace



Proposed HDD pipeline X-ing

VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM

PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Yellowstone main channel			Surveyors	BB, ME
GPS	WP:	N:	E:	Date/Time	7/17/09 9:40
Flow Condition	low to moderate - receding snowmelt hydrograph				

General Site Characteristics / Comments

meandering gravel bed river w/ silty to sandy siltstone 75-100' tall RB river bluffs. Tributary (not flowing) w/ culvert @ main ch. just US X-ing HDD site. Channel migration + scour potential would not threaten proposed HDD X-ing as explained by John

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	6 mm		
	D_{50}	25 mm		
	D_{84}	60-70 mm		
	% sand	<1 %		
	SOIL CLASS SYMBOL		GW	
Bed (sub-surface)	D_{16}	2 mm		
	D_{50}	4 mm		
	D_{84}	45 mm		
	% sand	<10	GM	
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}			
	D_{84}	See	bed	
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}		D_{50}	0.08 mm
	D_{84}		D_{84}	
	% sand		% sand	50
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	SM
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}		D_{50}	0.08 mm
	D_{84}		D_{84}	
	% sand		% sand	50
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	SM

Comments:

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	
	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 10 ft - 15 ft			Bank Height (ft)		
Bank Slope (°) ~~lower bank 12~~ 20°			Bank Slope (°)		
Woody Cover (%) ~10°			Woody Cover (%)		
Dominant Species willow			Dominant Species		
Root Depth (ft) 1-2 ft Observed Y / N			Root Depth (ft)	Observed Y / N	
Undercutting (Y/N)			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / N	Potential Y / N	Gradual Migration	Present Y / N	Potential Y / N
Slumping	Present Y / N	Potential Y / N	Slumping	Present Y / N	Potential Y / N
Landsliding	Present Y / N	Potential Y / N	Landsliding	Present Y / N	Potential Y / N
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: potential landsliding on right bank			Notes: no access available		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity immature / no organic		Soil Maturity	
Natural Levees (Y/N)		Natural Levees (Y/N)	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/N)	
Description:		Description:	
Side Channels → See Yellowstone Side channel		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N) Crossings	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Riparian Buffer Width (ft) NA		Riparian Buffer Width (ft)	
Riparian Plant Density (L,M,H)		Riparian Plant Density (L,M,H)	
Dominant Species grass + herbaceous unk (Lepedium?)		Dominant Species	
Crevasse Splays (Y/N)		Crevasse Splays (Y/N)	
Crevasse Channels (Y/N)		Crevasse Channels (Y/N)	
Notes: 40 ft wide gently sloping bowl woody debris & margins		Notes: Not present	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 230 m	Bridges (Y/N)
Bankfull Depth (ft) 20 m	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) racked wood along margin, break in slope	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 200 m	
	Roads (Y/N)
Incision Evidence NA	(RR, LB, US, DS)
	Other Infrastructure railroad on right bank
Aggradation Evidence NA	approximately 70 ft above river on bluff
Bars (Y/N) alternating, 300 ft long, 40 ft wide	
Vegetated Islands (Y/N)	
Pool Depths (ft) not observed; likely ~~>20 ft~~ >20 ft	
Channel in Low Elevation of Valley Floor (Y/N)	
Notes:	Notes: None threatened @ crossing

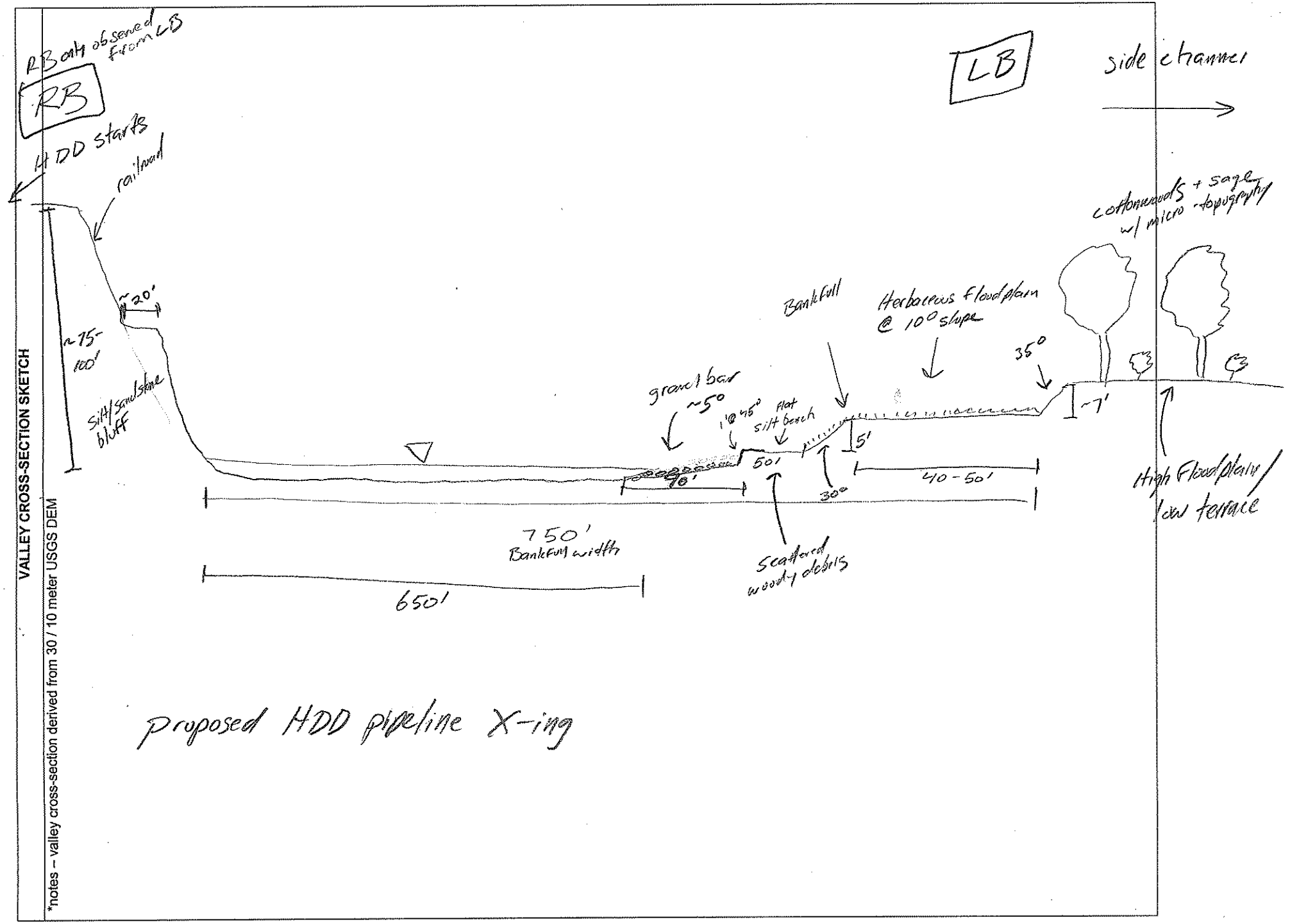
CHANNEL DISTURBANCE/PERTERBATIONS	
Natural —	Artificial —
Beaver dams —	In-stream structures —
Debris flow —	
	Flow Diversion —
Landslides —	
	Debris See woody debris
Woody debris scattered LWD not influencing morphology	
Other:	Other:

MANDATORY PHOTO CHECKLIST				
Photo		*Photo ID*	*View Direction*	*Description*
Site Overview	☒	55–61		panaramic 55- upstream → 61 ds
Channel US Showing Both Banks	☒	34,35,36		panaramic
Channel DS Showing Both Banks	☒	37,38,39		panaramic
Channel Bed Surface Alluvium	☒	see 30		
Channel Bed Sub-Surface Alluvium	☒	see 31		
Bar Alluvium	☒	30,31		30 -surface 31 -subsurface
Bars Overview	☒	32,33		32- upstream 33- downstream
Islands Overview	☒	—		- see from Yellowstone Side Channel photos
Left Bank Alluvium	☒	46		
Left Bank Toe Detail	☒	47		
Left Bank Top of Bank Detail	☒	49		
Left Bank Overview	☒	48		
Left Floodplain Alluvium	☒	52		
Left Floodplain Overview	☒	53,54		53 upstream 54 downstream
Left Floodplain Landforms	☒	NA		
Right Bank Alluvium	☒	—		
Right Bank Toe Detail	☒	—		
Right Bank Top of Bank Detail	☒	—		
Right Bank Overview	☒	40		
Right Floodplain Alluvium	☒	—		not present
Right Floodplain Overview	☒	—		not present
Right Floodplain Landforms	☒	—		not present
Infrastructure	☒	—		
Disturbance/Instability	☒	—		

SUPPLEMENTAL PHOTOS		
Photo ID	*View Direction*	*Description*
video 41		close to main channel @ pipeline crossing (HDD)
42-45		wood along bankfull margin
50 51		left bank dominant herbaceous spp. (Lepedium spp?)

* Note: RB + LB reversed

Yellowstone Main Channel



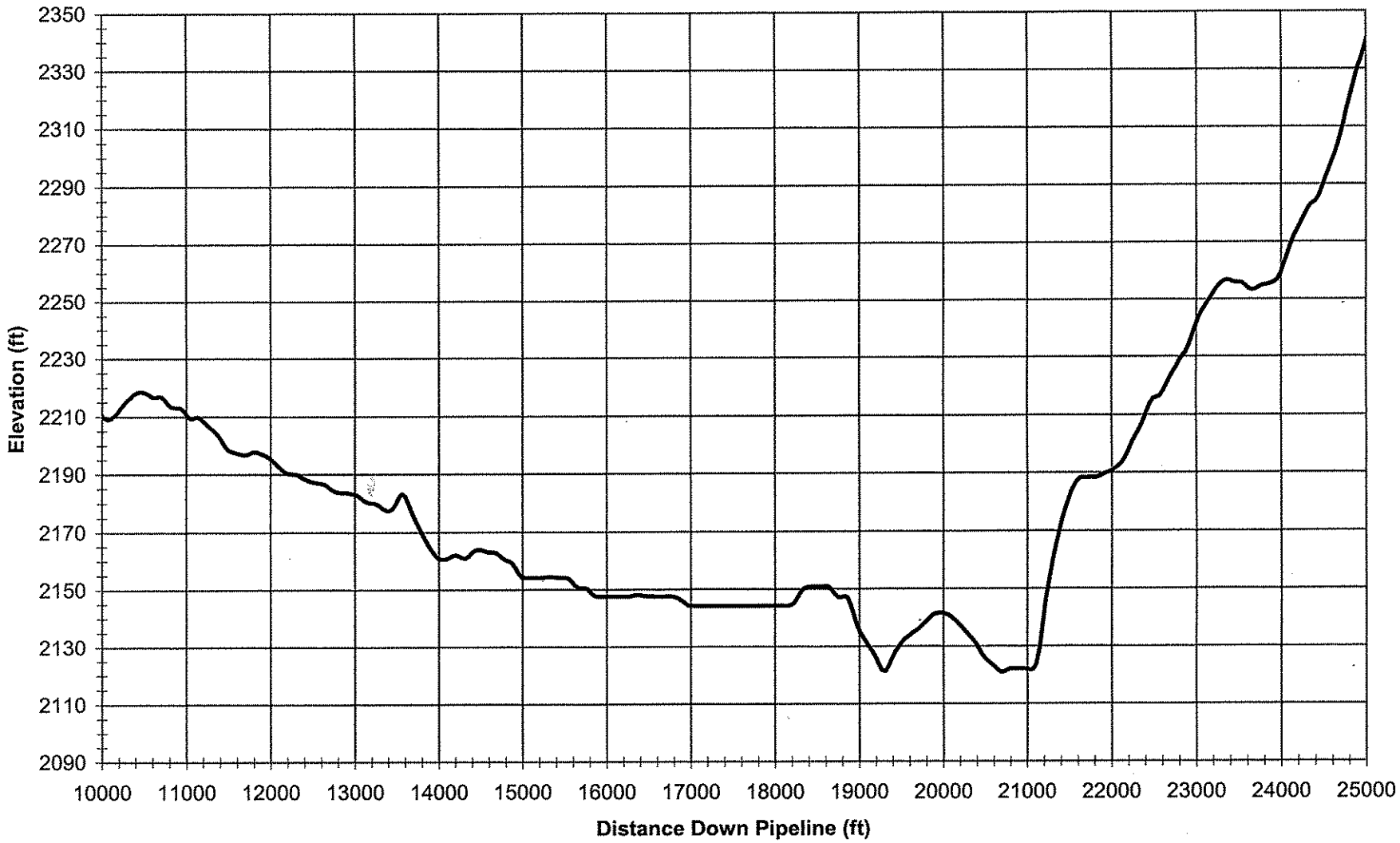
Proposed HDD pipeline X-ing

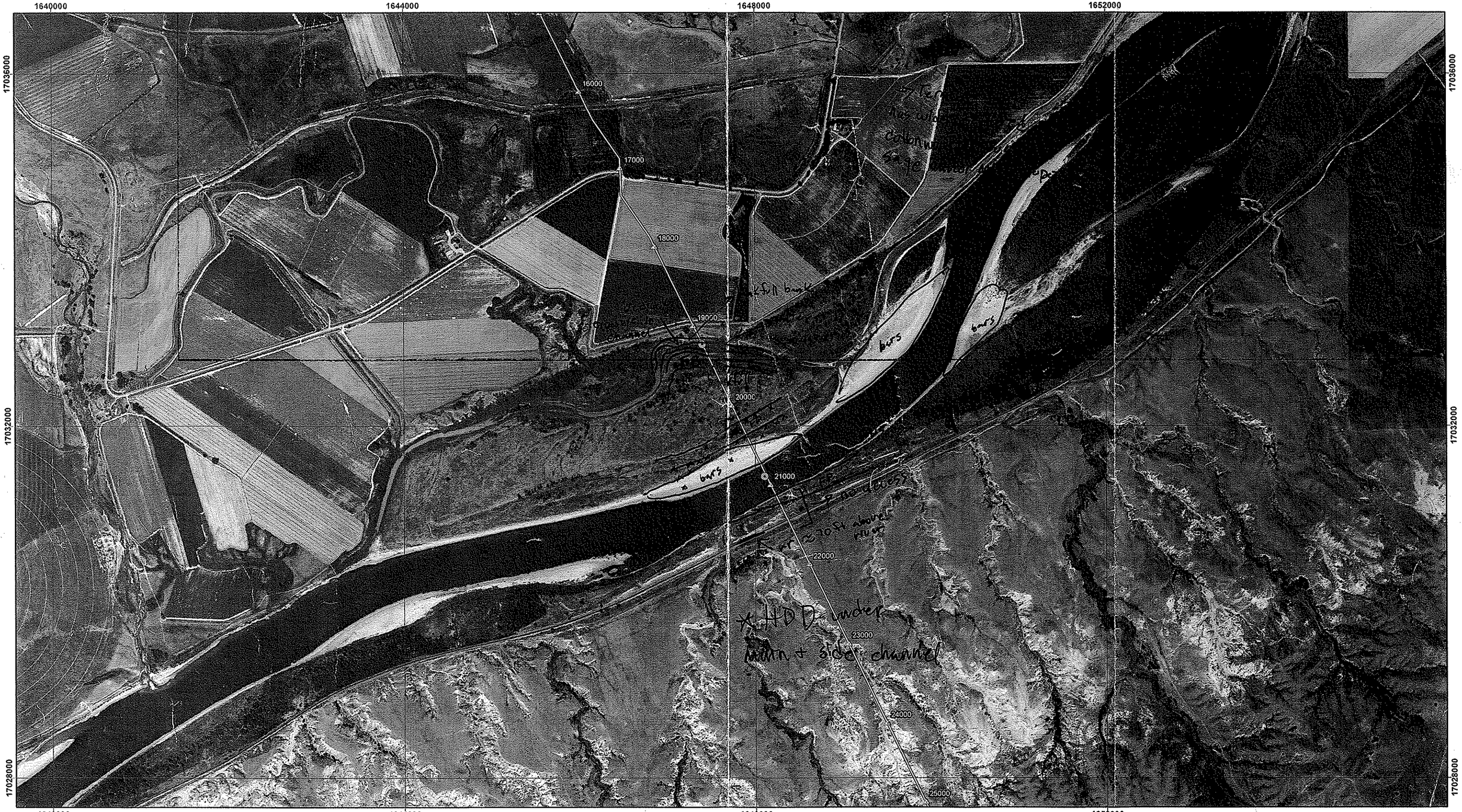
CHANNEL CROSS-SECTION SKETCH

PLANVIEW MAP

– image background date:

Yellowstone River - Proposed Keystone XL Pipeline Alignment Elevation Profile



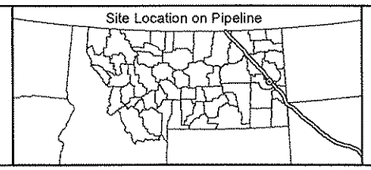


Legend

- Intermittent Stream Crossings
- Perennial Stream Crossings
- Proposed Pipeline Route
- 1,000 ft Profile Interval

Base Photo: 2005 U.S. Farm Services Agency National Agricultural Imagery Program (NAIP)

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

YELLOWSTONE RIVER - MILE POST 196
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

N W E S

0 500 1,000 2,000 Feet

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File: \\Sacramento-nas\Data\SHARED\Belby\Keystone Pipeline\gis\map\mxd\Keystone XS field map landscape tabloid.mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Dry Fork Creek MP 226.9			Surveyors	Ericsson
GPS	WP:	N:	E:	Date/Time	
Flow Condition	No flow, standing water in pools along thalgweg				
General Site Characteristics / Comments	Access denial a crossing. 2500' ~~downstream~~? of ~~original~~ new Crossing. Low gradient wide channel with very narrow floodplains. Entire channel bottom is wetland grasses. Very narrow 0-5' discontinuous unvegetated thalweg low flow channel with ponded water				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	clay		
	D_{50}	1/16 mm		
	D_{84}	1 mm		
	% sand	15-20		
	SOIL CLASS SYMBOL	CL		
Bed (sub-surface)	D_{16}			
	D_{50}	X		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}			
	D_{84}	X		
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}	clay	D_{16}	clay
	D_{50}	1/16 mm	D_{50}	1/12 mm
	D_{84}	1/4 mm	D_{84}	1 mm
	% sand	15	% sand	20-25
	SOIL CLASS SYMBOL	CL	SOIL CLASS SYMBOL	CL
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}	clay	D_{16}	clay
	D_{50}	1/8 mm	D_{50}	1/14 mm
	D_{84}	1/2 mm	D_{84}	1/4 mm
	% sand	30	% sand	10-15
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	CL

Comments:

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)		
		GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)		
		GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)		
		SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)		
		SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

- Clay rich soils, little sand, lots of annual grasses and sedges in bankfull channel. (potential capture/filter d.s.)

- unlikely

- no

- channel location seems pretty stable, and is bounded on both sides by high valley walls

- grassy riparian/wetland habitat loss

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 1.5'			Bank Height (ft) 6" (0.5')		
Bank Slope (°) 20°			Bank Slope (°) 10°		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species annuals			Dominant Species annuals		
Root Depth (ft) 1'-1.5' Observed Y / (N)			Root Depth (ft) 1'-1.5' Observed Y / (N)		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / (N)	Potential (Y) N	Gradual Migration	Present Y / (N)	Potential Y / (N)
Slumping	Present Y / (N)	Potential Y / (N)	Slumping	Present Y / (N)	Potential Y / (N)
Landsliding	Present Y / (N)	Potential Y / (N)	Landsliding	Present Y / (N)	Potential Y / (N)
Other:	Present Y / (N)	Potential Y / (N)	Other:	Present Y / (N)	Potential Y / (N)
Notes: on outside bend of meander gives potential for gradual migration			Notes: on inside bend of meander, bounded by 5'-6' high terrace on inside margin		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity ~4' dark organic horizon mature		Soil Maturity	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/N)	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 6	
Woody Riparian Plant Density (L,M,H) 0		Woody Riparian Plant Density (L,M,H) 0	
Dominant Woody Species —		Dominant Woody Species —	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes: ~45 ft wide, gently sloping toward thalweg (@ 10°) 5yr FP		Notes: hummocky terrain w/ high flow side channel, 1-1.5' below LB FP bankfull FP	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 150'	Bridges (Y/(N))
Bankfull Depth (ft) 2'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) bank	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 0-4'	
	Roads (Y/(N))
Incision Evidence —	(RR, LB, US, DS)
	Other Infrastructure —
Aggradation Evidence —	
Bars (Y/(N))	
Vegetated Islands (Y/(N))	
Pool Depths (ft) 1,5'	
Channel in Low Elevation of Valley Floor ((Y)/N)	
Notes: Single thread channel (meander bend) with high (2') FP on Left and low (6") FP on Right. Valley confined 100% w/ 6'+ wall on rb and 12'+ wall on lb	Notes:

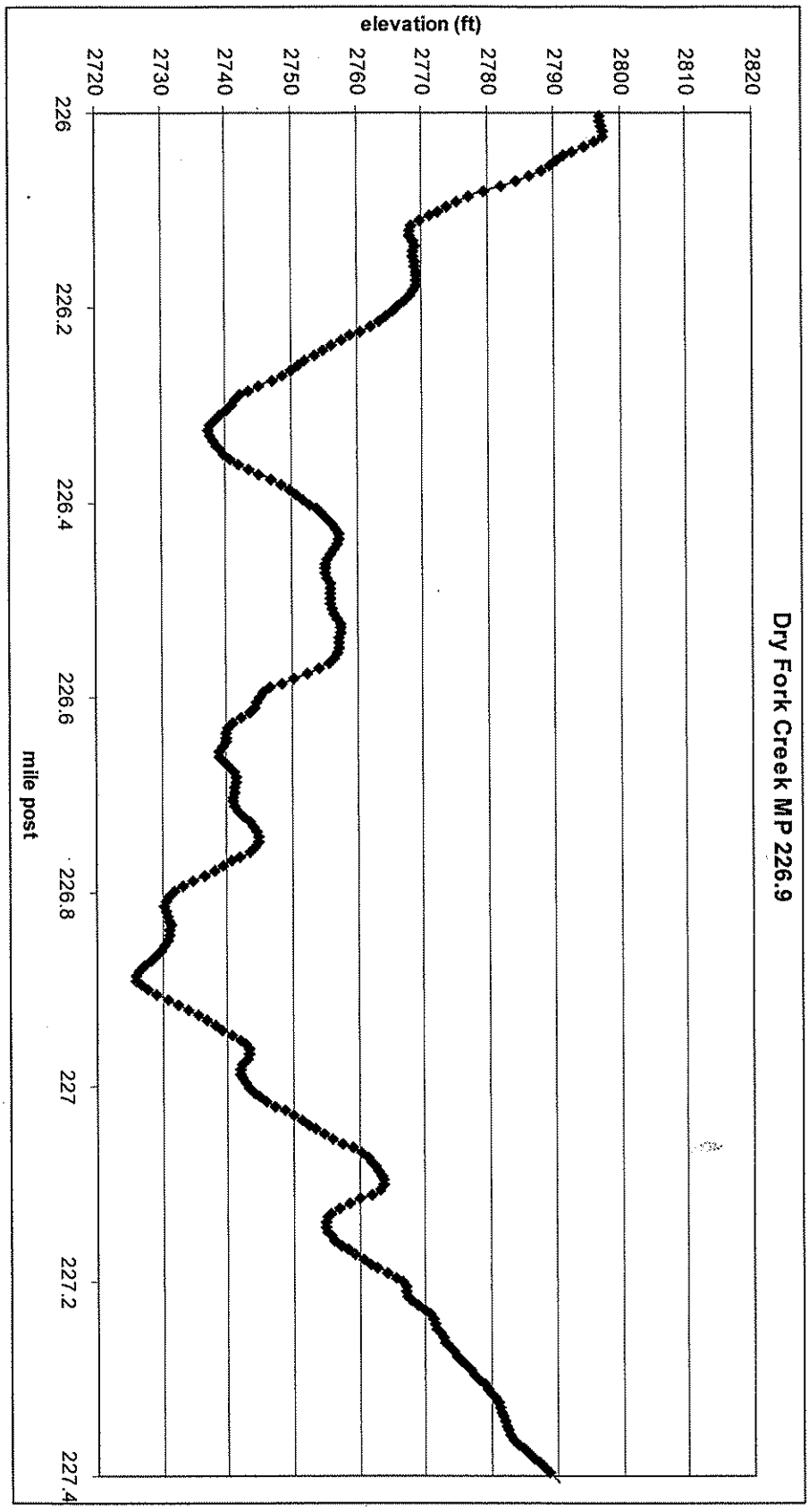
CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams —	In-stream structures —
Debris flow —	
	Flow Diversion —
Landslides —	
	Debris —
Woody debris —	
Other: —	Other: Fence line @ crossing and upstream

PHOTO CHECKLIST		
Site Overview	☒	233 - 237 (pan)
Channel US Showing Both Banks	☒	223-225 (pan)
Channel DS Showing Both Banks	☒	220-222 (pan)
Channel Bed Surface Alluvium	☒	214
Channel Bed Sub-Surface Alluvium	☒	NA
Bar Alluvium	☒	NA
Bars Overview	☒	NA
Islands Overview	☒	NA
Left Bank Alluvium	☒	215
Left Bank Toe Detail	☒	too grassy and low
Left Bank Top of Bank Detail	☒	too grassy and low
Left Bank Overview	☒	216
Left Floodplain Alluvium	☒	219
Left Floodplain Overview	☒	217 looking U.S. 218 looking D.S.
Left Floodplain Landforms	☒	NA
Right Bank Alluvium	☒	226
Right Bank Toe Detail	☒	too grassy and low
Right Bank Top of Bank Detail	☒	too grassy and low
Right Bank Overview	☒	227
Right Floodplain Alluvium	☒	228-229 pan looking upstream 230 looking downstream
Right Floodplain Overview	☒	232
Right Floodplain Landforms	☒	NA
Infrastructure	☒	cattle pen 231
Disturbance/Instability	☒	NA

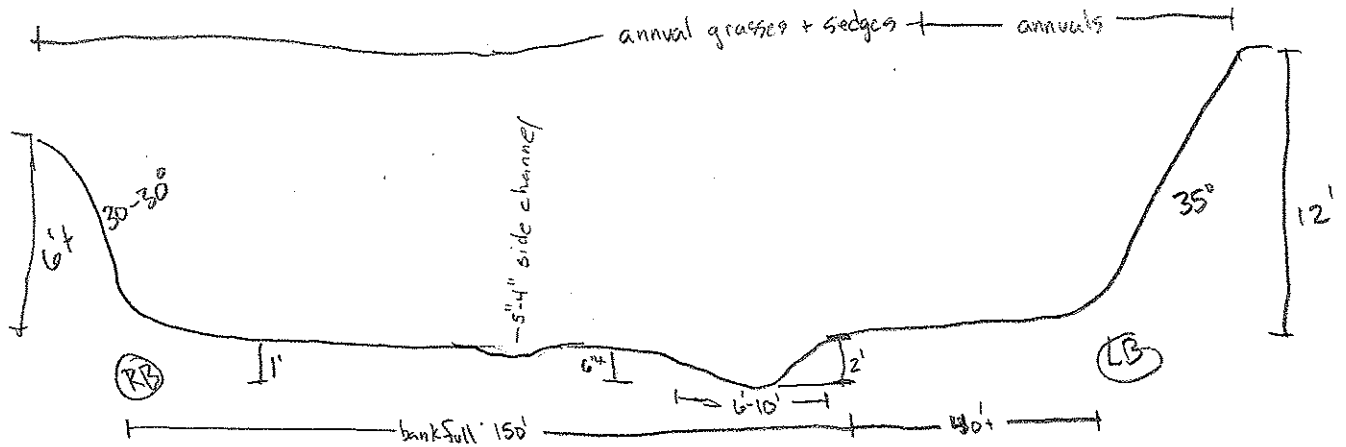
PHOTO LOG		
Photo ID	View Direction	Description

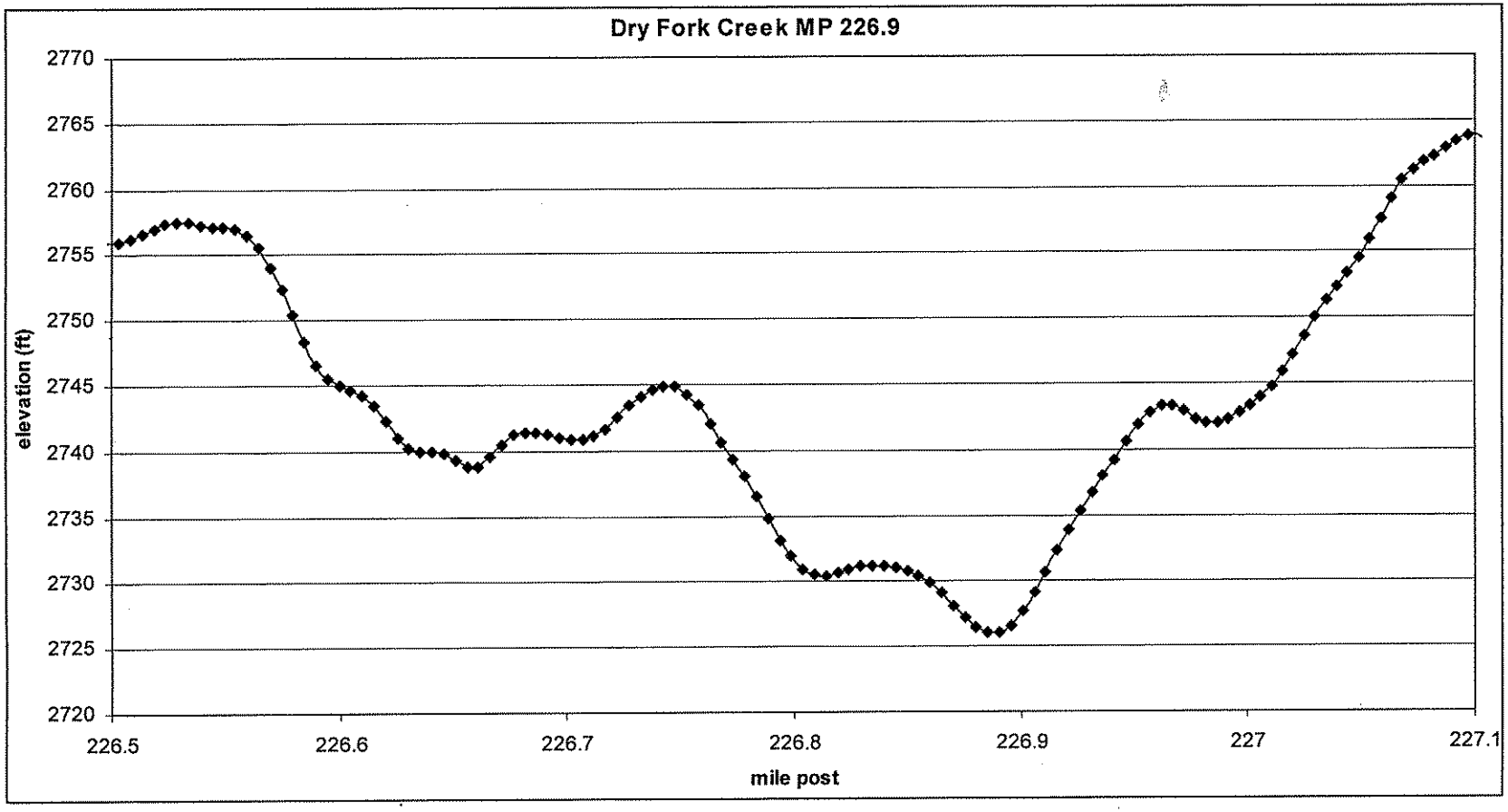
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



CHANNEL CROSS-SECTION SKETCH

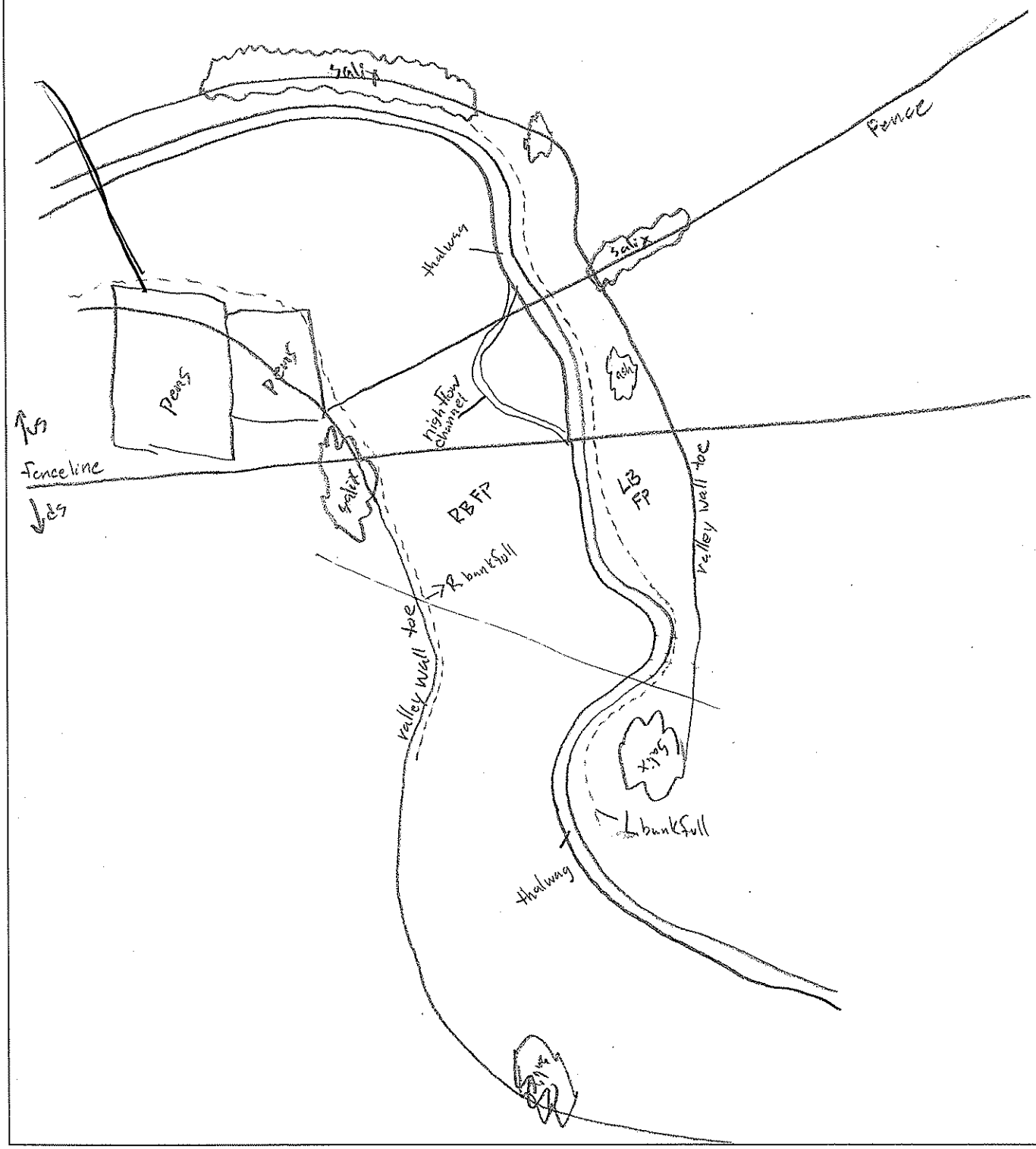




*notes – channel cross-section derived from 30 / 10 meter USGS DEM

PLANVIEW MAP

*notes – image background date:



KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA

Site	Dry Fork Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression	28.16	--	--	--	1,123	3,812	6,566	10,298	13,418	14,257
No Gage Station Data Available										

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)

Gradient : 0.2, 0.5

width	min	max	mean	std dev
	21	80	52	22

meander wavelength (ft) 531

meander amplitude (ft) 390

Sinuosity 2.59, 2.11

radius of curvature (ft)	Upstream East Trib (ft)		Downstream of Dam(ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	1568	420	2434	554
	2119	236	3159	485
	2621	336	3628	417
	3388	289	4451	525

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 29.31

Valley

Gradient: <0.1, 0.4

width	min	max	mean	std dev
	761	2276	1496	605

describe geology (lithology, erodibility):

Sandstone, sandy and silty shale and coal. Alluvial plain. Thickness 984 ft.

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:

US 0.00-0.20 mi river left

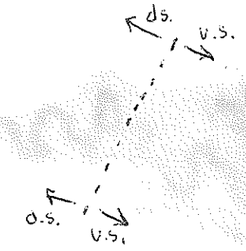
channel cut-offs:

US 0.00-0.20 mi river left

Oxbow and avulsion (0.00-0.20 mi river left)

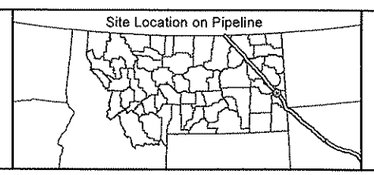
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
The floodplain elevation is higher than the elevation of the channel's water surface.
Unique features, exceptions, etc.
DS of the crossing is a dam whose backwater conditions have allowed for extensive sediment deposition in man made pond, some islands have formed. The channel's width increases when it reaches the area of the backwater effect.
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 (0.20 mi River left)
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.

d.s. - potential meander cut-off immediately d.s. of dashed line
- Meander immediately d.s. of potential cut-off



- Intermittent Stream Crossings
- Perennial Stream Crossings
- SteeleCitySegmentMP
- Proposed Pipeline Route

Aerials: USGS EarthExplorer
http://edcsns17.cr.usgs.gov/EarthExplorer/



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Dry Fork Creek - MILE POST 226.9
1980 Historic Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
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www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Little Beaver Creek MP 262.4			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/8/09
Flow Condition	Low Flow ~5 cfs silty water				

General Site Characteristics / Comments low gradient, meandering, sand + gravel bed, pool + riffle channel w/ well developed floodplain, alternating channel widths @ sedge ledges. steep + tall sand bluffs on some outer bends

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}		Sandy gravel	2
	D_{50}			16
	D_{84}			64
	% sand			10
	SOIL CLASS SYMBOL		GM	
Bed (sub-surface)	D_{16}		Sandy gravel	2
	D_{50}			16
	D_{84}			64
	% sand		~20	
	SOIL CLASS SYMBOL		GM	
Bars	D_{16}		Sedges	
	D_{50}		silty sands w/ organics	
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL		OL	
Banks	RIGHT BANK see LB		LEFT BANK silty sand	
	D_{16}		D_{16}	some clay
	D_{50}		D_{50} FS	moderately
	D_{84}		D_{84}	cohesive
	% sand		% sand	>80
	SOIL CLASS SYMBOL	SM	SOIL CLASS SYMBOL	SM
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}	FS	D_{50}	F.S.
	D_{84}		D_{84}	
	% sand		% sand	
	SOIL CLASS SYMBOL	SP	SOIL CLASS SYMBOL	SP

Comments: Hanly-Ryell Fine sandy loams 7B

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	
	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 3			Bank Height (ft) 4.5		
Bank Slope (°) lower 2.5'@ 20°, upper 0.5'@ 90°			Bank Slope (°) 15-20		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species grass			Dominant Species		
Root Depth (ft) 1	Observed Y / N		Root Depth (ft) 1	Observed Y / N	
Undercutting (Y/N)			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / N	Potential Y / N	Gradual Migration	Present Y / N	Potential Y / N
Slumping	Present Y / N	Potential Y / N	Slumping	Present Y / N	Potential Y / N
Landsliding	Present Y / N	Potential Y / N	Landsliding	Present Y / N	Potential Y / N
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: evidence of slumping, slumped bank material leads to sediment trapping & development of bars / ledges vegetated w/ sedges sedge bars likely limit lateral migration			Notes: dense sedges @ toe, grassy above no active erosion on inside bend		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity none		Soil Maturity none	
Natural Levees (Y/N)		Natural Levees (Y/N)	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species		Dominant Woody Species	
Crevasse Splays (Y/N)		Crevasse Splays (Y/N)	
Crevasse Channels (Y/N)		Crevasse Channels (Y/N)	
Notes: well developed, grassy F.P. ~1 hummocky topo		Notes: ~1-1.5' higher than LFP, transitions to terrace w/in ~30'	

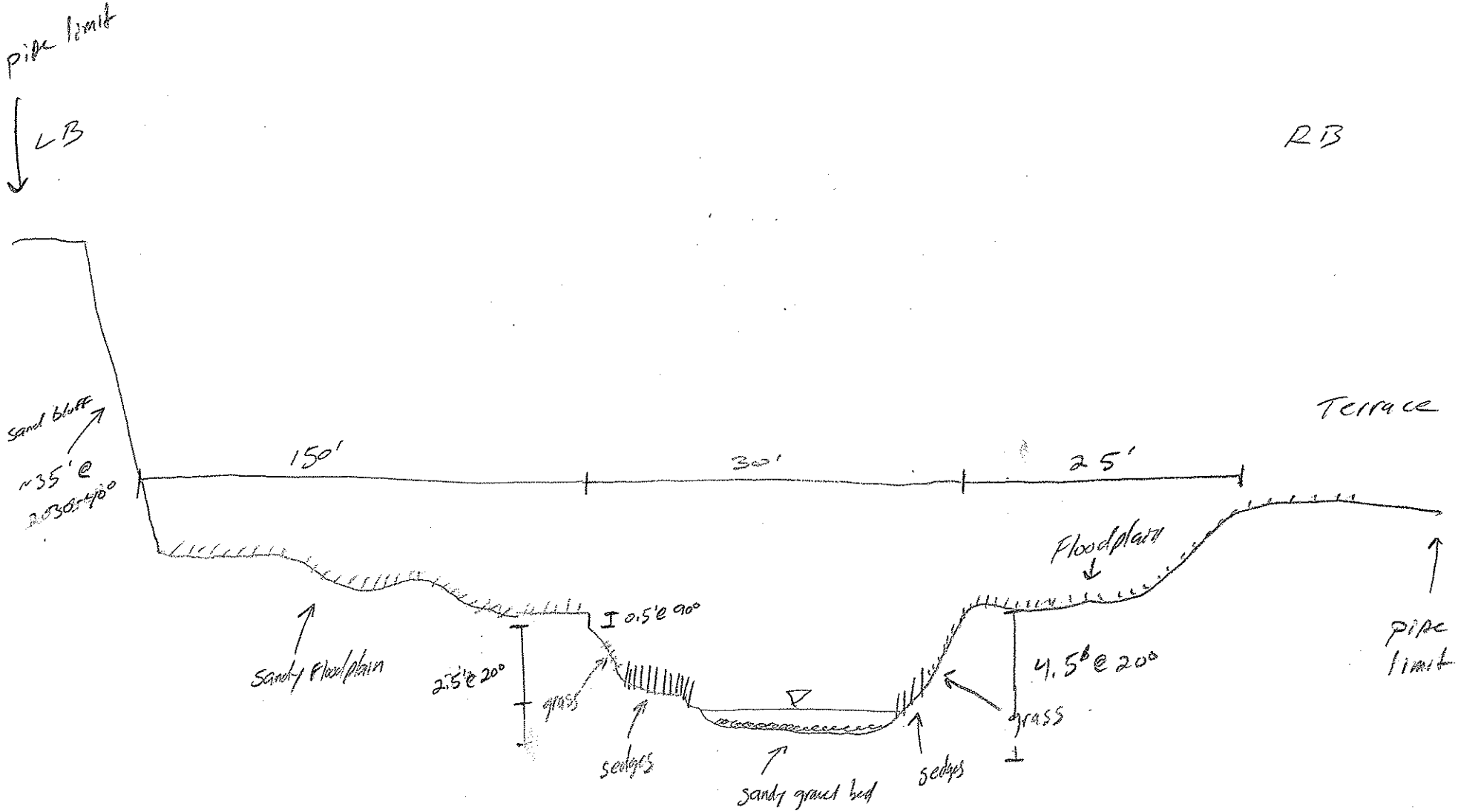
CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 30	Bridges (Y/N)
Bankfull Depth (ft) 4	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) topo - banks	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) varies 12 - 20' around	
sedge islands	Roads (Y/N)
Incision Evidence NO	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence NO	
Bars (Y/N) - sedges	
Vegetated Islands (Y/N)	
Pool Depths (ft) ~2' deeper than riffles - not measured	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS heavy cattle use near springs and on LFP	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

PHOTO CHECKLIST		
Site Overview	☒	14-20 DS to US order from Top Left BLUFF
Channel US Showing Both Banks	☒	36-38
Channel DS Showing Both Banks	☒	39-41
Channel Bed Surface Alluvium	☒	51
Channel Bed Sub-Surface Alluvium	☒	51
Bar Alluvium	☒	44/1 -
Bars Overview	☒	42-43 sedge bars / lobes 42 US, 43 DS
Islands Overview	☒	NA
Left Bank Alluvium	☒	27
Left Bank Toe Detail	☒	28
Left Bank Top of Bank Detail	☒	29
Left Bank Overview	☒	30
Left Floodplain Alluvium	☒	26
Left Floodplain Overview	☒	31-34 US to DS, 35 along X-ing ~~Hbisat~~
Left Floodplain Landforms	☒	45-47 steep Left bluff sandstone @ x-ing US to DS
Right Bank Alluvium	☒	see photo 27 same materials
Right Bank Toe Detail	☐	52
Right Bank Top of Bank Detail	☐	53
Right Bank Overview	☐	54
Right Floodplain Alluvium	☒	see photo 26
Right Floodplain Overview	☒	55-58
Right Floodplain Landforms	☒	NA
Infrastructure	☒	48-50 spring + livestock water basin - DS
Disturbance/Instability	☒	NA

PHOTO LOG		
Photo ID	View Direction	Description
11	N-NW	Floodplain depressions - relic Ch.
12	W	" "
13	N	" "
21	DS	From top Left bluff
22	RB	" "
23, 24	US	" "
59	DS	LB slumped blocks - pre-cursor to sedge bar development

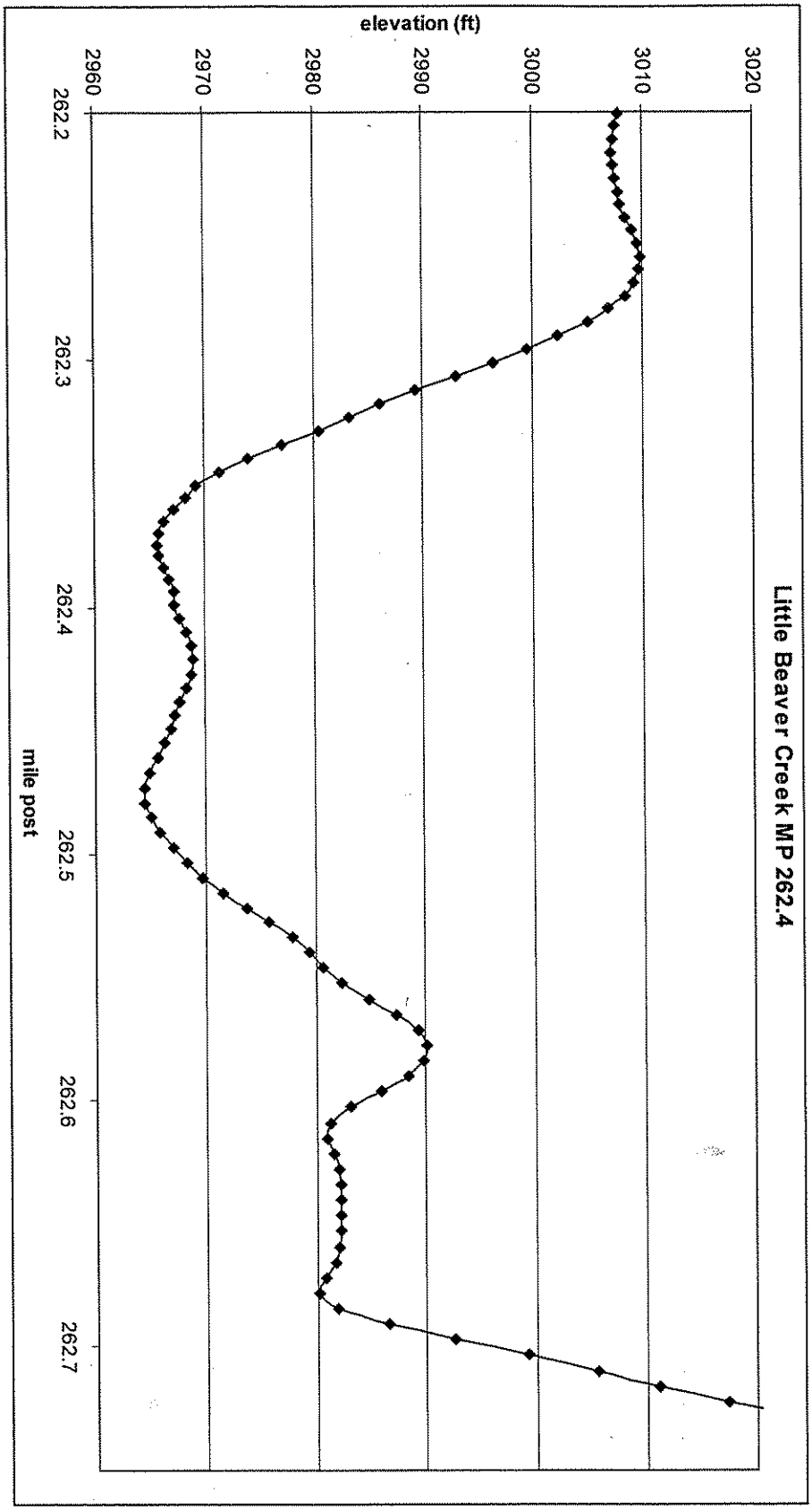
25 - video overview taken from Top Left bluff @ X-ing



- Keep pipe buried deep through entire Floodplain
- extra attention to turbidity due to active flow
- reconstruct Left hill slope to blend in w/ undisturbed sections

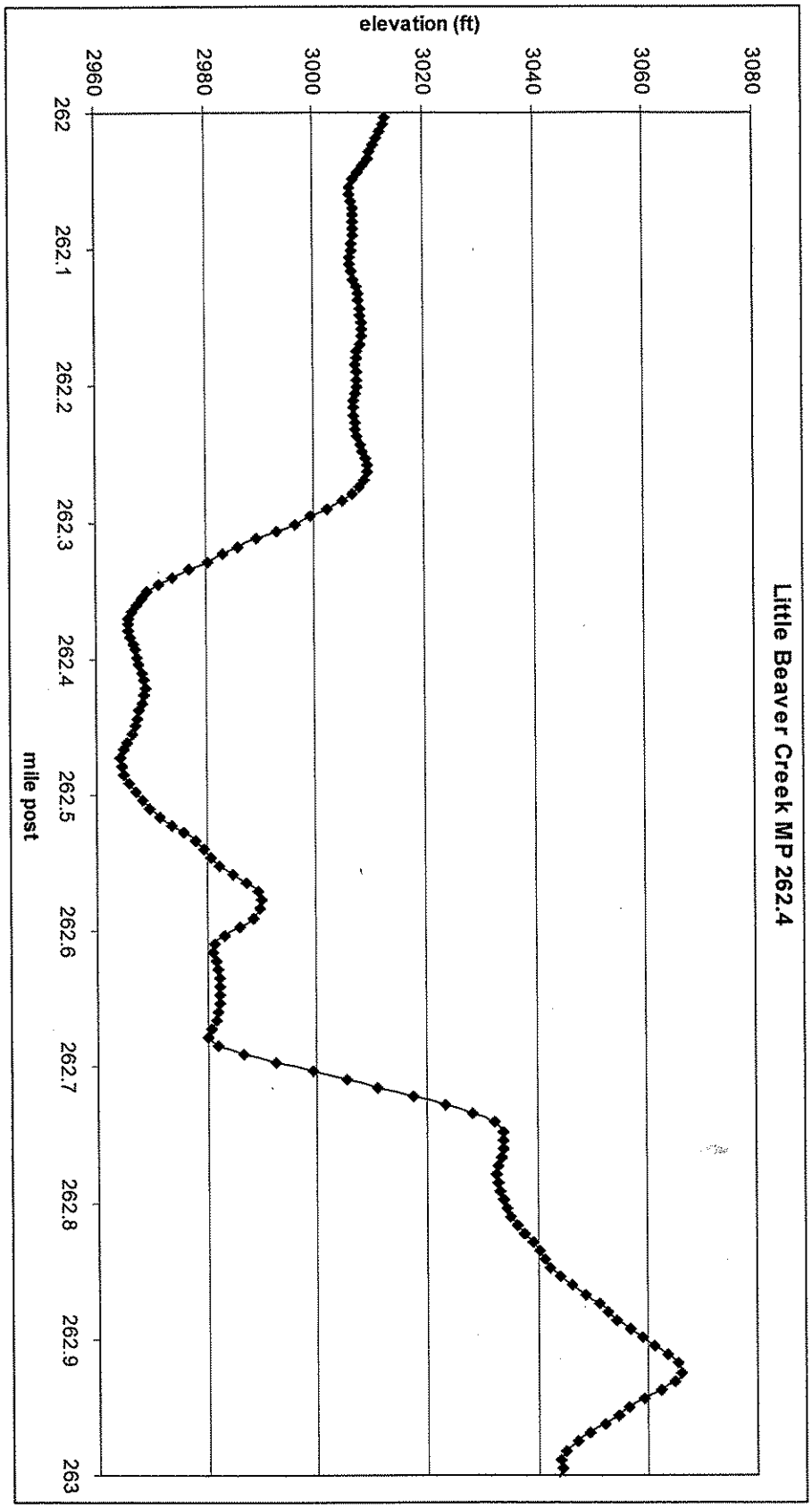
CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA

Site	Little Beaver Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression	391.9	--	--	--	3,546	11,345	19,153	28,908	37,097	40,050
No Gage Station Data Available										

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 : 0.20

Width (ft)	min	max	mean	std dev
	18	44	29	10

meander wavelength (ft) 2158

meander amplitude (ft): 1548

Sinuosity: 2.34

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	8945	2801	2680	2217
	4336	4195	5865	2102
	2040	1922		
	420	1738		
	8945	2801		

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c):72.0

Valley

Gradient: 0.40

width	Min	max	mean	std dev
	1607	2246	1891	237

describe geology (lithology, erodibility):

Alluvium of modern channels and flood plains.

Claystone that alternates with sandstone with interbedded shale. Fluvial and flood plain. Thickness 1,100 ft

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:

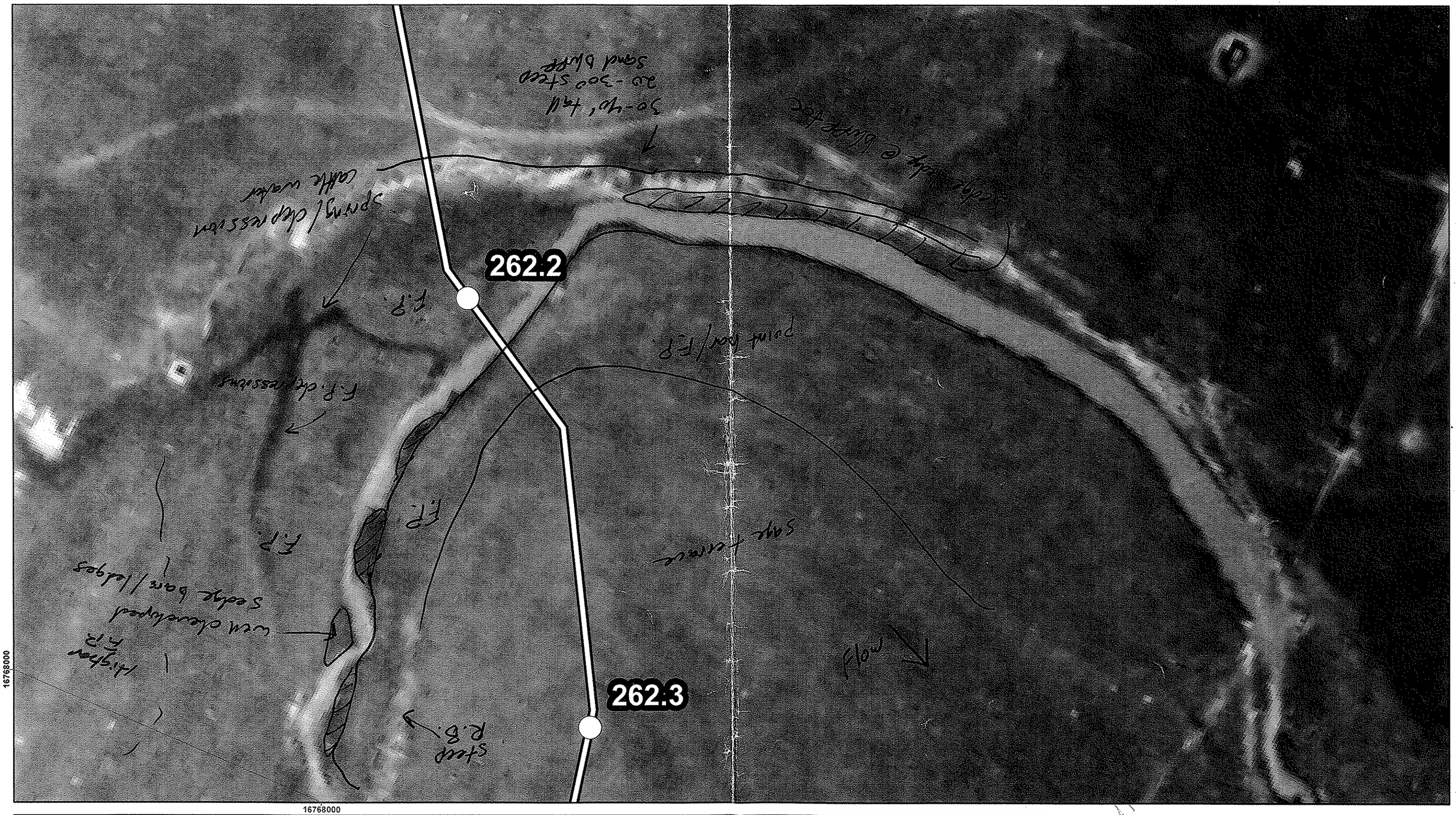
None

Oxbows and channel cut-offs

US (0.47 mi 2x oxbow River R and L, 1.20 1x oxbow). Relic Channel (0.60 mi River right)

DS (0.10 mi oxbox river R) (<0.10 mi relic channel)

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:
None
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
DS (0.50 mi 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):
DS 1. Private residence (0.55 mi River left)
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None



Perennial Stream Crossings
Intermittent Stream Crossings
Proposed Pipeline Route
1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline

KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Little Beaver Creek - MILE POST 262.4
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 50 100 200 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

1840000 1844000 1848000 1852000 1856000

16772000

16768000

260.8
260.9
261
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1840000 1844000 1848000 1852000 1856000

- Perennial Stream Crossings
- Intermittent Stream Crossings
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- 1/10 Mile Post

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Site Location on Pipeline

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GEOMORPHOLOGY ASSESSMENT

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N W E S

0 625 1,250 2,500 Feet

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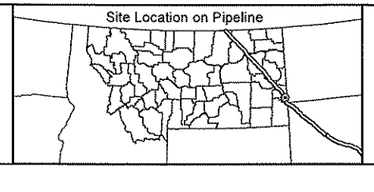
Intermittent Stream Crossings
Perennial Stream Crossings
SteeleCitySegmentMP
Proposed Pipeline Route

Aerials: USGS EarthExplorer
http://edcsns17.cr.usgs.gov/EarthExplorer/



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Little Beaver Creek
MILE POST 262.4 - 1980 Historic Aerial

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KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Boxelder Creek MP 281.4			Surveyors	Ericsson
GPS	WP:	N:	E:	Date/Time	8/10/09 8:30AM
Flow Condition	6-9 cfs				
General Site Characteristics / Comments	pool-riffle single thread meandering channel, on meander bend apex (rb outside; lb inside). Rb is unconsolidated 15'+ high bank (shale).				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	silt		
	D_{50}	1cm		
	D_{84}	7cm		
	% sand	~~60~~ 30		
	SOIL CLASS SYMBOL	GW		
Bed (sub-surface)	D_{16}			
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}	silt		
	D_{50}	1cm		
	D_{84}	7cm		
	% sand	30		
	SOIL CLASS SYMBOL	GW		
Banks	RIGHT BANK		LEFT BANK	
	D_{16}	1/16 mm	D_{16}	
	D_{50}	0.8	D_{50}	
	D_{84}	2.2	D_{84}	
	% sand	80	% sand	
	SOIL CLASS SYMBOL	SW	SOIL CLASS SYMBOL	
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}	silt	D_{16}	
	D_{50}	1/4 mm	D_{50}	
	D_{84}	1mm	D_{84}	
	% sand	80	% sand	
	SOIL CLASS SYMBOL	SP	SOIL CLASS SYMBOL	

Comments: RFP = 50 yr

LFP low = 2yr LFP high = 8-10yr

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 2'-2.5'			Bank Height (ft) 20-15'		
Bank Slope (°) 75'			Bank Slope (°) 90°-50°		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species —			Dominant Species —		
Root Depth (ft) 1.5' Observed Y/N			Root Depth (ft) 1.5' Observed Y/N		
Undercutting (Y/N)			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / N	Potential Y / N	Gradual Migration	Present Y / N	Potential Y / N
Slumping	Present Y / N	Potential Y / N	Slumping	Present Y / N	Potential Y / N
Landsliding	Present Y / N	Potential Y / N	Landsliding	Present Y / N	Potential Y / N
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: bank from waters edge to low floodplain			Notes: large failure @ crossing several noted up and downstream as well		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity NA		Soil Maturity young	
Natural Levees (Y/N)		Natural Levees (Y/N)	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H) —		Woody Riparian Plant Density (L,M,H) —	
Dominant Woody Species —		Dominant Woody Species —	
Crevasse Splays (Y/N)		Crevasse Splays (Y/N)	
Crevasse Channels (Y/N)		Crevasse Channels (Y/N)	
Notes: ~~[illegible]~~ ~~[illegible]~~ high FP (10yr)		Notes:	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft)	Bridges (Y/N)
Bankfull Depth (ft)	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) bank	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 35'	
	Roads (Y/N)
Incision Evidence vertical and slumped/outside of meander bend	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence NA	
Bars (Y/N)	
	—
Vegetated Islands (Y/N)	
Pool Depths (ft) 4'-5'	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams ✓	In-stream structures —
Debris flow —	
	Flow Diversion —
Landslides —	
	Debris —
Woody debris —	
Other: —	Other: -

PHOTO CHECKLIST		
Site Overview	☒	~~7,8 (pan)~~ 20-25 (pan).
Channel US Showing Both Banks	☒	5,6 (pan)
Channel DS Showing Both Banks	☒	7,8 (pan
Channel Bed Surface Alluvium	☒	1
Channel Bed Sub-Surface Alluvium	☒	3
Bar Alluvium	☒	1
Bars Overview	☒	4
Islands Overview	☒	NA
Left Bank Alluvium	☐	
Left Bank Toe Detail	☒	13
Left Bank Top of Bank Detail	☐	—
Left Bank Overview	☒	12
Left Floodplain Alluvium	☒	29 (bankfull FP) 30 (5yr FP)
Left Floodplain Overview	☐	31-32 (looking ds from 5yr) 33-34 (looking us from 5yr)
Left Floodplain Landforms	☐	N/A
Right Bank Alluvium	☒	26
Right Bank Toe Detail	☒	11
Right Bank Top of Bank Detail	☒	10
Right Bank Overview	☒	9
Right Floodplain Alluvium	☒	16
Right Floodplain Overview	☐	17-18 (looking ds) 19 (looking us)
Right Floodplain Landforms	☒	NA
Infrastructure	☒	NA
Disturbance/Instability	☒	NA

PHOTO LOG		
Photo ID	View Direction	Description
27+28	ds/us.	unvegetated top of bankfull

Questions:

What is the likelihood the project will impact turbidity at the site?

Sandy banks w/ <10% fines to cobble/gravel bed

What is the potential impact on incision and erosion?

right bank erosion

Will the project activate historical instability?

no

What actions or alternatives can mitigate project effects?

move alignment 100' or so downstream where right bank is laid back

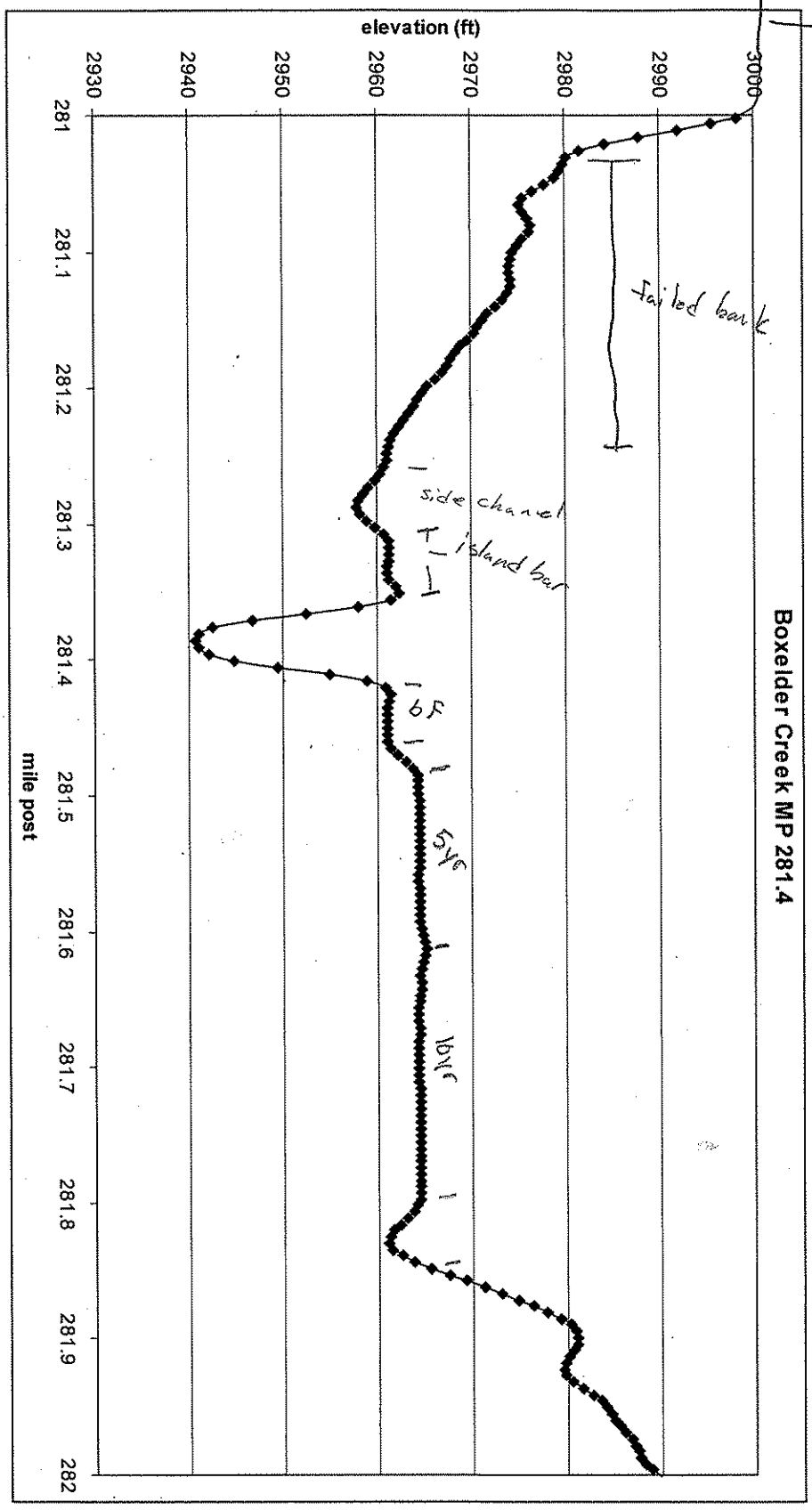
Are there any cumulative effects of pipeline?

minimal habitat loss (ri riparian zone) loss of cottonwoods?

General Notes:

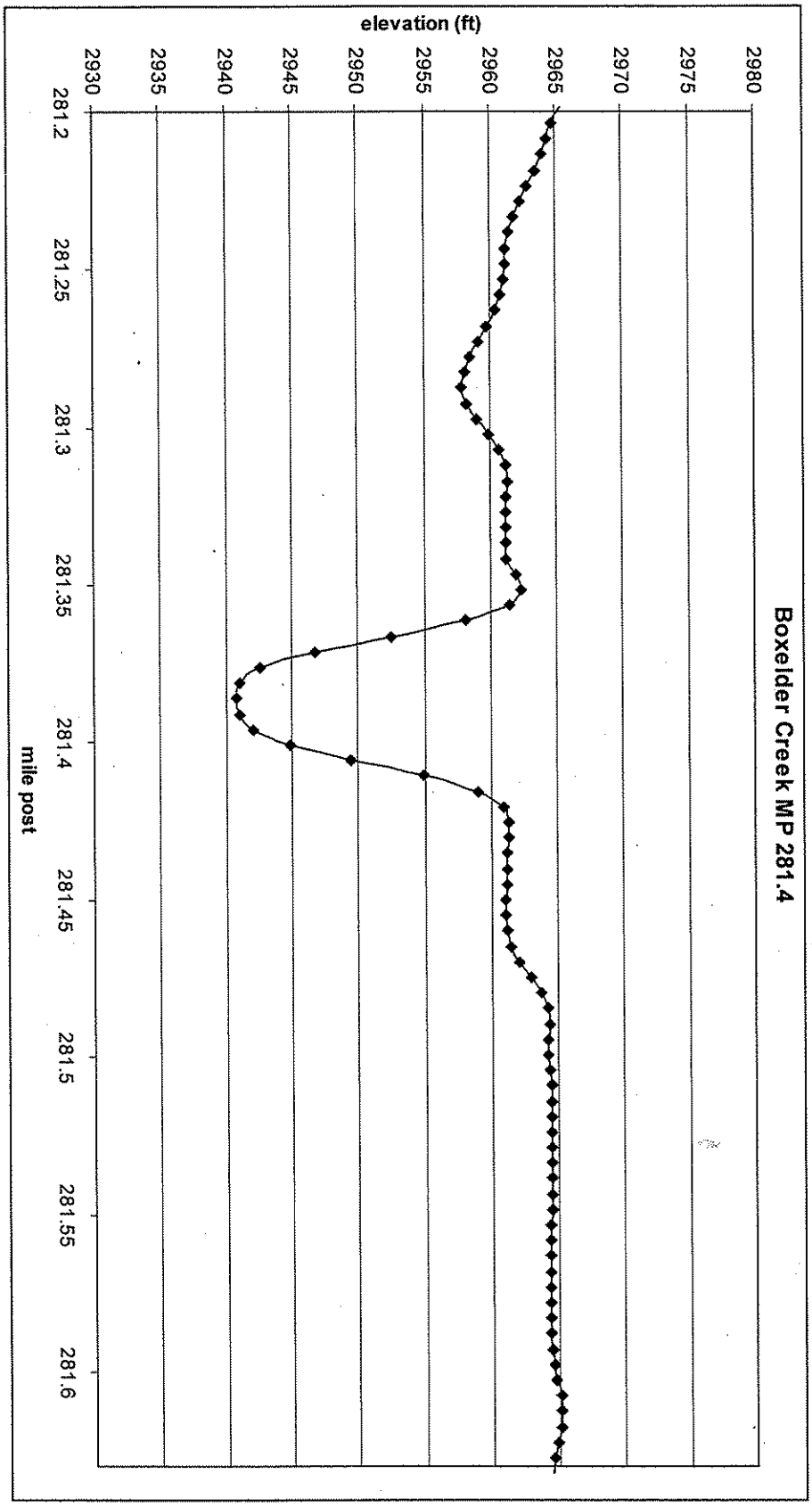
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA

Site	Boxelder Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression	1088.9	–	–	–	22,478	49,437	70,296	103,957	124,243	175,293
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

Gradient: 0.70

Width (ft)	min	max	mean	std dev
	38	69	52	11

meander wavelength (ft) 4,188

meander amplitude (ft) 3,598

Sinuosity 2.21

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	6471	4851	2014	811
	11467	3290	4149	1948
	15341	4838	5825	700
	20185	4579		

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 51.27

Valley

Gradient: 0.002

width	min	max	mean	std dev
	1168	4303	3017	1134

describe geology (lithology, erodibility):

Alluvium of modern channels and flood plains.

Floodplain

FEMA National Database Y/N

if yes, describe widths below

Width (ft)	min	max	mean	std dev

Describe abundance and location(s) of:

scroll bars:

None

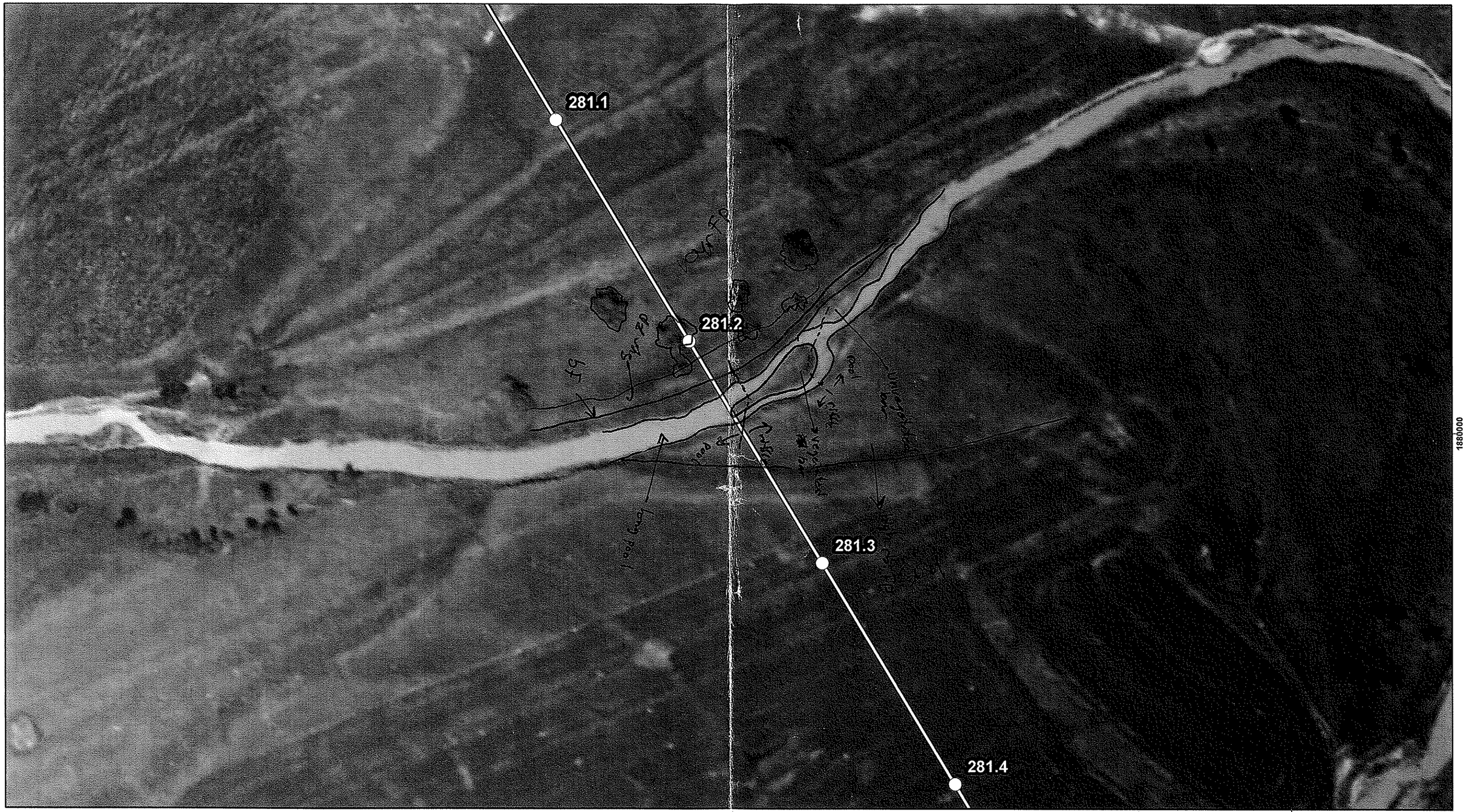
oxbows:

US Oxbow pond (man made perhaps 0.36 mi river right)

channel cut-offs:

none

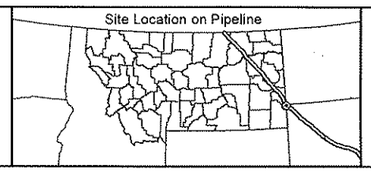
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
The elevation of the flood plain is greater than the channel's water surface elevation.
Unique features, exceptions, etc:
US 1. Sediment deposition bar (0.00-0.10 mi, located at proposed crossing) 2. Relic Channels (0.00-0.20 River Right, 0.15 mi due north)
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. Private Residence (0.60 mi river right)
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None



- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Boxelder Creek - MILE POST 281.4
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500, Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 75 150 300 Feet

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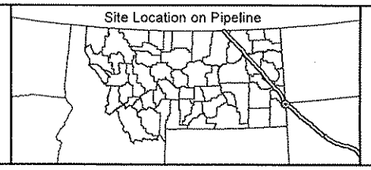
File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

- Intermittent Stream Crossings
- Perennial Stream Crossings
- SteeleCitySegmentMP
- Proposed Pipeline Route

Aerials: USGS EarthExplorer
http://edcsns17.cr.usgs.gov/EarthExplorer/

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Boxelder Creek - MILE POST 281.4
1972 Historic Aerial

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Cabin Creek US Spring Creek			Surveyors	BB, ME
GPS	WP:	N:	E:	Date/Time	7/16/09 11:00
Flow Condition	low, very muddy water				

General Site Characteristics / Comments

low gradient meandering channel w/ densely revegetated grass banks
incised ~ 10' into alluvium
* X-ing location identified by John, should extend ≥ 15' from high bank

no flow in Spring Creek

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}			
	D_{50}	6mm		
	D_{84}			
	% sand	10		
	SOIL CLASS SYMBOL	GW		
Bed (sub-surface)	D_{16}	Same		
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}	6mm		
	D_{84}			
	% sand	10		
	SOIL CLASS SYMBOL	GW		
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}	sandy silt	D_{50}	sandy silt
	D_{84}		D_{84}	
	% sand	30	% sand	30
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}	[illegible]	D_{50}	sandy silt
	D_{84}		D_{84}	
	% sand	30	% sand	30
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML

Comments: more clay in LFP (~20%) than banks

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 1 - 3.5 varies			Bank Height (ft) 4		
Bank Slope (°) 40 - 90 varies			Bank Slope (°) ~ 90° throughout outer bend		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species Grasses			Dominant Species grasses		
Root Depth (ft) 2 - 3 Observed (Y) N			Root Depth (ft) 2 - 3 Observed (Y) N		
Undercutting (Y/N) minor < 1'			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / (N)	Potential (Y) / N	Gradual Migration	Present Y / (N)	Potential (Y) N
Slumping	Present (Y) / N	Potential (Y) / N	Slumping	Present (Y) / N	Potential (Y) N
Landsliding	Present Y / (N)	Potential Y / (N)	Landsliding	Present Y (N)	Potential Y (N)
Other:	Present Y / (N)	Potential Y (N)	Other:	Present Y / N	Potential Y / N
Notes: potential for very slow migration underundercutting is minor			Notes: banks may have been previously undercut, which led to current slumping		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity weak		Soil Maturity weak	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/(N))	Relic/Abandoned (Y/N)	Intermittent (Y/N)	Relic/Abandoned (Y/(N))
possible on inner bend - See maps + office analysis			
Riparian Buffer Width (ft) 0 - grasses		Riparian Buffer Width (ft) 0 - grasses	
Riparian Plant Density (L,M,H)		Riparian Plant Density (L,M,H)	
Dominant Species - no woody species		Dominant Species - no woody species	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes:		Notes:	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 19'	Bridges (Y/N)
Bankfull Depth (ft) 5'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) topography, gravel bar @ LB interaction	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 73'	
	Roads (Y/N)
Incision Evidence no recent evidence	(RR, LB, US, DS)
	Other Infrastructure grassy 2' high berm ~
Aggradation Evidence no	20' wide running across terrace - approaches channel @ X-ing on RB
Bars (Y/N) Sand and gravel side bar on	
LB ~ 25' long and 5' wide @ max	
Vegetated Islands (Y/N)	
Pool Depths (ft) no observed pools - Flat water	
surface - relatively planar channel	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes: slumping banks, yet channel appears to be stable - not widening or downcutting channel inset 5-10' into alluvium	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams N/A	In-stream structures N/A
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

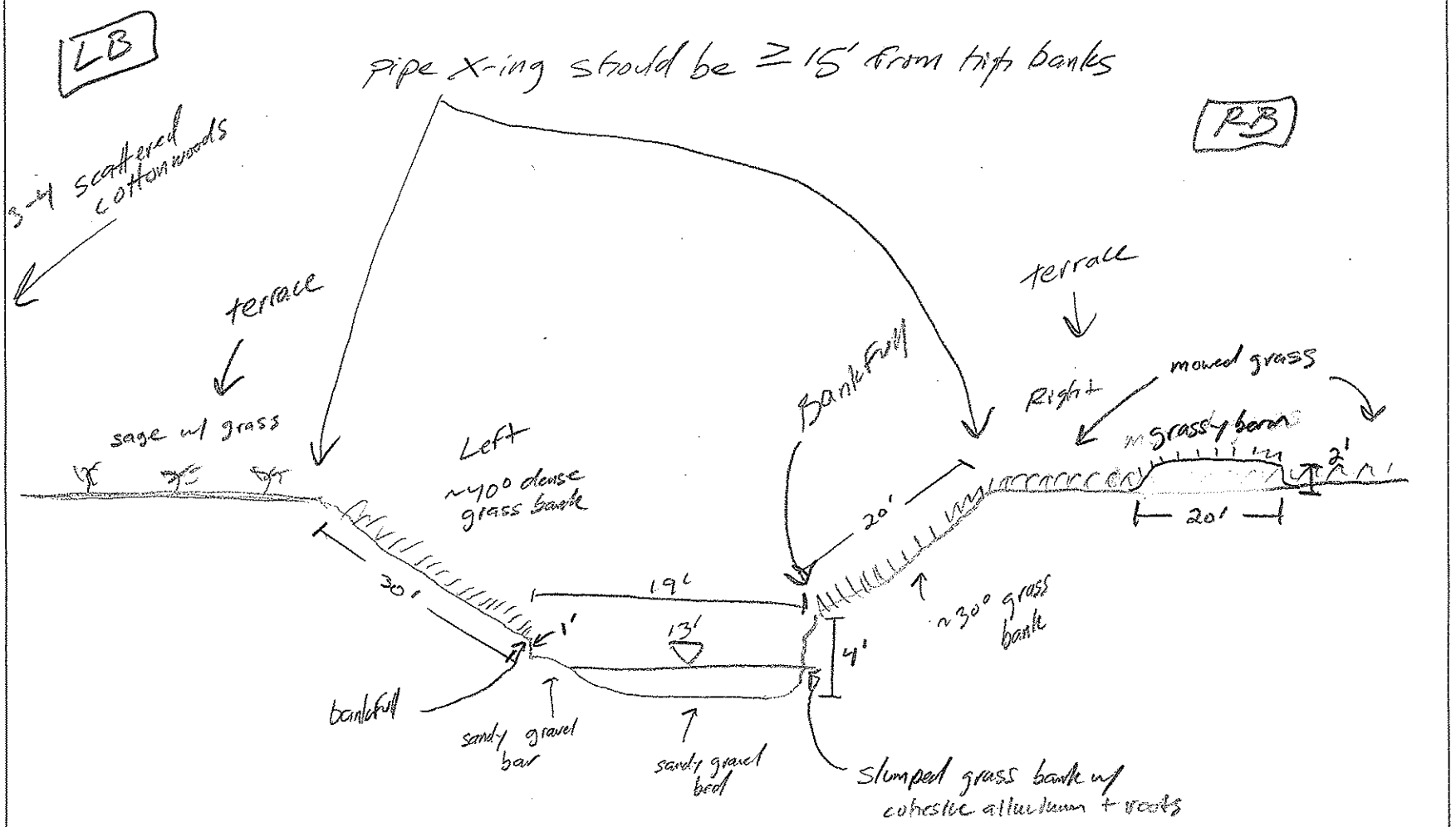
MANDATORY PHOTO CHECKLIST				
Photo		*Photo ID*	*View Direction*	*Description*
Site Overview	☒	49-52	US to DS	
Channel US Showing Both Banks	☒	44		
Channel DS Showing Both Banks	☒	28		
Channel Bed Surface Alluvium	☒	29		
Channel Bed Sub-Surface Alluvium	☒	30		
Bar Alluvium	☒	29		
Bars Overview	☒	31		
Islands Overview	☐	NA		
Left Bank Alluvium	☒	32		
Left Bank Toe Detail	☒	33		
Left Bank Top of Bank Detail	☒	34		
Left Bank Overview	☒	45		
Left Floodplain Alluvium	☒	26,27		
Left Floodplain Overview	☒	35		
Left Floodplain Landforms	☐	NA		
Right Bank Alluvium	☒	32	see LB alluvium	
Right Bank Toe Detail	☒	38		
Right Bank Top of Bank Detail	☒	37		
Right Bank Overview	☒	36		
Right Floodplain Alluvium	☒	26,27	see LB floodplain alluvium	
Right Floodplain Overview	☒	46	R. FP minor feature - pretty deformed	
Right Floodplain Landforms	☐	NA		
Infrastructure	☒	47,48	US, DS Berm running across terrace	
Disturbance/Instability	☐	NA		

SUPPLEMENTAL PHOTOS		
Photo ID	*View Direction*	*Description*
39	US on inner bend	check air photo details to see if relic channel
40	DS	LB brush revetment just DS of Spring Creek
42	US	view up Spring Creek confluence
43	DS	grassy low bench/FP on RB btw X-ing + Spring Cr.

Video 41 creek crossing
Video 53 site overview

Cabin Creek upstream

CHANNEL CROSS-SECTION SKETCH



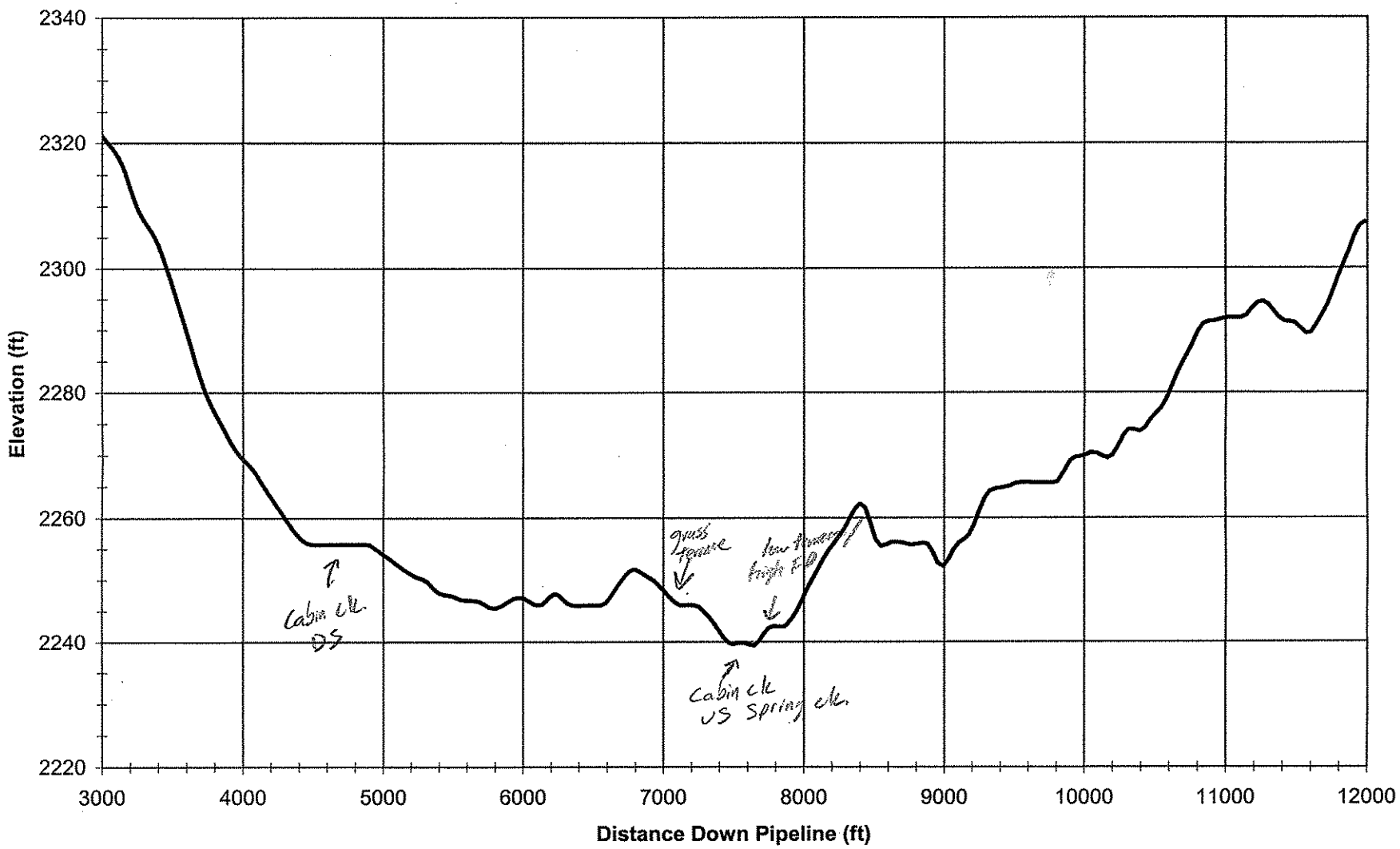
VALLEY CROSS-SECTION SKETCH

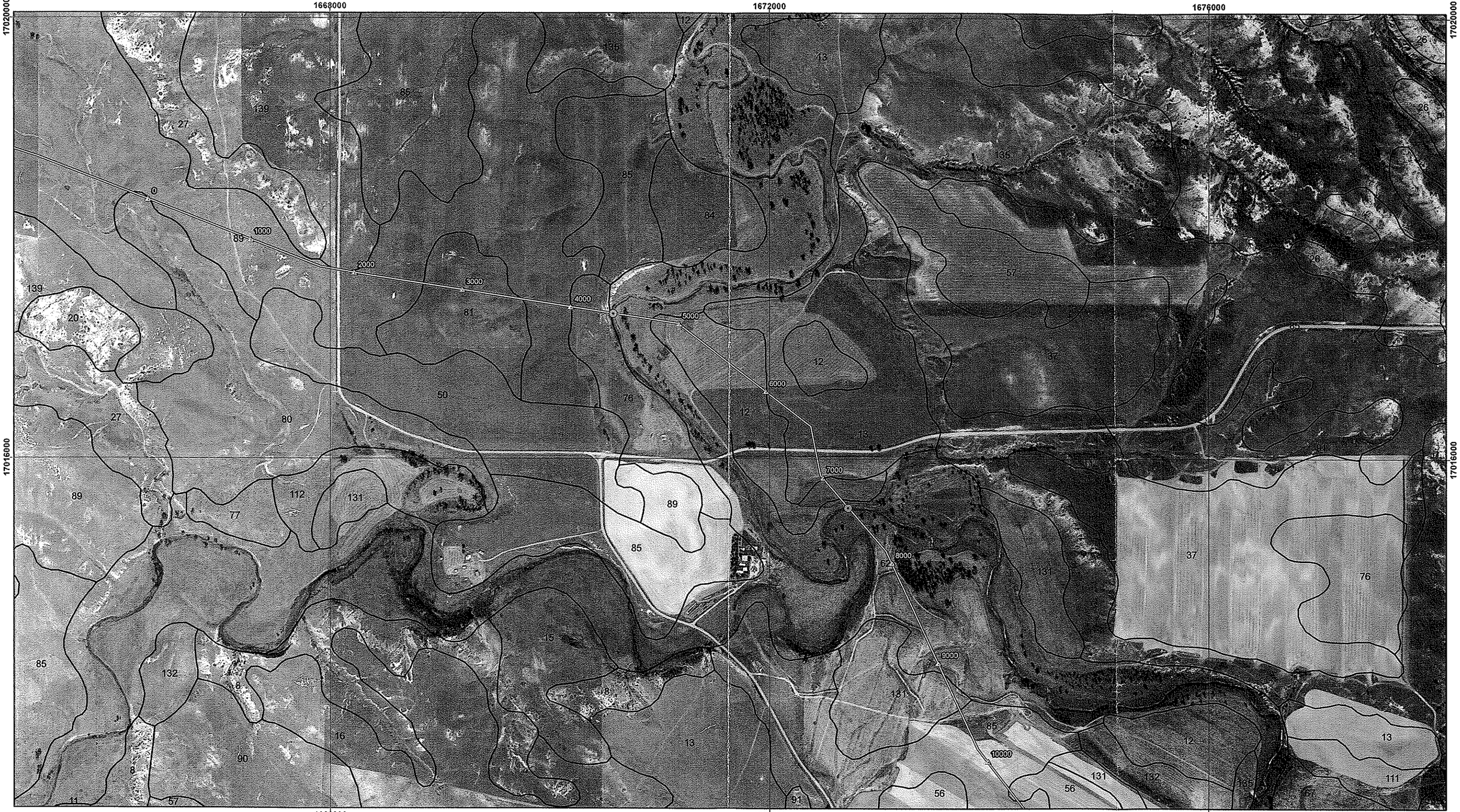
*notes – valley cross-section derived from 30 / 10 meter USGS DEM

PLANVIEW MAP

*notes – image background date:

Cabin Creek - Proposed Keystone XL Pipeline Alignment Elevation Profile





Legend

- Intermittent Stream Crossings
- Perennial Stream Crossings
- Proposed Pipeline Route
- 1,000 ft Profile Interval

Base Photo: 2005 U.S. Farm Services Agency
National Agricultural Imagery Program (NAIP)
Soils: National Resource Conservation Service
http://soildatamart.nrcs.usda.gov/

Site Location on Pipeline

KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

CABIN CREEK - MILE POST 201.4 & 202
NRCS SSURGO Soils

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N W E S

0 400 800 1,600 Feet

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File: \\Sacramento-nas\Data\SHARED\Belby\Keystone Pipeline\gis\map\mxd\Keystone XS field map landscape tabloid.mxd

1668000 1672000 1676000

17020000

17016000

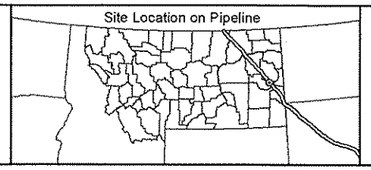
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

Legend

- Intermittent Stream Crossings
- Perennial Stream Crossings
- Proposed Pipeline Route
- 1,000 ft Profile Interval

Aerials: USGS EarthExplorer
http://edcsns17.cr.usgs.gov/EarthExplorer/

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

CABIN CREEK - MILE POST 201.4 & 202
10/20/1965 Historic Aerial

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N W E S

0 400 800 1,600 Feet

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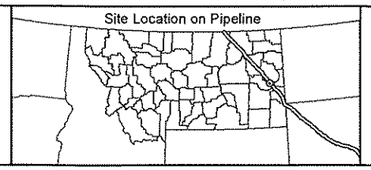
Legend

- Intermittent Stream Crossings
- Perennial Stream Crossings
- Proposed Pipeline Route
- 1,000 ft Profile Interval

Base Photo: 2005 U.S. Farm Services Agency National Agricultural Imagery Program (NAIP)

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS GEOMORPHOLOGY ASSESSMENT

CABIN CREEK - MILE POST 201.4 & 202
2005 NAIP Aerial

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Seattle, WA 98119
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Coordinate System: NAD 1983 UTM Zone 13 feet

N W E S

0 400 800 1,600 Feet

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File: \\Sacramento-nas\Data\SHARED\Belby\Keystone Pipeline\gis\map\mxd\Keystone XS field map landscape tabloid.mxd

1668000 1672000 1676000

17020000 17016000

Tongue River Member of Fort Union Formation

Alluvium of modern channels and flood plains

Ludlow Member of Fort Union Formation

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

Tongue River Member of Fort Union Formation

Ludlow Member of Fort Union Formation

Alluvium of modern channels and flood plains

Ludlow Member of Fort Union Formation

Ludlow Member of Fort Union Formation

1668000 1672000 1676000

Legend

- Intermittent Stream Crossings
- Perennial Stream Crossings
- Proposed Pipeline Route
- 1,000 ft Profile Interval

Base Photo: 2005 U.S. Farm Services Agency National Agricultural Imagery Program (NAIP)
Geology: Montana Bureau of Mines & Geology

Site Location on Pipeline

KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

CABIN CREEK - MILE POST 201.4 & 202
1:100,000 GEOLOGY

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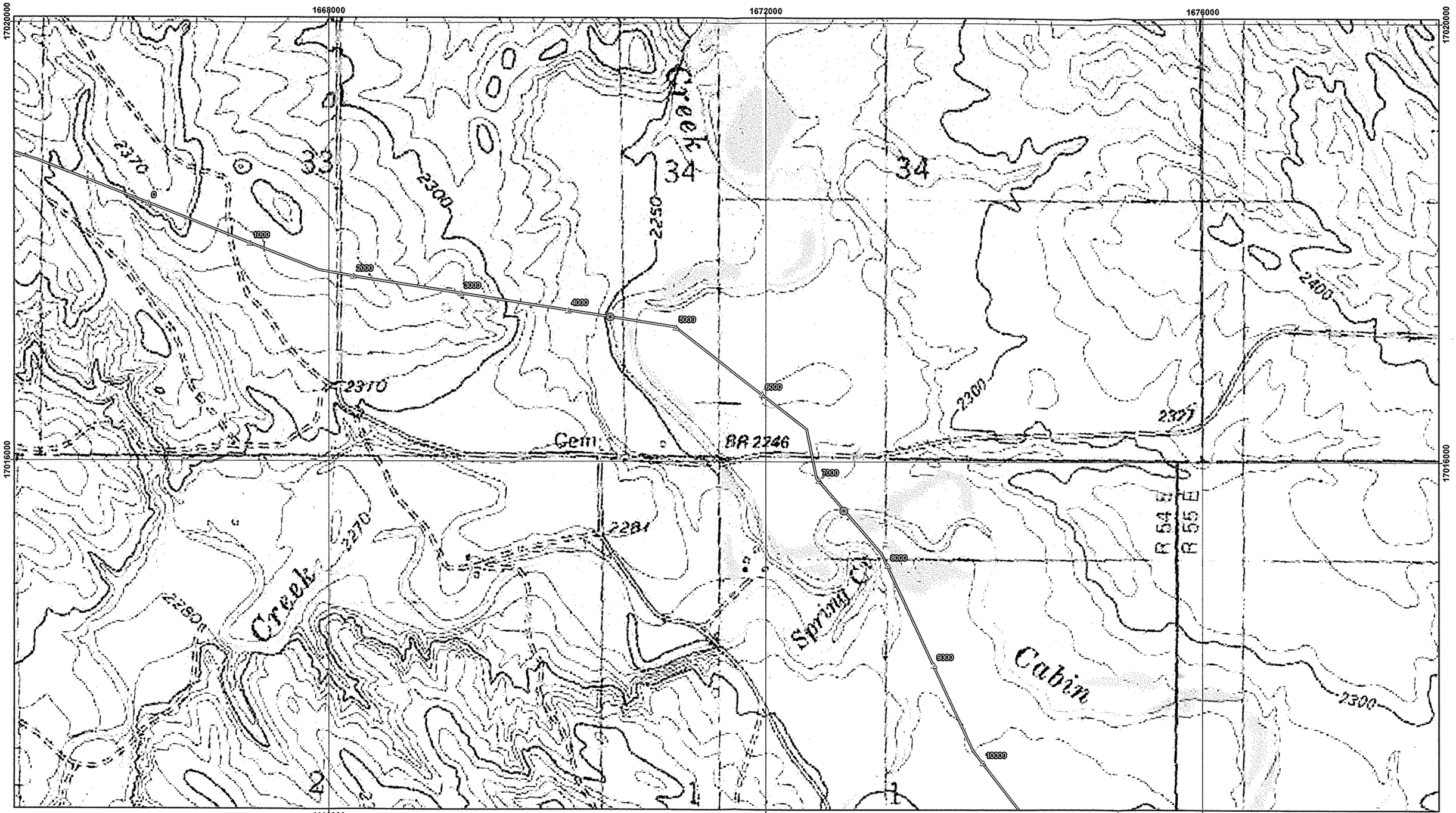
Coordinate System: NAD 1983 UTM Zone 13 feet

N W E S

0 400 800 1,600 Feet

This map and all data contained within are supplied as is with no warranty. Entrix, Inc. expressly disclaims responsibility for damages or liability from any claims that may arise out of the use or misuse of this map. It is the sole responsibility of the user to determine if the data on this map meets the user's needs. This map was not created as survey data, nor should it be used as such. It is the user's responsibility to obtain proper survey data, prepared by a licensed surveyor, where required by law.

File: \\Sacramento-nas\Data\SHARED\Belby\Keystone Pipeline\gis\map\mxd\Keystone XS field map landscape tabloid.mxd

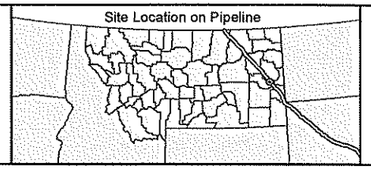


Legend

- Intermittent Stream Crossings
- Perennial Stream Crossings
- Proposed Pipeline Route
- 1,000 ft Profile Interval

USGS 1:24:000 Quadrangles:
http://nris.mt.gov/nsdi/drgpages/quadsid.html

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

CABIN CREEK - MILE POST 201.4 & 202
USGS 1:24000 Quadrangles

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

N W E S

0 400 800 1,600 Feet

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File: \\Sacramento-nas\Data\SHARED\Belby\Keystone Pipeline\gis\map\mxd\Keystone XS field map landscape tabloid.mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Cabin Ck Downstream - North			Surveyors	BB, ME
GPS	WP:	N:	E:	Date/Time	7/16/09 8:45
Flow Condition	low - base flow				

General Site Characteristics / Comments

- low gradient, meandering, fine grained channel - agricultural ditch
- heavy roots w/ some cottonwoods. High bank cohesion w/ fine grained material & dense sedges *see XS sketch for X-ing recommendations
- highly stable channel w/ low energy & dense sedges & grass
- Bedrock control DS - low scour potential

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}			
	D_{50} silt			
	D_{84} lb			
	% sand 5			
	SOIL CLASS SYMBOL	GM		
Bed (sub-surface)	D_{16}			
	D_{50} silt			
	D_{84}			
	% sand 5			
	SOIL CLASS SYMBOL	ML		
Bars	D_{16} N/A			
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}	~90% silt	D_{16}	~90% silt
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	5	% sand	5
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	~5	% sand	~5
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML

Comments: mostly silt alluvium, some clay

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

* DEM profile doesn't capture channel + floodplain detail

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 2			Bank Height (ft) 3.5		
Bank Slope (°) ~90			Bank Slope (°) 20		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species sedges			Dominant Species sedges		
Root Depth (ft) >1' Observed Y / (N)			Root Depth (ft) >1' Observed Y (N)		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y (N)	Potential (Y) / N	Gradual Migration	Present Y (N)	Potential (Y) / N
Slumping	Present (Y) / N	Potential (Y) / N	Slumping	Present (Y) / N	Potential Y / N
Landsliding	Present (Y) / N	Potential Y / (N)	Landsliding	Present Y (N)	Potential Y / (N)
Other:	Present Y / (N)	Potential Y (N)	Other:	Present Y / (N)	Potential Y / (N)
Notes: potential for ~20' of lateral migration & outer bank until steep, high left hillslope begins			Notes: very high potential for landsliding & outer bends & outerops - low energy channel - migration would be very gradual		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity Young - little O horizon		Soil Maturity Young little O horizon	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Riparian Buffer Width (ft) 0', sedges 100%		Riparian Buffer Width (ft) 0	
Riparian Plant Density(L,M,H) sedges		Riparian Plant Density(L,M,H)	
Dominant Species sedges		Dominant Species grasses w/ intermixed cottonwoods	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes:		Notes: mostly grass FP	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 19	Bridges (Y/N)
Bankfull Depth (ft) 3	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) topography - a Marked flat	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 16	
	Roads (Y/N)
Incision Evidence None	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence None	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) None observed - planar bed etc - Flat	
water surface	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes: Reference riffle ~ 100' DS of X-ing	Notes:
silty sandstone, gravel in banks & riffle	
Provides grade control for X-ing US	

CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other: - evidence of cattle grazing, but	Other:
not leading to bank instability	
-	

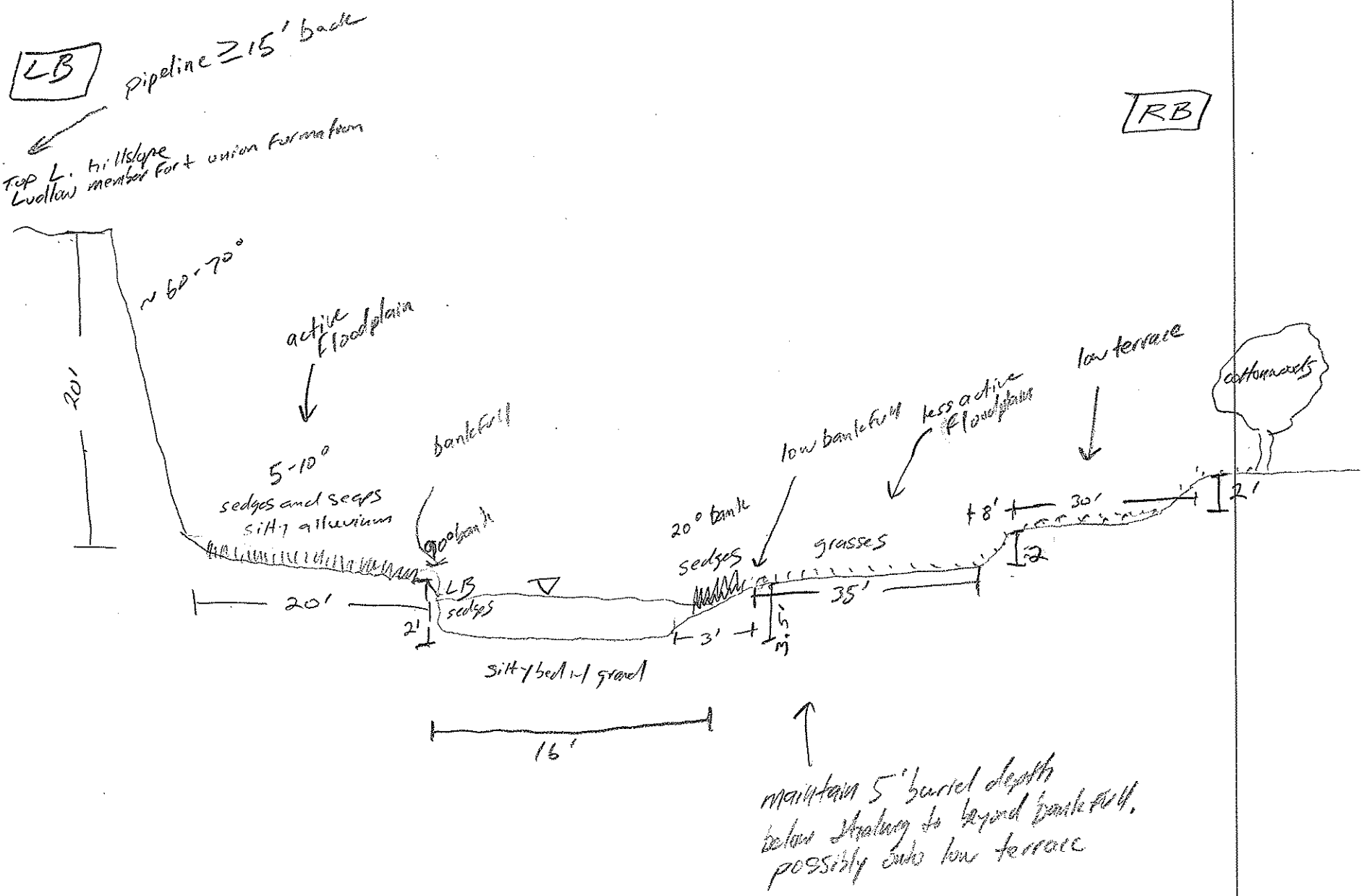
MANDATORY PHOTO CHECKLIST				
Photo		*Photo ID*	*View Direction*	*Description*
Site Overview	☒	13-15	see video	start panoramas DS - end US
Channel US Showing Both Banks	☒	5		
Channel DS Showing Both Banks	☒	6		
Channel Bed Surface Alluvium	☐	water too muddy, see bedrock oblique photos		
Channel Bed Sub-Surface Alluvium	☐	"		"
Bar Alluvium	☐	NA		
Bars Overview	☐	NA		
Islands Overview	☐	NA		
Left Bank Alluvium	☒	7		
Left Bank Toe Detail	☒	18		
Left Bank Top of Bank Detail	☒	19		
Left Bank Overview	☒	20		
Left Floodplain Alluvium	☒	7		same photo
Left Floodplain Overview	☒	11,12		
Left Floodplain Landforms	☐	NA		
Right Bank Alluvium	☒	21,22		
Right Bank Toe Detail	☒	8		
Right Bank Top of Bank Detail	☒	9		
Right Bank Overview	☒	10		
Right Floodplain Alluvium	☒	22		same photo
Right Floodplain Overview	☒	16		
Right Floodplain Landforms	☐	NA		
Infrastructure	☐	NA		
Disturbance/Instability	☐	NA		

SUPPLEMENTAL PHOTOS		
Photo ID	*View Direction*	*Description*
1	RB	bedrock riffle w/ low DS X-ing
2	US	" "
3	US	" " showing X-ing site
4	DS	" "

Video 17 - overview from top left hillslope @ proposed X-ing
Video 23 - silt in channel from RB
Video 24 - from RB floodplain

Cabin Creek Downstream

VALLEY CROSS-SECTION SKETCH



*notes – valley cross-section derived from 30 / 10 meter USGS DEM

CHANNEL CROSS-SECTION SKETCH

PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	~~Hay Coulee MP 38~~ Pennel Creek (on Plevna Rd downstream)			Surveyors	Ericsson
GPS	WP:	N:	E:	Date/Time	08/08/09 5:00pm
Flow Condition	2-4 cfs				
General Site Characteristics / Comments	All measurements and observations taken from Plevna Rd. well defined terraces on both sides of the river. Old relic meander features on high terrace. Right bank floodplain has a few scattered cottonwoods ~~Site~~ Site characteristics taken looking downstream				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}			
	D_{50}			
	D_{84}	No access		
	% sand			
	SOIL CLASS SYMBOL			
Bed (sub-surface)	D_{16}			
	D_{50}			
	D_{84}	No access		
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}	No access		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}	No access?	D_{84}	No access?
	% sand		% sand	
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}	No access?	D_{84}	No access?
	% sand		% sand	
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	

Comments:

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 6'+ (bankfull) 3' (med/high FP boundary)			Bank Height (ft) 6'+ (bankfull) 4'+ (med to high FP bndry)		
Bank Slope (°) 55° (bf) 50° (med/high Fb bndry)			Bank Slope (°) Same as left bank		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species —			Dominant Species —		
Root Depth (ft) 2'+ Observed Y / N			Root Depth (ft) 2'+ Observed Y / N		
Undercutting (Y/N)			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / N	Potential Y N	Gradual Migration	Present Y / N	Potential Y N
Slumping	Present Y / N	Potential Y N	Slumping	Present Y / N	Potential Y N
Landsliding	Present Y / N	Potential Y / N	Landsliding	Present Y / N	Potential Y / N
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: not accessable, however given the slopes and nearby site (Dry Fork Creek) expect clay-rich soils			Notes: Same as left bank		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity NA (no access)		Soil Maturity NA (no access)	
Natural Levees (Y/N)		Natural Levees (Y/N)	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H) —		Woody Riparian Plant Density (L,M,H) —	
Dominant Woody Species —		Dominant Woody Species —	
Crevasse Splays (Y/N)		Crevasse Splays (Y/N)	
Crevasse Channels (Y/N)		Crevasse Channels (Y/N)	
Notes: low, med, high all present		Notes: low, med, high all present	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 90'	Bridges (Y/N)
Bankfull Depth (ft) 8'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) 6' bank bounding meanders	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 0.5' to 3'	
	Roads (Y/N)
Incision Evidence yes, but not expected at crossing	(RR, LB, US, DS)
(@ bridge)	
	Other Infrastructure
Aggradation Evidence NA	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) 2'	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes: Entrenched meandering system	Notes: need to review aerial at crossing

CHANNEL DISTURBANCE/PERTERBATIONS	
Natural not expected	Artificial need to review aerial at crossing
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

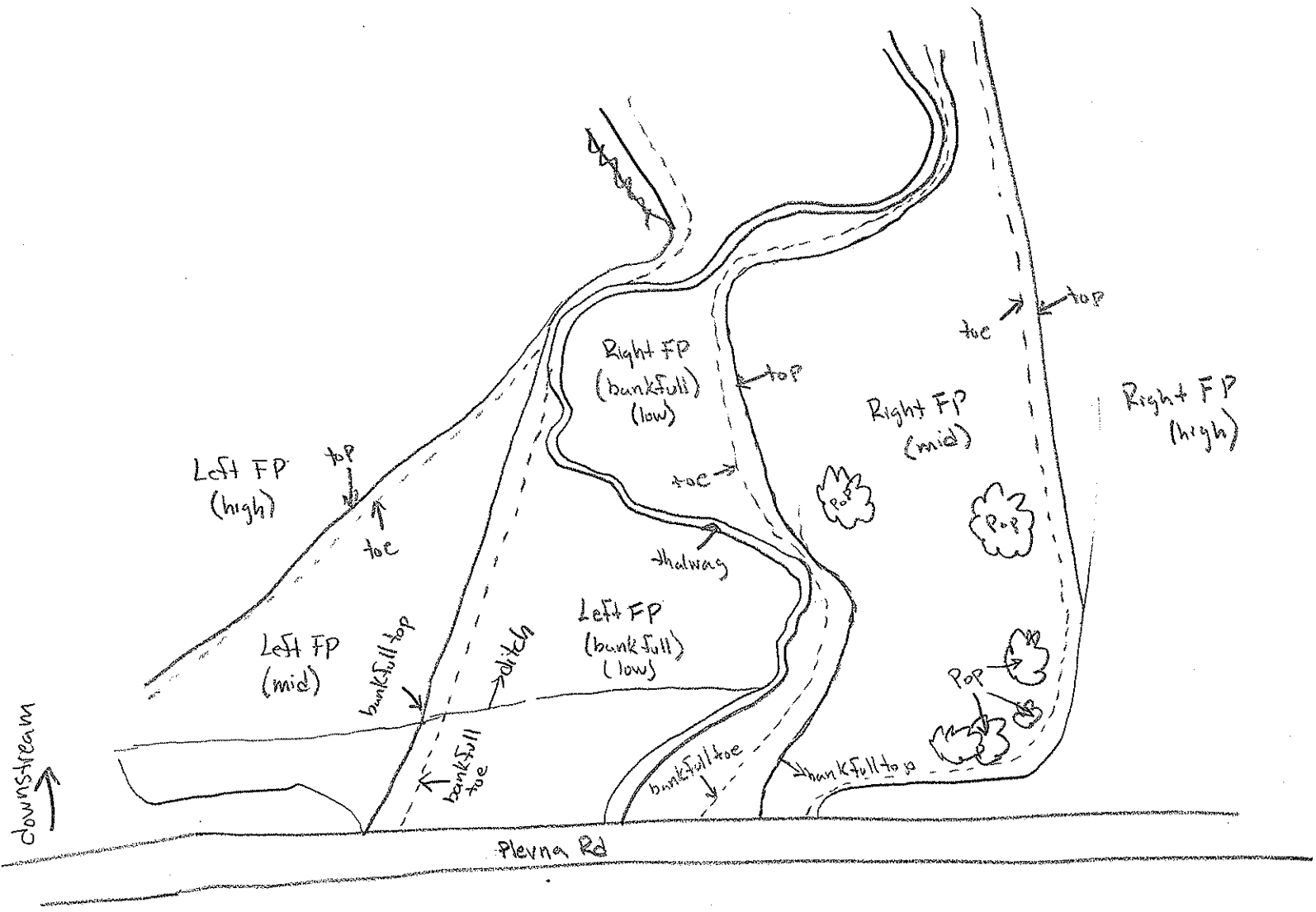
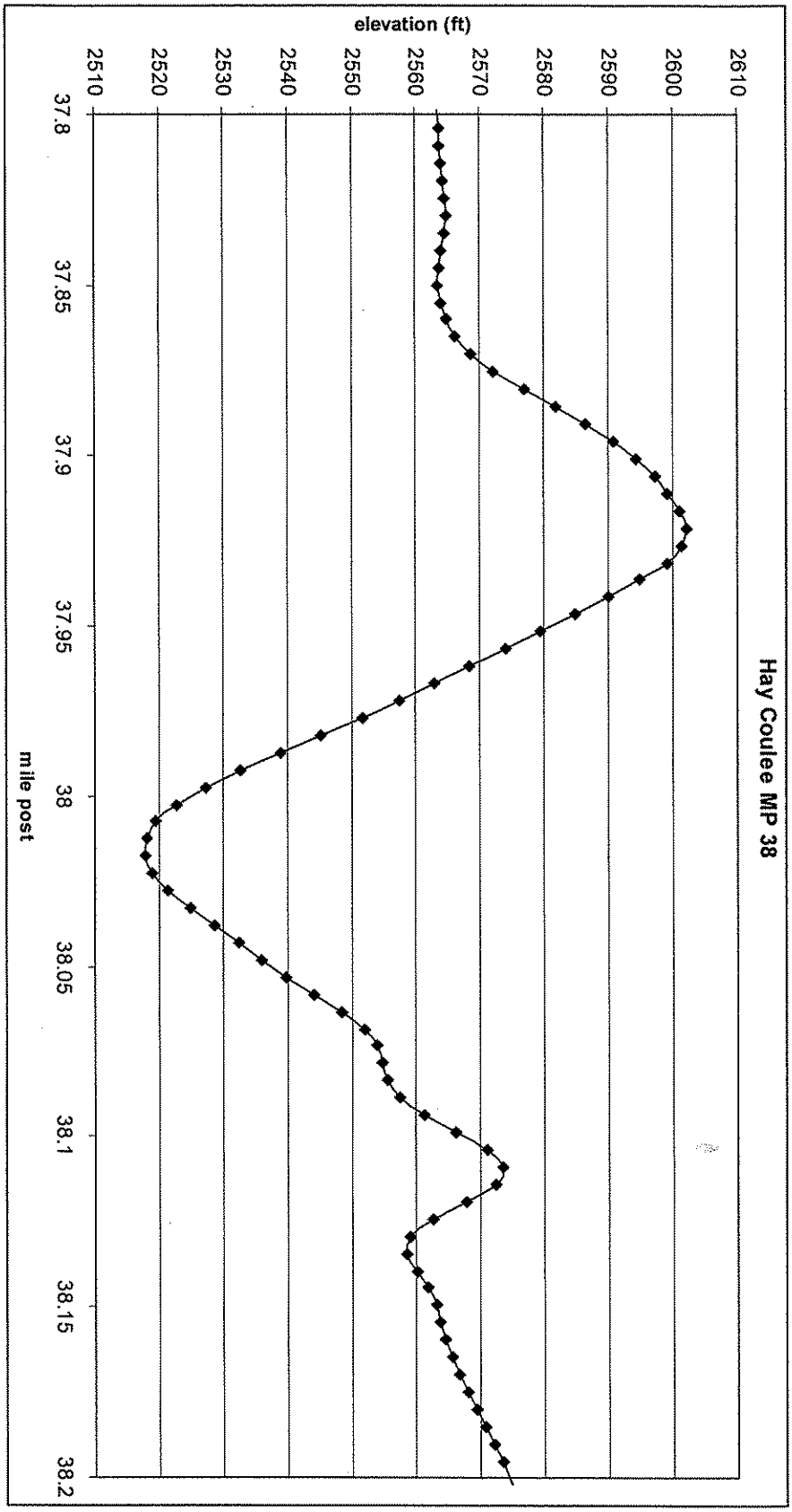

Left FP
(high)
top
toe
Left FP
(mid)
bankfull top
ditch
bankfull
toe
Left FP
(bankfull)
(low)
thalweg
Right FP
(bankfull)
(low)
top
toe
Right FP
(mid)
POP
POP
POP
top
toe
Right FP
(high)
bankfull toe
bankfull toe
downstream
Plevna Rd

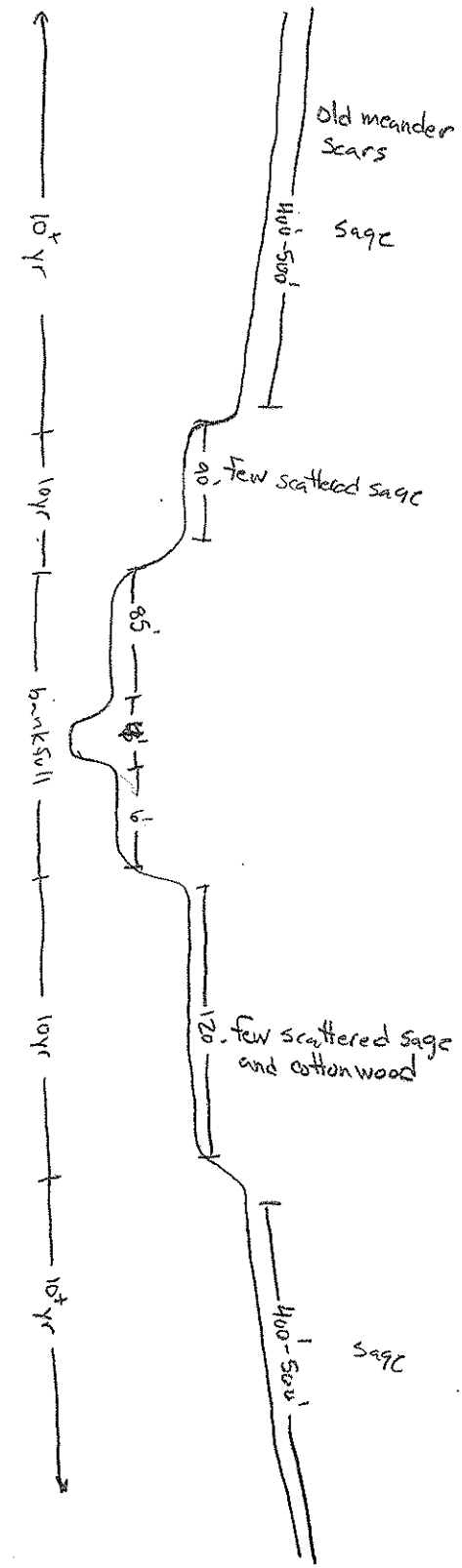
PHOTO CHECKLIST		
Site Overview	☒	238-241 (looking downstream) 242-245 (looking upstream)
Channel US Showing Both Banks	☒	NA
Channel DS Showing Both Banks	☒	site is ds of crossing (see overview)
Channel Bed Surface Alluvium	☒	NA no access
Channel Bed Sub-Surface Alluvium	☒	NA no access
Bar Alluvium	☒	NA no access
Bars Overview	☒	NA no access
Islands Overview	☒	NA no access
Left Bank Alluvium	☒	NA no access
Left Bank Toe Detail	☐	—
Left Bank Top of Bank Detail	☐	—
Left Bank Overview	☐	247
Left Floodplain Alluvium	☒	NA no access
Left Floodplain Overview	☐	249 (med fp) 250 (low fp) 257 (high fp)
Left Floodplain Landforms	☐	NA no access
Right Bank Alluvium	☒	NA no access
Right Bank Toe Detail	☐	—
Right Bank Top of Bank Detail	☐	—
Right Bank Overview	☐	246
Right Floodplain Alluvium	☒	NA no access
Right Floodplain Overview	☐	248 (med fp) 251 (low fp) 252 (high fp)
Right Floodplain Landforms	☐	NA no access
Infrastructure	☐	check aerial
Disturbance/Instability	☐	check aerial

PHOTO LOG		
Photo ID	View Direction	Description
253-255	⊥ valley	old landslide downstream of bridge on left bank
256	"	"
258-261	⊥ valley	relic channel on lf high FP

VALLEY CROSS-SECTION SKETCH

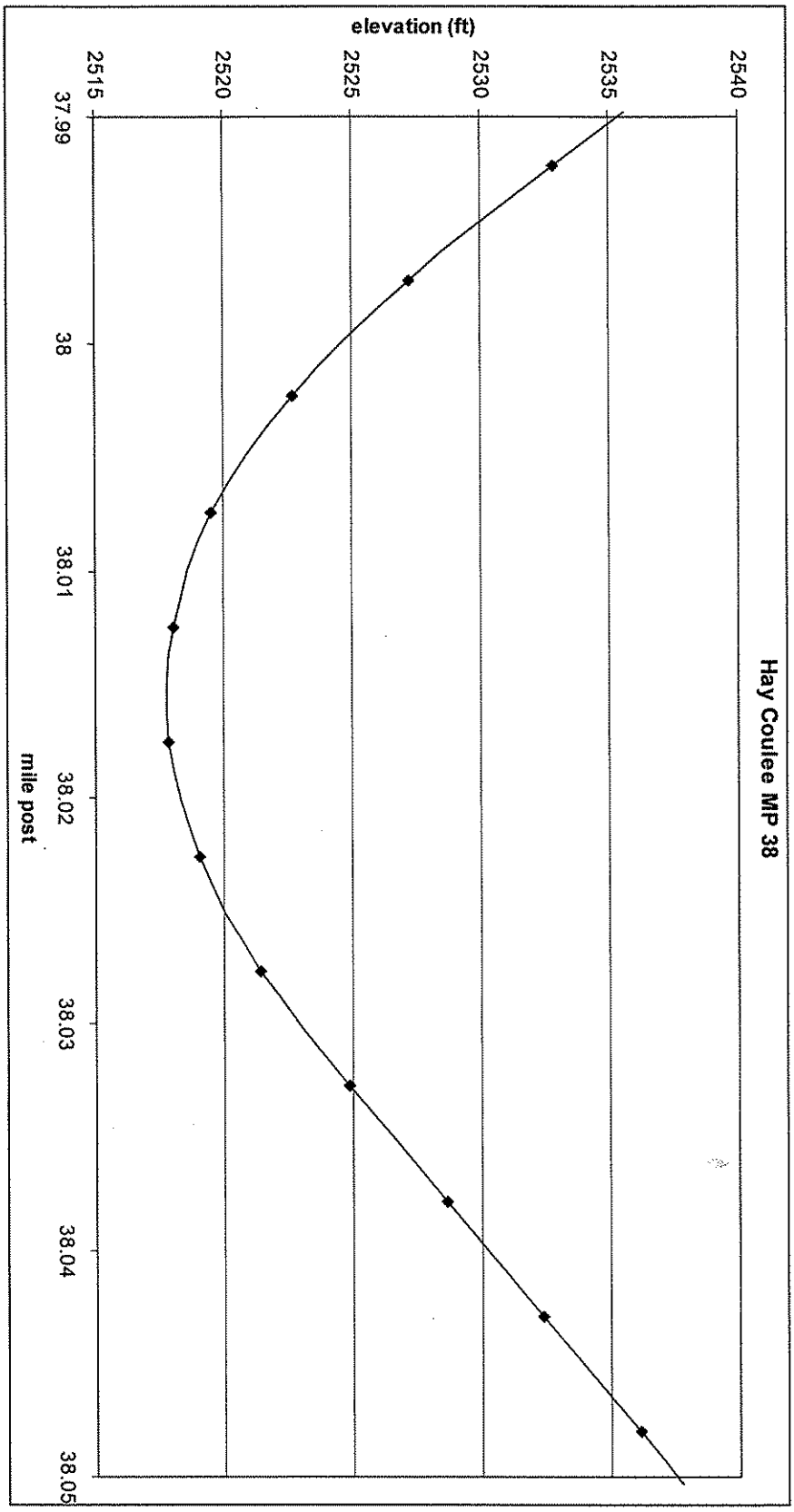
*notes – valley cross-section derived from 30 / 10 meter USGS DEM





CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Corral Coulee MP 20.8			Surveyors	Ericsson
GPS	WP:	N:	E:	Date/Time	1115 pm 08/05/2009
Flow Condition	no flow present				
General Site Characteristics / Comments	entrenched meandering system @ confluence with tributary coming in from the left bank. Main channel widens x2 at crossing immediately upstream of tributary confluence. Evidence of lateral migration at crossing, more stable upstream and downstream				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	clay		
	D_{50}	1/2 mm		
	D_{84}	7-9 cm		
	% sand	95 %		
	SOIL CLASS SYMBOL	SP		
Bed (sub-surface)	D_{16}			
	D_{50}			
	D_{84}	NA		
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}	NA		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}	1/10 mm	D_{16}	silt
	D_{50}	1/4 mm	D_{50}	1/8 mm
	D_{84}	1 mm	D_{84}	1/4 mm
	% sand	95	% sand	85
	SOIL CLASS SYMBOL	SP	SOIL CLASS SYMBOL	~~SP~~ SM
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}	silt	D_{16}	1/10 mm
	D_{50}	1/16 mm	D_{50}	1/4 mm
	D_{84}	1/4 mm	D_{84}	2 mm
	% sand	85	% sand	95%
	SOIL CLASS SYMBOL	SM	SOIL CLASS SYMBOL	SP

Comments:

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
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		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 3.5'			Bank Height (ft) 2'		
Bank Slope (°) ~90°			Bank Slope (°) 30'		
Woody Cover (%) 25			Woody Cover (%) olive look-alike > 20%		
Dominant Species olive look-alike			Dominant Species		
Root Depth (ft) 2.5 Observed (Y)/N			Root Depth (ft) 2 Observed Y/(N)		
Undercutting (Y/N) very minor			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y/(N)	Potential (Y) N	Gradual Migration	Present Y/(N)	Potential (Y) N
Slumping	Present (Y) N	Potential (Y) N	Slumping	Present Y/(N)	Potential Y/(N)
Landsliding	Present Y/(N)	Potential Y/(N)	Landsliding	Present Y/(N)	Potential Y/(N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: bank collapse on left bank at crossing / at outside bend of meander			Notes: inside of meander bend		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity minimal 1' dark surface		Soil Maturity minimal 1' dark surface	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral ((Y)/N)
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft) 3'		Woody Riparian Buffer Width (ft) 8'	
Woody Riparian Plant Density (L,(M),H)		Woody Riparian Plant Density (L,(M),H)	
Dominant Woody Species olive look-alike		Dominant Woody Species olive look-alike	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes: 1.5'→2' tributary runs through FP		Notes: 1.5'–2' side channel along valley margin	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 40'	Bridges (Y/(N))
Bankfull Depth (ft) 3'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) bank	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 0 → 3'	
	Roads (Y/(N))
Incision Evidence NA	(RR, LB, US, DS)
	Other Infrastructure NA
Aggradation Evidence N.A	
Bars (Y/(N))	
Vegetated Islands (Y/(N))	
Pool Depths (ft) NA	
Channel In Low Elevation of Valley Floor ((Y)/N)	
Notes: active lateral migration on left bank	Notes:

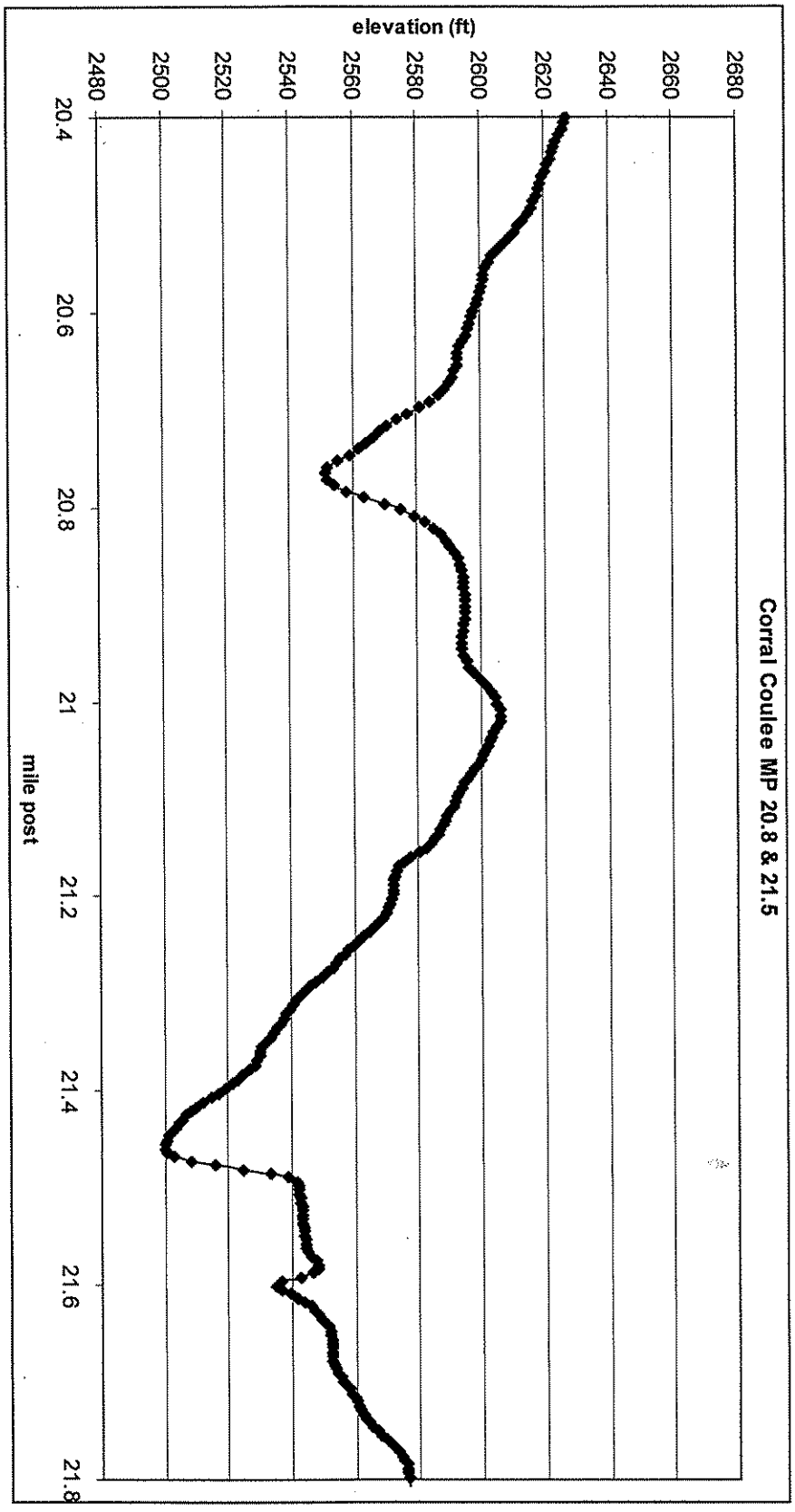
CHANNEL DISTURBANCE/PERTERBATIONS	
Natural NA	Artificial stock pond on trib.
Beaver dams NA	In-stream structures NA
Debris flow NA	
	Flow Diversion NA
Landslides NA	
	Debris NA
Woody debris NA	
Other: stock pond upstream on tributary	Other:

PHOTO CHECKLIST		
Site Overview	☒	334 335
Channel US Showing Both Banks	☒	317
Channel DS Showing Both Banks	☒	315-316 panaramic of crossing looking d.s.
Channel Bed Surface Alluvium	☒	321
Channel Bed Sub-Surface Alluvium	☐	NA
Bar Alluvium	☐	NA
Bars Overview	☐	NA
Islands Overview	☐	NA
Left Bank Alluvium	☒	~~326~~ 324
Left Bank Toe Detail	☒	325
Left Bank Top of Bank Detail	☒	323
Left Bank Overview	☒	~~326~~ 322
Left Floodplain Alluvium	☒	318
Left Floodplain Overview	☒	319
Left Floodplain Landforms	☒	320 trib channel
Right Bank Alluvium	☐	NA heavily vegetated
Right Bank Toe Detail	☐	NA heavily vegetated
Right Bank Top of Bank Detail	☐	NA heavily vegetated
Right Bank Overview	☒	328
Right Floodplain Alluvium	☒	330
Right Floodplain Overview	☒	329
Right Floodplain Landforms	☒	side channel 331
Infrastructure	☐	NA
Disturbance/Instability	☒	undercut bank 326-327

PHOTO LOG		
Photo ID	View Direction	Description
332	E	left bank ~~slumping~~ rotational failure
333		" + undercut banks

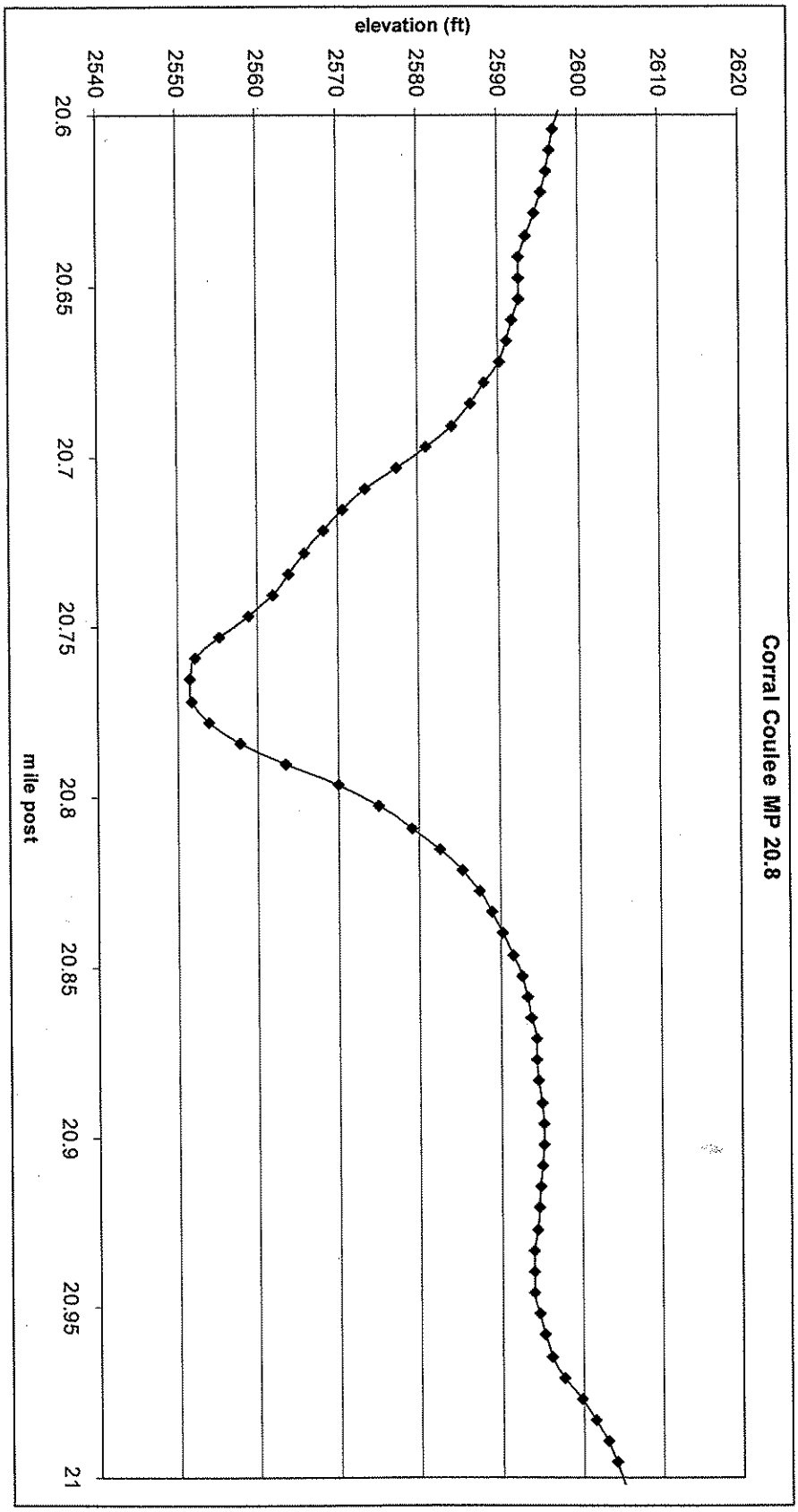
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM

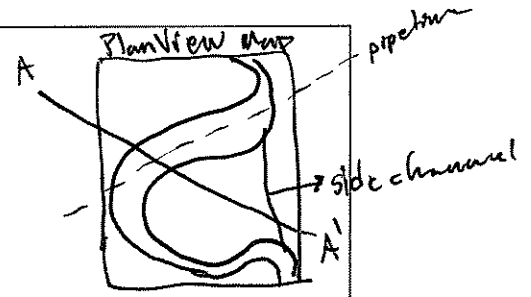


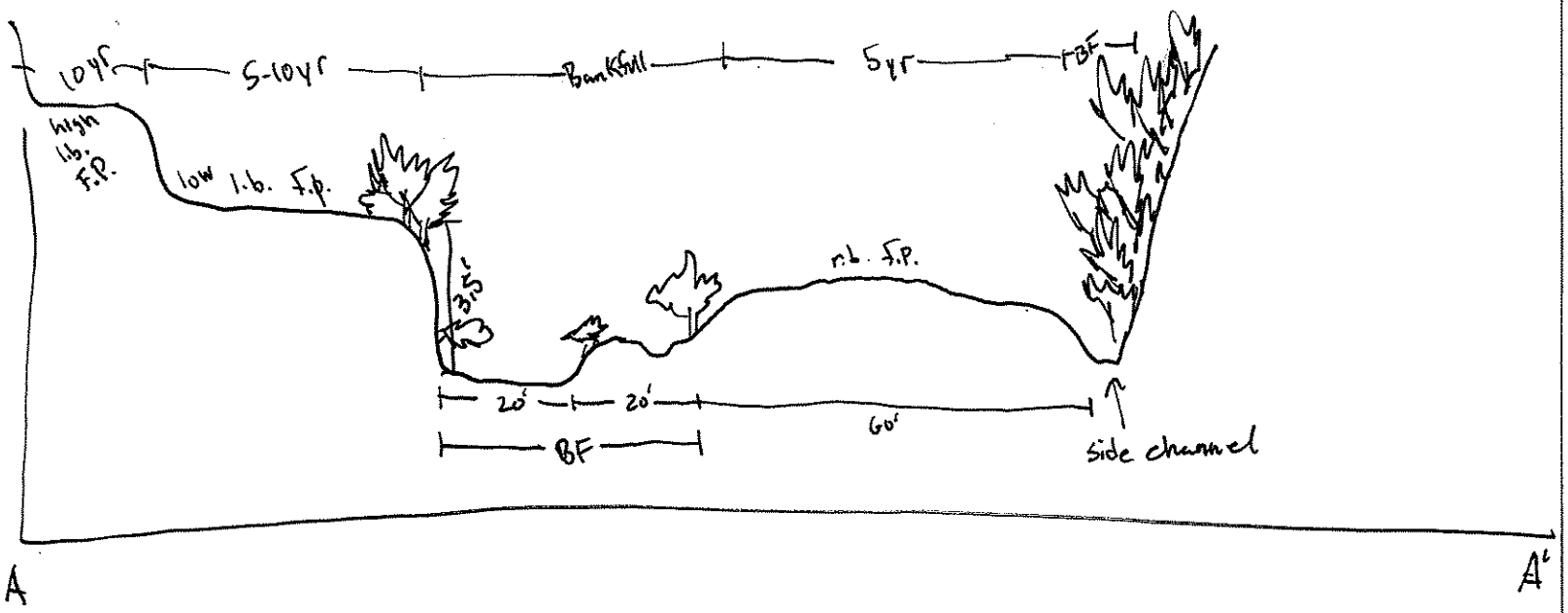
CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP





*notes – image background date:

Questions:

What is the likelihood the project will impact turbidity at the site? Intermittent site, mostly sandy soils w/ <10% fines

What is the potential impact on incision and erosion? Site is currently migrating laterally

Will the project activate historical instability? Site is currently instable

What actions or alternatives can mitigate project effects? & rebuild channel in stable form

Are there any cumulative effects of pipeline? May increase stability of the site if rebuilt in stable form

General Notes:

The left bank (outside meander) is actively migrating laterally (evidence by undercut banks, rotational failure with live grass on surface) that will ultimately lead to a meander cut-off. Need to recommend maintaining minimum 5' cover depth below the thalweg from valley margin to valley margin.

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	Corral Creek MP 20.8	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Regional Regression	8.91	--	--	--	74	360	736	1,543	2,426	3,637
No Gage Station Data Available										

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 : 0.9

Width (ft) vegetation made it difficult to assess channel width	min	max	mean	stnd dev
	15	37	26	7

meander wavelength: (ft) 806

meander amplitude (ft) 218

Sinuosity: 1.33

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	244	712	413	626
	413	626	977	413
	977	413	1469	390
			1922	410

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 17.45

Valley

Gradient: 1.2

	min	max	mean	stnd dev
width	107	584	278	153

describe geology (lithology, erodibility):

Gravel, sand and silt alluvium of channels and flood plains.

Conglomerate with limestone and sandstone

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: None

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

The channel is incised because the surrounding valley elevation is generally 8.0-10ft above the surface water elevation of the channel.
Unique features, exceptions, etc
None

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
US 0.17 mi, river left, there appears to be a sign of bank instability.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
None
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.

Questions:

What is the likelihood the project will impact turbidity at the site?

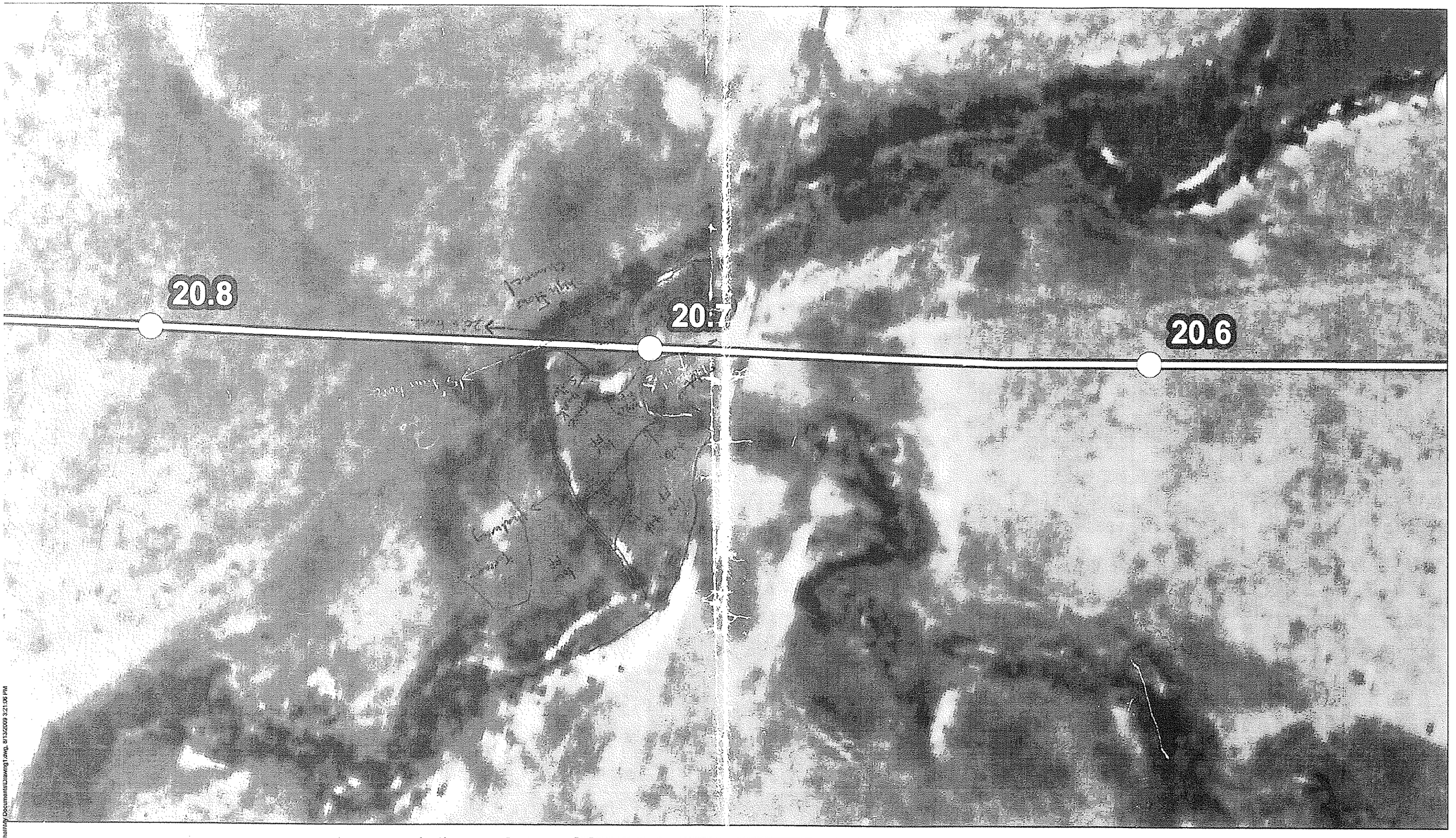
What is the potential impact on incision and erosion?

Will the project activate historical instability?

What actions or alternatives can mitigate project effects?

Are there any cumulative effects of pipeline?

General Notes:



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

ENTRIX

0 50 100 200
Feet

C:\Documents and Settings\Marshall\My Documents\Drawing1.dwg, 8/13/2009 3:21:06 PM

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Corral Coulee MP 21.5			Surveyors	Ericsson
GPS	WP:	N:	E:	Date/Time	8/5/09 11:00 am
Flow Condition	no flow				

General Site Characteristics / Comments: entrenched meandering system with unconsolidated alluvial valley margins. Sparse cottonwood and ash along bankfull margins. Historic channel deposit on inside of meander and preserved as a low terrace on the right bank floodplain. Vertical 65-80' valley wall on left bank with channel thalweg at its base. wall is unconsolidated clayey sand

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	0.5		
	D_{50}	1.2		
	D_{84}	6		
	% sand	35		
	SOIL CLASS SYMBOL	GC		
Bed (sub-surface)	D_{16}			
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}	NA		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}	clay	D_{16}	clay
	D_{50}	0.25	D_{50}	0.1
	D_{84}	~~clay~~ 1	D_{84}	~~clay~~ 0.5
	% sand	75	% sand	80
	SOIL CLASS SYMBOL	SC	SOIL CLASS SYMBOL	SC
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN silt	
	D_{16}	1/16 mm	D_{16}	1/16 mm
	D_{50}	1/4 mm	D_{50}	1/4 mm
	D_{84}	1/2 mm	D_{84}	1/2 mm
	% sand	95	% sand	90
	SOIL CLASS SYMBOL	SP	SOIL CLASS SYMBOL	SC

Comments:

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 1.5'			Bank Height (ft) 2'		
Bank Slope (°) 10			Bank Slope (°) 33		
Woody Cover (%)			Woody Cover (%)		
Dominant Species			Dominant Species		
Root Depth (ft) 1' Observed Y / (N)			Root Depth (ft) 1-1.5' Observed Y / (N)		
Undercutting (Y/N)			Undercutting (Y/N) downstream of crossing		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / N	Potential (Y) N	Gradual Migration	Present Y / N	Potential (Y) N
Slumping	Present Y / N	Potential (Y) / N	Slumping	Present Y / N	Potential (Y) / N
Landsliding	Present Y / N	Potential (Y) / N	Landsliding	Present Y / N	Potential Y / (N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: 35-40' vertical valley wall consisting on unconsolidated clayey-sand			Notes:		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity Young		Soil Maturity Young ~1" dark surface	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 3	
Woody Riparian Plant Density (L,M,H) 0		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species NA		Dominant Woody Species Ash?	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes: narrow, ~10-15' wide and is the same elevation as the low r.b. floodplain		Notes: low floodplain is an old channel deposit low and high floodplains present	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 35-40'	Bridges (Y/N)
Bankfull Depth (ft) 3'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) bank	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 0-5'	
	Roads (Y/N)
Incision Evidence undercut banks in some locations;	(RR, LB, US, DS)
right bank low floodplain is old channel deposit	
	Other Infrastructure NA
Aggradation Evidence NA	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) NA	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes: old dead tree on rt. bank low floodplain	Notes:
margin ~ 50-75 yrs old. Alternating pools/	
riffles in channel thalweg, some rounded	
boulders present in thalweg	

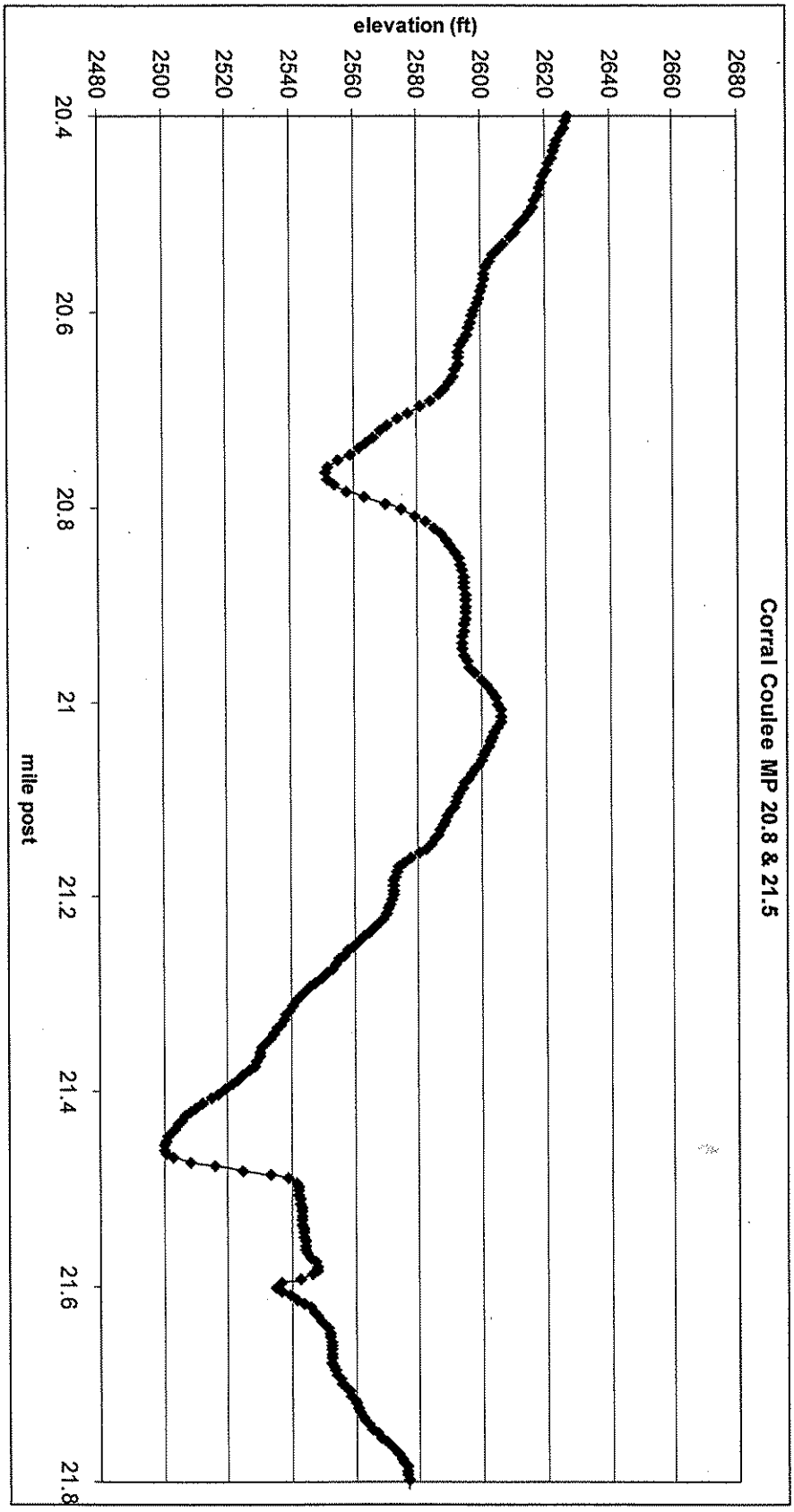
CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams NA	In-stream structures
Debris flow NA	
	Flow Diversion
Landslides NA (potential)	
	Debris
Woody debris NA	
Other:	Other:

PHOTO CHECKLIST		
Site Overview	☒	292 looking upstream
Channel US Showing Both Banks	☒	304
Channel DS Showing Both Banks	☒	306-307 panaramic
Channel Bed Surface Alluvium	☒	293
Channel Bed Sub-Surface Alluvium	☒	294
Bar Alluvium	☐	NA
Bars Overview	☐	NA
Islands Overview	☐	NA
Left Bank Alluvium	☒	296
Left Bank Toe Detail	☐	NA heavily vegetated and low slope
Left Bank Top of Bank Detail	☐	NA heavily vegetated and low slope
Left Bank Overview	☐	299 looking upstream / bank is in middle of photo
Left Floodplain Alluvium	☒	297
Left Floodplain Overview	☒	298 looking upstream @ crossing
Left Floodplain Landforms	☐	NA
Right Bank Alluvium	☒	295
Right Bank Toe Detail	☒	302
Right Bank Top of Bank Detail	☒	303
Right Bank Overview	☒	301 looking upstream @ crossing
Right Floodplain Alluvium	☒	304
Right Floodplain Overview	☒	309-310 panaramic (dead tree in background @ low/high boundary)
Right Floodplain Landforms	☐	NA
Infrastructure	☐	NA
Disturbance/Instability	☐	

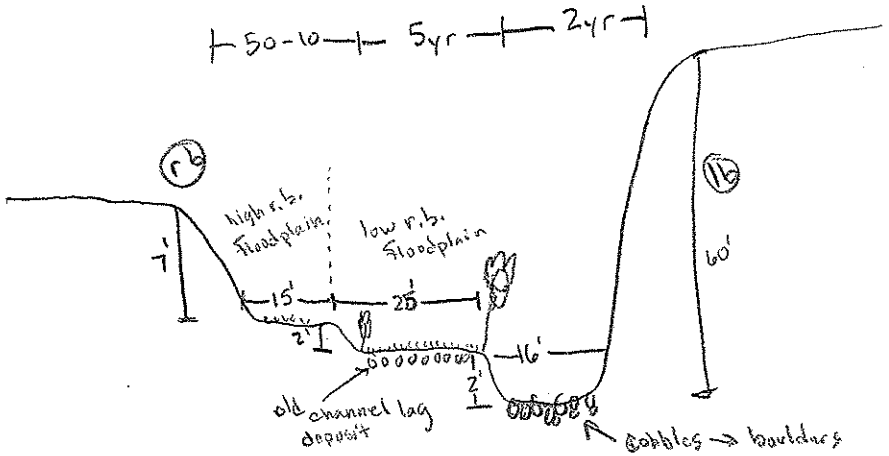
PHOTO LOG		
Photo ID	View Direction	Description
305		undercut bank on rt bank immediately d.s. of crossing
305		racked wood on left bank @ crossing
311		left bank valley wall
312		toe of left bank valley wall
313-314		panaramic looking downstream @ crossing

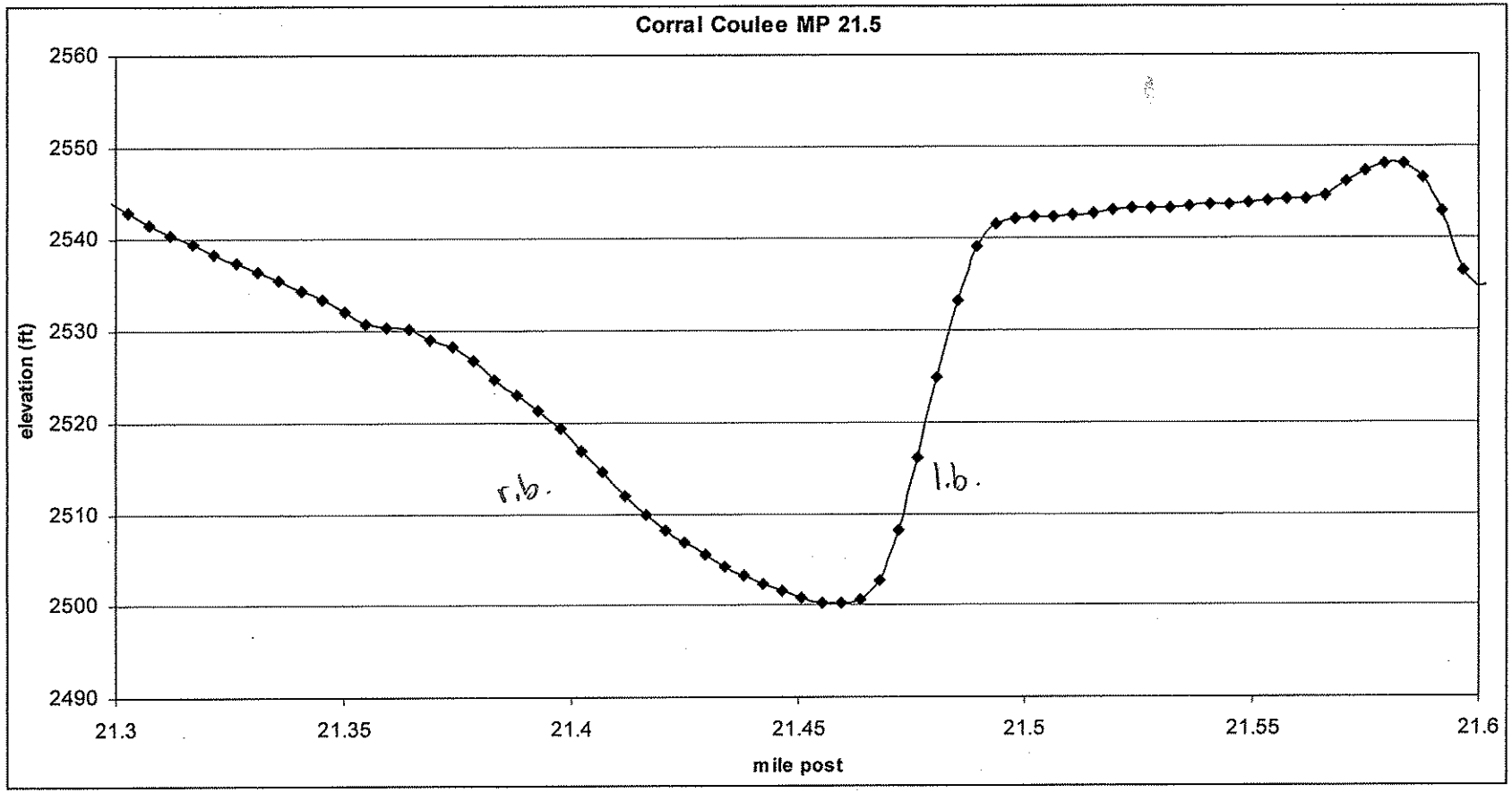
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



CHANNEL CROSS-SECTION SKETCH





*notes – channel cross-section derived from 30 / 10 meter USGS DEM

PLANVIEW MAP

*notes – image background date:

- Intermittent crossing with < 20% fines overall
  clay is dominant fine, plastic
  once flow is introduced after pipeline trenching a plume of fines will likely move downstream and redistribute

- bed has many boulders/cobbles, need to make sure the final cover material over the bankfull channel is similar sized material, else headcuts could occur
  In addition the route is immediately adjacent to a very high (>60') wall on the left bank. Would be impossible to recontour close to original grade. However if removed it may accelerate lateral migration toward the left bank.

- Unlikely to activate historic instability.

- Suggest moving the pipeline alignment downstream to avoid very high wall on left bank. Maintain minimum 5' cover through both floodplains.

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	Corral Coulee MP 21.5	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression	9.79	--	--	--	80	384	784	1,642	2,581	3,867
No Gage Station Data Available										

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:1.1

Width (ft) Vegetation made it difficult to determine width	min	max	mean	std dev
	11	20	15	4

meander wavelength (ft) 570

meander amplitude (ft) 184

Sinuosity 1.44

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	91	197	200	264
	200	264	636	189
	636	189	1062	430
			1426	249

Channel form (braided, anabranching, single thread):

Single Braid

Channel confinement at crossing (W_v / W_c): 31.0

Valley

Gradient:1.8

	min	max	mean	std dev
width	179	571	319	142

describe geology (lithology, erodibility):

Claystone interbedded with sandstone, conglomeratic sandstone and siltstone. Fluvial thickness 2,510 ft

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

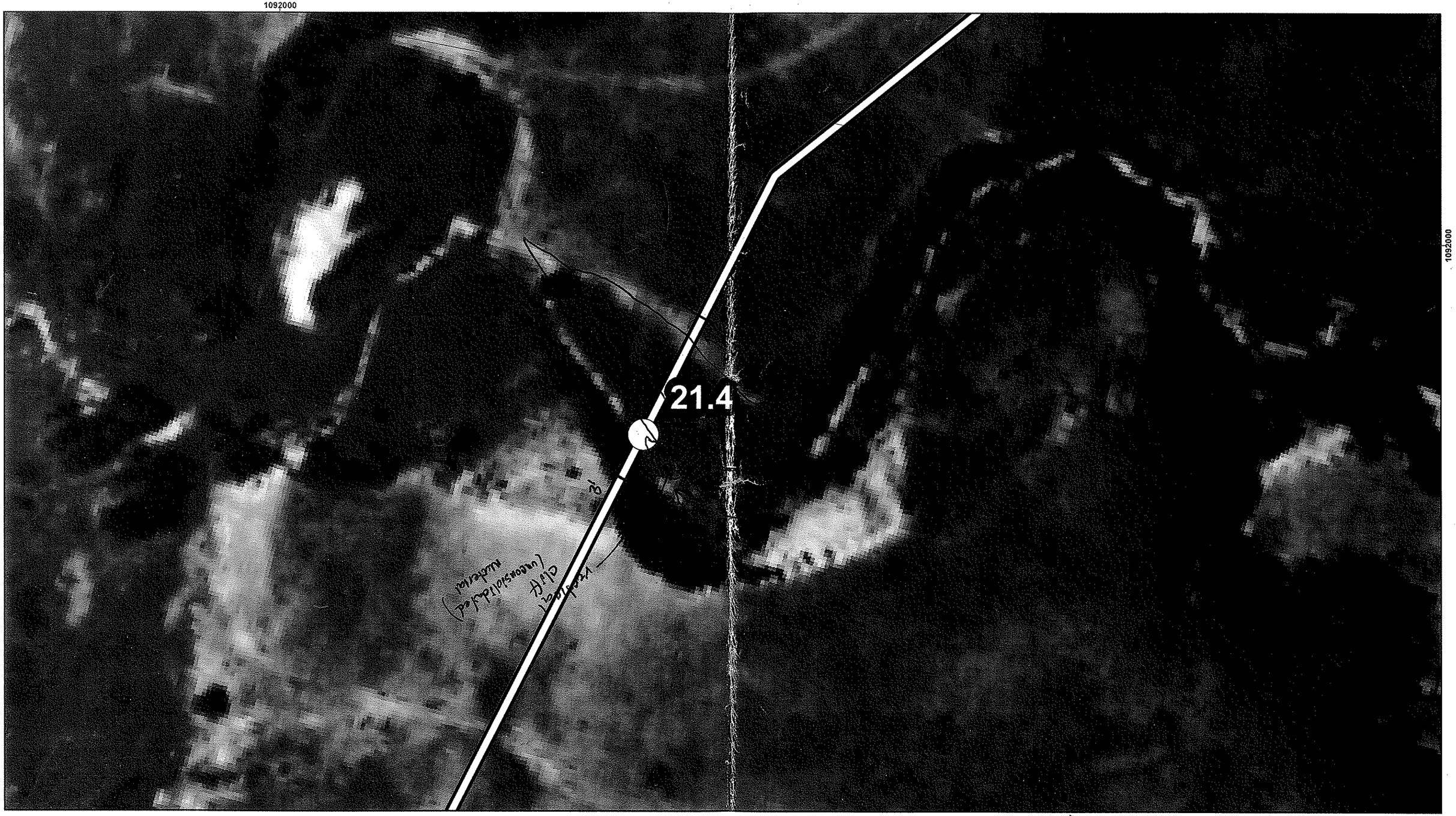
channel cut-offs: None

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 :
None

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
US (0.02 and 0.20 mi, river left, outside of meanders, severe erosion is apparent)
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. Dam (0.25 mi River left up the eastern trib.)
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.

1092000

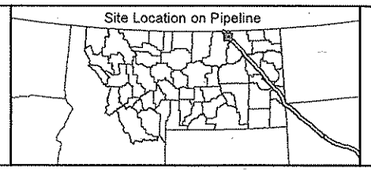


1092000

- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Corral Coulee - MILE POST 21.5
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 37.5 75 150 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Stock Pond MP 69.2			Surveyors	Eriksson
GPS	WP:	N:	E:	Date/Time	8/7/09 8:15 AM
Flow Condition	No Flow				
General Site Characteristics / Comments	Intermittent stream with dam approx - 800-850' downstream. Crossing is near where the OHW of the intermittent pond reduces to that of the creek feeding it. Cattle grazing and gathering spot, all banks significantly laid back along margins of pond compared to stream upstream				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	clay		
	D_{50}	1/12 mm		
	D_{84}	1/3 mm		
	% sand	25		
	SOIL CLASS SYMBOL	ML		
Bed (sub-surface)	D_{16}	silt		
	D_{50}	1/4 mm		
	D_{84}	0.75 cm		
	% sand	80		
	SOIL CLASS SYMBOL	GM		
Bars	D_{16}			
	D_{50}			
	D_{84}	NA		
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}	silt	D_{16}	silt
	D_{50}	1/4 mm	D_{50}	1/4 mm
	D_{84}	1 mm	D_{84}	1 mm
	% sand	85	% sand	85
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}	silt	D_{16}	silt
	D_{50}	1/16 mm	D_{50}	1/16 mm
	D_{84}	1/2 mm	D_{84}	1/4 mm
	% sand	80	% sand	75
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML

Comments:

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 1'			Bank Height (ft) 0.75'-1'		
Bank Slope (°) 15°			Bank Slope (°) 10°		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species —			Dominant Species —		
Root Depth (ft) 0.5-1' Observed Y / (N)			Root Depth (ft) 0.5-1' Observed Y / (N)		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / (N)	Potential Y / (N)	Gradual Migration	Present Y / (N)	Potential Y / N
Slumping	Present Y / (N)	Potential Y / (N)	Slumping	Present Y / (N)	Potential Y / N
Landsliding	Present Y / (N)	Potential Y / (N)	Landsliding	Present Y / (N)	Potential Y / (N)
Other:	Present Y / (N)	Potential Y / (N)	Other:	Present Y / (N)	Potential Y / (N)
Notes: very laid back bank, likely inundated annually, banks are relic from before dam was built. Now given significant duration of saturation and cows they are laid back significantly			Notes: same notes as left bank parameters		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity young 1-3" dark surface		Soil Maturity young 2-3" dark surface	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H) 0		Woody Riparian Plant Density (L,M,H) 0	
Dominant Woody Species —		Dominant Woody Species —	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes: wide and hummocky, sloped toward channel		Notes: wide and hummocky, sloped toward channel	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 150'	Bridges (Y/N)
Bankfull Depth (ft) 3'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) bank, vegetation (no sage within bankfull)	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 0	
	Roads (Y/N)
Incision Evidence NA	(RR, LB, US, DS)
	Other Infrastructure dam
Aggradation Evidence NA	- 800'-850' downstream of crossing
	- causes annual inundation to and upstream ~ 100'-200'
Bars (Y/N)	- looks approximately 12'-10' high
Vegetated Islands (Y/N)	
Pool Depths (ft) —	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes: site is a head of stock pond and is inundated annually to bankfull. Incision is dampened due to reservoir downstream (local base level)	Notes:

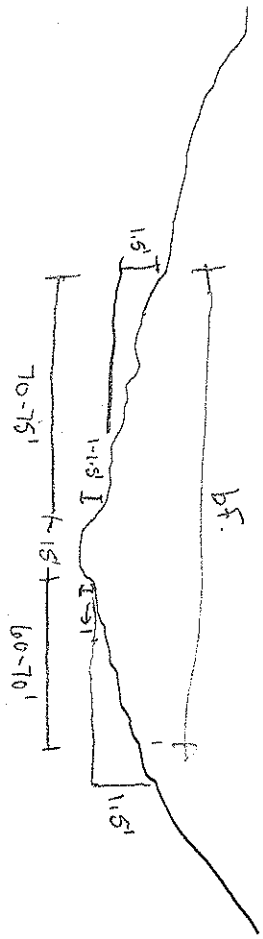
CHANNEL DISTURBANCE/PERTERBATIONS	
Natural —	Artificial
Beaver dams NA	In-stream structures dam 800-850' downstream
Debris flow NA	
	Flow Diversion — NA
Landslides NA	
	Debris NA
Woody debris NA	
Other: NA	Other: NA

PHOTO CHECKLIST		
Site Overview	☒	310 (from rt FP to lf FP along route)
Channel US Showing Both Banks	☒	292–294 panaramic
Channel DS Showing Both Banks	☒	295-296 panaramic
Channel Bed Surface Alluvium	☒	297
Channel Bed Sub-Surface Alluvium	☒	298
Bar Alluvium	☒	NA
Bars Overview	☒	NA
Islands Overview	☒	NA
Left Bank Alluvium	☒	300
Left Bank Toe Detail	☐	NA
Left Bank Top of Bank Detail	☐	NA
Left Bank Overview	☒	299
Left Floodplain Alluvium	☒	301
Left Floodplain Overview	☒	302 (looking upstream). 303 (looking downstream)
Left Floodplain Landforms	☒	hummocky terrain 304
Right Bank Alluvium	☒	~~300~~
Right Bank Toe Detail	☒	NA
Right Bank Top of Bank Detail	☒	NA
Right Bank Overview	☒	~~299~~
Right Floodplain Alluvium	☒	309
Right Floodplain Overview	☒	306 (looking downstream) 307 (looking upstream)
Right Floodplain Landforms	☐	hummocky terrain 308
Infrastructure	☐	Dam 305
Disturbance/Instability	☒	NA

PHOTO LOG		
Photo ID	View Direction	Description
311-312	upstream	view of channel 100' upstream of crossing (beyond pond)
313-314	downstream	view downstream from 311-312 panaramic

VALLEY CROSS-SECTION SKETCH

*notes -- valley cross-section derived from 30 / 10 meter USGS DEM



CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM

PLANVIEW MAP

*notes – image background date:

- lots of fines in the upper 2" of soils, more sand @ depth.
  site is within the annual inundation extent of the stock pond downstream

- minimal

- no

- any turbidity would fall out in reservoir downstream

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	**Stock Pond**	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression	0.93	--	--	--	17	93	204	461	753	1,176
No Gage Station Data Available										

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: 0.8

Width (ft)	min	max	mean	stnd dev
The lack of water in the channel made it hard to determine the channel width	11	19	17	3

meander wavelength (ft) 1030

meander amplitude (ft) 233

Sinuosity 1.24

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	1099	310	1797	358
	1788	413	2680	295
	2211	277	2977	246
	2726	558	3563	367

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 8.81

Valley

Gradient: 0.7

	min	max	mean	stnd dev
width	169	571	363	166

describe geology (lithology, erodibility):

Shale with several zones of calcareous concretions Thickness (984ft)

Floodplain

FEMA National Database N

if yes, describe widths below

Width (ft)	min	max	mean	stnd dev

Describe abundance and location(s) of:

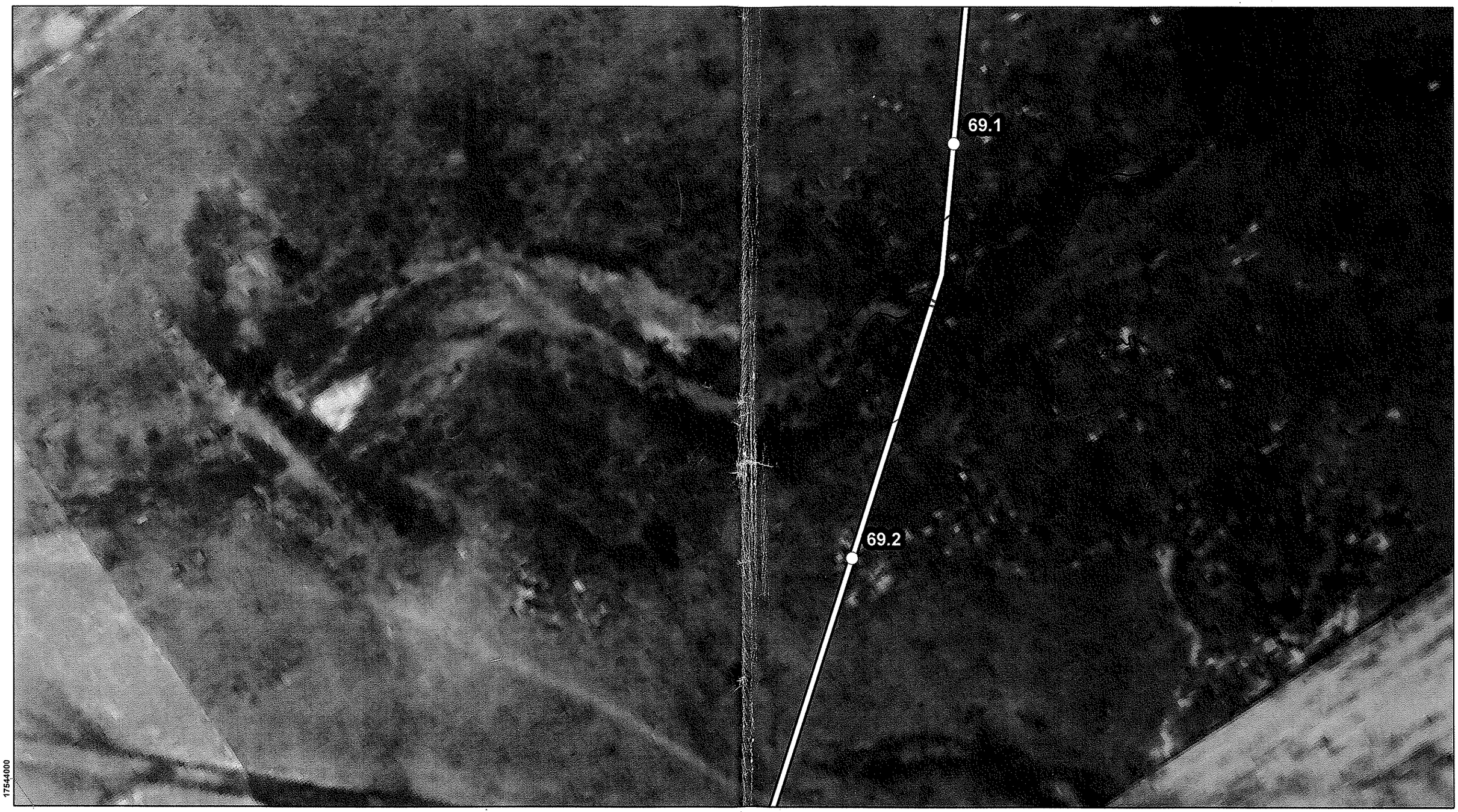
scroll bars: None

oxbows: None

channel cut-offs: None

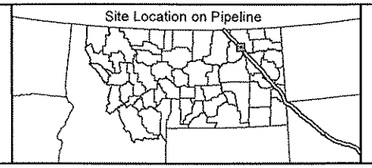
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
Not perched, the thalwag of the channel is below the elevation of the floodplain.
Unique features, exceptions, etc
The dam created downstream of the crossing could create backwater conditions near the crossing.

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
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.)
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.



- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Stock Pond - MILE POST 69.2
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
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Coordinate System: NAD 1983 UTM Zone 13 feet

0 50 100 200 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Spring Coulee MP 70.4			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/6/09
Flow Condition					

General Site Characteristics / Comments: wetland area - dense sedges + cattails in low flow channel - no flow at time of inspection - very stable swale / channel - see map for 8/6/09 re-route of pipeline x-ing

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/(N)) If Yes, enter Bed (subsurface)			
	D_{16}			
	D_{50}	Sedges + cattails		
	D_{84}			
	% sand	< 5		
	SOIL CLASS SYMBOL	PT, OL		
Bed (sub-surface)	D_{16}			
	D_{50}	w/ ~5% gravel + cobble		
	D_{84}			
	% sand	< 5		
	SOIL CLASS SYMBOL	PT, OL		
Bars	D_{16}			
	D_{50}	NA		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	< 5	% sand	< 5
	SOIL CLASS SYMBOL	ML, OL	SOIL CLASS SYMBOL	ML
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	< 5	% sand	< 5
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	ML

Comments: Natural Resources Conservation Service Map Unit 2 DS soil map 28 is Havre-Riverwash complex

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 2			Bank Height (ft) 1.5		
Bank Slope (°) 20 - 35			Bank Slope (°) 15-25		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species sedges			Dominant Species sedges		
Root Depth (ft) >1 Observed Y /(N)			Root Depth (ft) >1 Observed Y /(N)		
Undercutting (Y/(N)			Undercutting (Y/(N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y /(N)	Potential Y /(N)	Gradual Migration	Present Y /(N)	Potential Y /(N)
Slumping	Present Y /(N)	Potential Y /(N)	Slumping	Present Y /(N)	Potential Y /(N)
Landsliding	Present Y /(N)	Potential Y /(N)	Landsliding	Present Y /(N)	Potential Y /(N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes:			Notes:		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity ~1'' O horizon		Soil Maturity ~1" O horizon	
Natural Levees (Y/(N)		Natural Levees (Y/(N)	
Description:		Description	
Artificial Levees (Y/(N)		Artificial Levees (Y/(N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N)	Ephemeral (Y/(N)	Perennial (Y/(N)	Ephemeral (Y/(N)
Intermittent (Y/(N)	Relic/Abandoned (Y/(N)	Intermittent (Y/(N)	Relic/Abandoned (Y/(N)
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species Scattered large Sages		Dominant Woody Species scattered large Sages	
Crevasse Splays (Y/(N)		Crevasse Splays (Y/(N)	
Crevasse Channels (Y/(N)		Crevasse Channels (Y/(N)	
Notes:		Notes:	

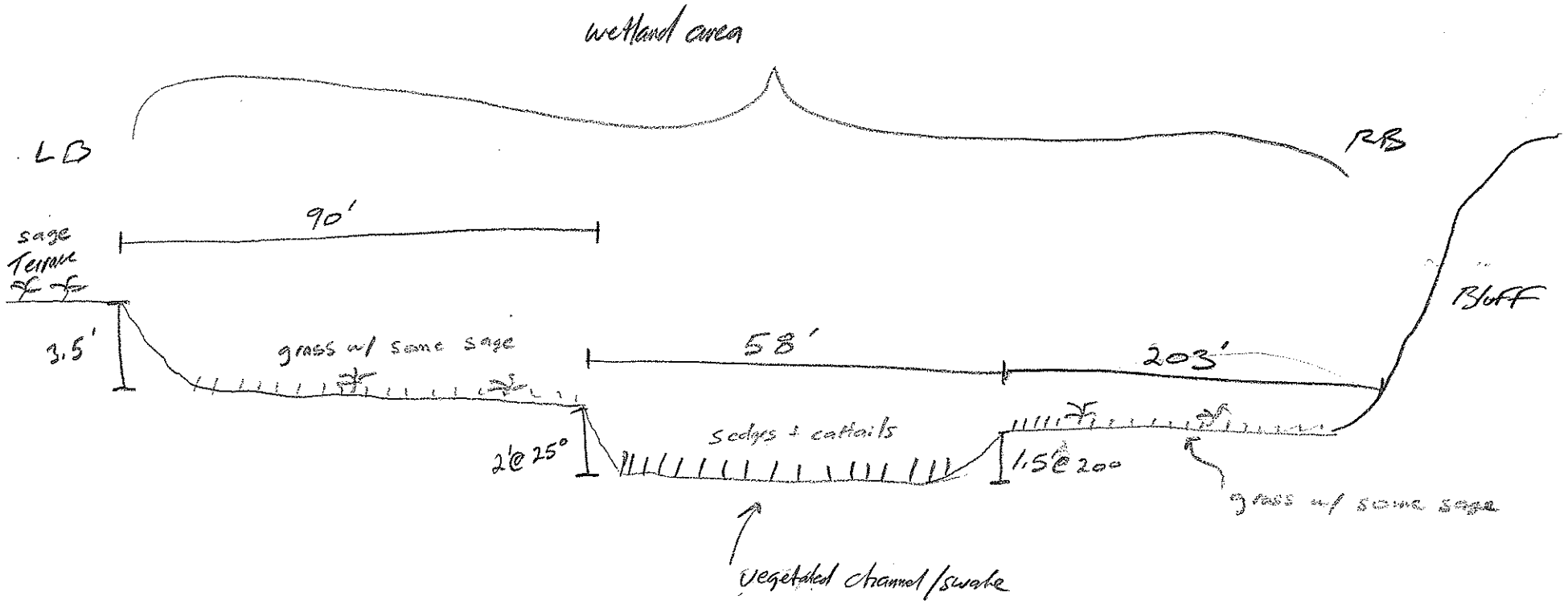
CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 58'	Bridges (Y/(N))
Bankfull Depth (ft) 2-3	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) topography	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) entire ch. vegetated w/	
sedges + cattails, bottom w ≈ 52'	Roads (Y/(N))
Incision Evidence NO	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence NO	
Bars (Y/(N))	
Vegetated Islands (Y/(N))	
Pool Depths (ft) NO pools - grassy swale	
Channel In Low Elevation of Valley Floor ((Y)/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS None	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

PHOTO CHECKLIST		
Site Overview	☒	looking U/S 383, 384, 385, 386, 387
Channel US Showing Both Banks	☒	388
Channel DS Showing Both Banks	☒	389
Channel Bed Surface Alluvium	☒	390
Channel Bed Sub-Surface Alluvium	☒	391
Bar Alluvium	☒	N/A
Bars Overview	☒	N/A
Islands Overview	☒	N/A
Left Bank Alluvium	☒	392
Left Bank Toe Detail	☒	393
Left Bank Top of Bank Detail	☒	394
Left Bank Overview	☒	395
Left Floodplain Alluvium	☒	396
Left Floodplain Overview	☒	397
Left Floodplain Landforms	☒	N/A
Right Bank Alluvium	☒	398
Right Bank Toe Detail	☒	399
Right Bank Top of Bank Detail	☒	400
Right Bank Overview	☒	401
Right Floodplain Alluvium	☒	402
Right Floodplain Overview	☒	403
Right Floodplain Landforms	☒	N/A
Infrastructure	☒	N/A
Disturbance/Instability	☒	N/A

PHOTO LOG		
Photo ID	View Direction	Description

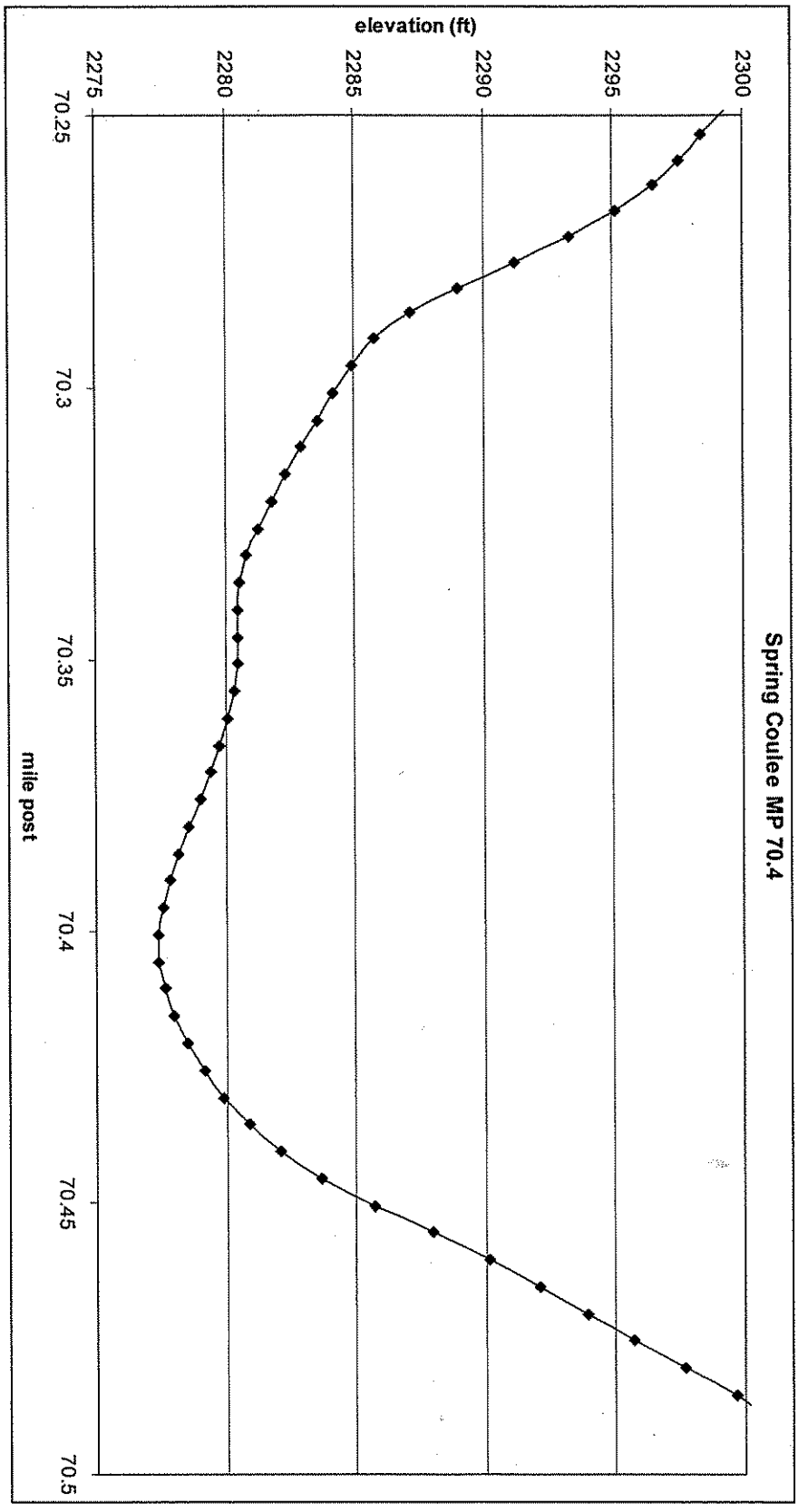
404 - Video



- recommend burying pipeline deep through entire wetland area
- low-flow channel very stable, migration unlikely

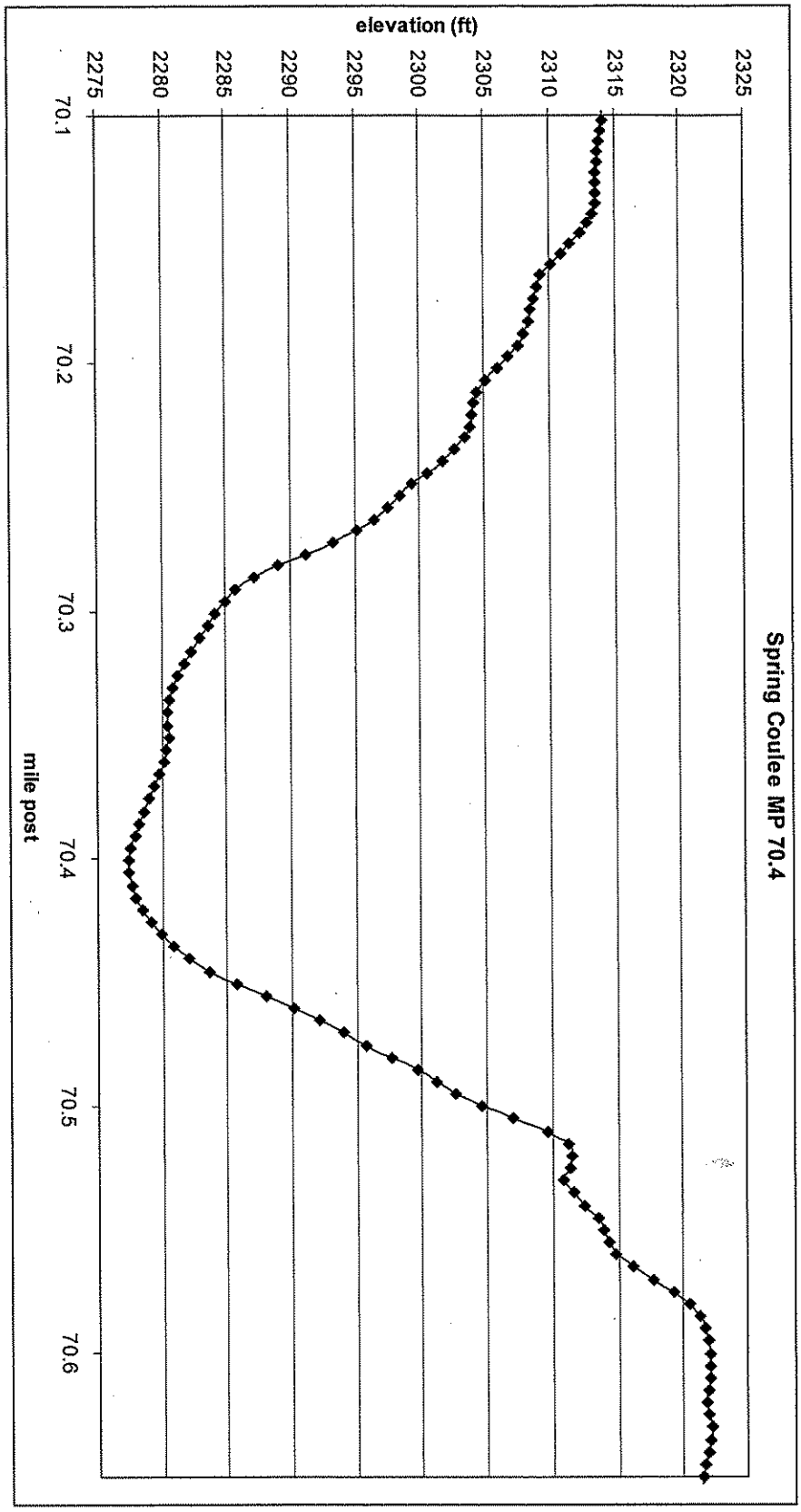
CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	**Spring Coulee**	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Regional Regression	18.2	--	--	--	124	594	1,208	2,516	3,948	5,909
No Gage Station Data Available										

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 0.6

Width (ft)	min	max	mean	stnd dev
	10	15	12	2

meander wavelength (ft) 468

meander amplitude (ft) 135

Sinuosity 1.43

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	278	186	203	93
	420	197	759	206
	1804	324	961	175
	2145	203	1132	215
			1410	444

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 28.52

Valley

Gradient: 1.0

width	Min	max	mean	stnd dev
	332	669	431	133

describe geology (lithology, erodibility):

Alluvium-Collovium

Shale with several zones of calcareous concretions Thickness (984ft)

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: None

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:
US 1. 4*Pits (0.00-0.20 mi, river right) 2. Scour hole (<0.10 mi river left) DS 1. relic channel (<0.10 mi river right)

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. Sand Quarry (0.75 mi river right) 2. Residence (0.10 mi river right) 3. Road (0.10 river right, par.) DS 1. Residence (0.15 mi river right)
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

Spring Coulee

Questions:

What is the likelihood the project will impact turbidity at the site?

low, if constructed in dry season

What is the potential impact on incision and erosion?

none

Will the project activate historical instability?

NO

What actions or alternatives can mitigate project effects?

extra sensitivity because of wetland soils + vegetation

Are there any cumulative effects of pipeline?

NO

General Notes:

17540000

17544000

70.1

70.2

70.3

70.4

70.5

70.6

70.7

1264000

17540000

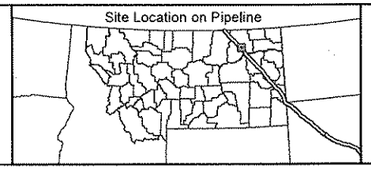
17544000

1264000

- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Spring Coulee - MILE POST 70.4
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 150 300 600 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	East Fork Cherry Creek MP 70.9			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/6/09
Flow Condition	NO flow - ponded water				

General Site Characteristics / Comments: low gradient, meandering channel with distinct mean pools separated by non-distinct gravy sample flow path - On RB - pipe would first cross Hawk Coulee, then it goes across CMZ until crossing E. Fork Cherry Ck. Confluence is <100' DS of pipeline. Note - re-rate of X-ing on 8/6/09 in field to ~75' US - See map

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	4		
	D_{50}	8		
	D_{84}	45		
	% sand	10		
	SOIL CLASS SYMBOL	GW		
Bed (sub - surface)	D_{16}	4		
	D_{50}	8		
	D_{84}	45		
	% sand	10		
	SOIL CLASS SYMBOL	GW		
Bars	D_{16}			
	D_{50}	NA		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	<2	% sand	50
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	GM
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	<2	% sand	<2
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	CL

Comments: Ustic Torri Fluvents soils

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	
	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 2.5			Bank Height (ft) 2.5		
Bank Slope (°) 20-90			Bank Slope (°) 20 to 90		
dominant ~ 20°			dominant ~ 20°		
Woody Cover (%) <5			Woody Cover (%) <5		
Dominant Species cottonwood			Dominant Species eastern cottonwood		
Root Depth (ft) 1	Observed (Y)/N		Root Depth (ft) 1	Observed (Y)/N	
Undercutting (Y/N) minor - not causing bank failure			Undercutting (Y/N) minor - not causing bank failure		
Bank Failure			Bank Failure		
Gradual Migration	Present Y /(N)	Potential (Y)/ N	Gradual Migration	Present Y /(N)	Potential (Y)/ N
Slumping	Present Y /(N)	Potential (Y)/ N	Slumping	Present Y /(N)	Potential (Y)/ N
Landsliding	Present Y /(N)	Potential Y (N)	Landsliding	Present Y /(N)	Potential Y /(N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: generally stable, vegetated banks			Notes: generally stable, vegetated banks		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity little		Soil Maturity little	
Natural Levees (Y/(N)		Natural Levees (Y/(N)	
Description:		Description	
Artificial Levees (Y/(N)		Artificial Levees (Y/(N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N)	Ephemeral (Y/(N)	Perennial (Y/(N)	Ephemeral (Y/(N)
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Woody Riparian Buffer Width (ft) <10' in some sections		Woody Riparian Buffer Width (ft) <10' in some sections	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species cottonwood		Dominant Woody Species eastern cottonwood	
Crevasse Splays (Y/(N)		Crevasse Splays (Y/(N)	
Crevasse Channels (Y/(N)		Crevasse Channels (Y/(N)	
Notes: Ch. change abruptly between deposited channel into open water (here you could take multiple pts)		Notes: ← see	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) varies 15-20'	Bridges (Y/N)
Bankfull Depth (ft) ~3' on average	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) topography	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) mostly all vegetated -	
bottom width ~10'	Roads (Y/N)
Incision Evidence NO	(RR, LB, US, DS)
	Other Infrastructure [illegible]
Aggradation Evidence NO	road crosses, and plugs, E. Fork
	Cherry Ck. Unpaved road - goes
Bars (Y/N)	across CM2
	E. Fork Cherry Ck. makes a bad
Vegetated Islands (Y/N) at high flow, water	right turn at road
could split around floodplain	- pipeline would follow 2-track
Pool Depths (ft) 2-5. variable	road
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS None - See Road description above	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

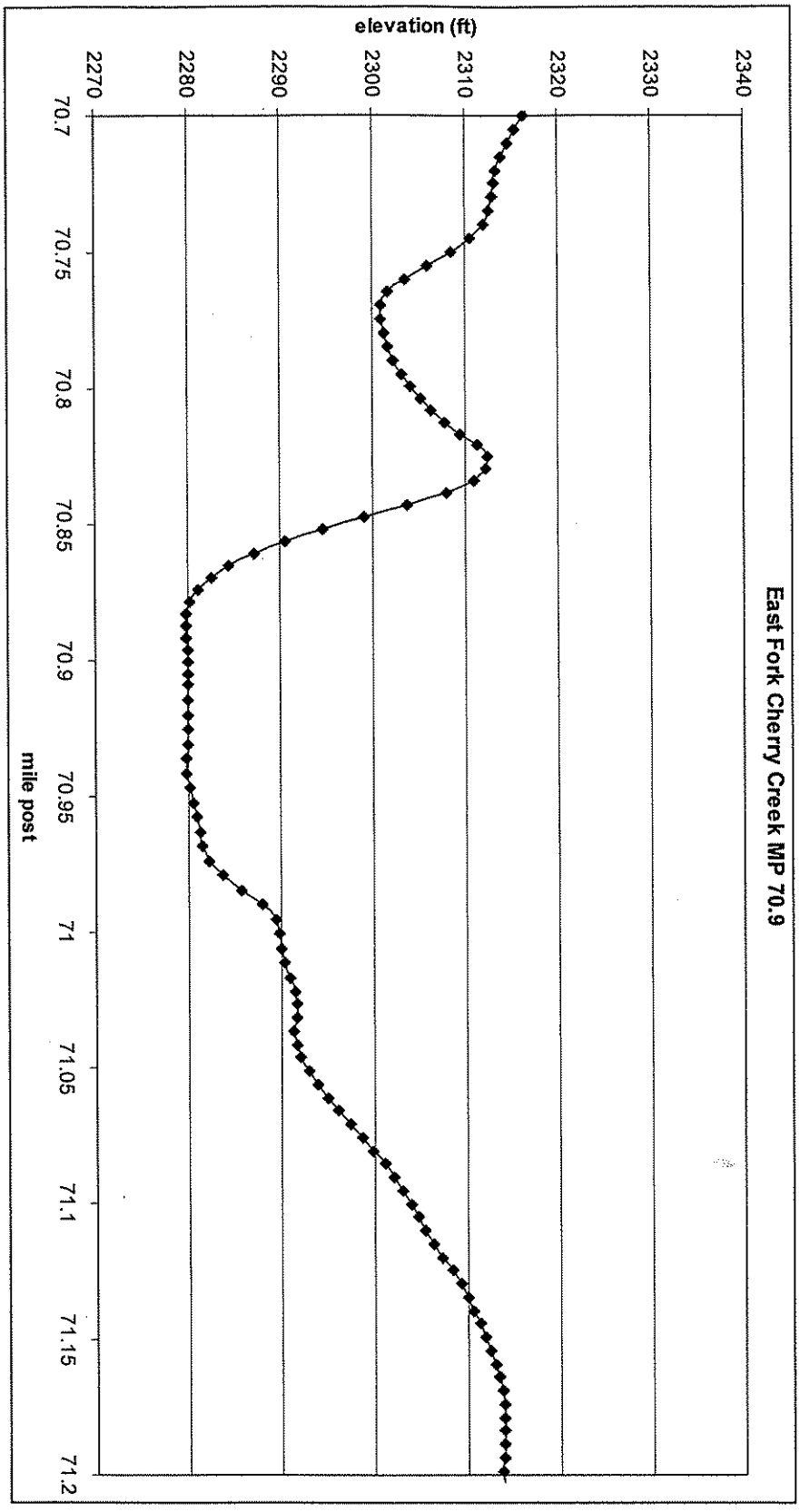
PHOTO CHECKLIST			
Site Overview	☐	N. looks U/S Hawk Coulee 356/Confluence of E. Fork & Hawk 357/S U/S E Fork 358	
Channel US Showing Both Banks	☒	359 Hawk Coulee	379 " "
Channel DS Showing Both Banks	☒	360 " "	378 E Fork
Channel Bed Surface Alluvium	☒	361 " "	
Channel Bed Sub-Surface Alluvium	☒	362 " "	
Bar Alluvium	☒	N/A	
Bars Overview	☒	N/A	
Islands Overview	☒	N/A	
Left Bank Alluvium	☒	363 " "	
Left Bank Toe Detail	☒	364 " "	
Left Bank Top of Bank Detail	☒	365 " "	
Left Bank Overview	☒	366 " "	
Left Floodplain Alluvium	☒	367 " "	
Left Floodplain Overview	☒	368 " "	
Left Floodplain Landforms	☒	N/A	
Right Bank Alluvium	☒	369 " "	
Right Bank Toe Detail	☒	370 " "	
Right Bank Top of Bank Detail	☒	371 " "	
Right Bank Overview	☒	372 " "	
Right Floodplain Alluvium	☒	373 " "	
Right Floodplain Overview	☒	374 " "	
Right Floodplain Landforms	☒	N/A	
Infrastructure	☒	N/A	
Disturbance/Instability	☒	N/A	

PHOTO LOG		
Photo ID	View Direction	Description
SE Pipeline Alignment		375
Site Overview looking	N	377
Road Crossing looking	D/S E Fork	380
U/S E Fork		381
D/S E Fork		382

Video - 376

VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

E. Fork Cherry Ck + Hawk Coulee

Questions:

What is the likelihood the project will impact turbidity at the site?

little - no flow

What is the potential impact on incision and erosion?

none

Will the project activate historical instability?

NO

What actions or alternatives can mitigate project effects?

bury pipe deep through entire CMZ

Are there any cumulative effects of pipeline?

NO

General Notes:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	East Fork Cherry Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing Regional Regression *	27.7	--	--	--	169	810	1,641	3,418	5,365	8,034
No Gage Station Data Available										

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

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: 0.3

Width (ft)	Min	max	mean	stnd dev.
	7	14	11	3

meander wavelength (ft) 549

meander amplitude (ft) 70

Sinuosity 1.26

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	739	218	197	310
	1042	270	141	98
	1374	144	1014	255
	1485	129	1358	183
	1694	234	1583	212
	1883	145		

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 32

Valley

Gradient: 0.3

width	min	max	mean	stnd dev.
	289	963	556	263

describe geology (lithology, erodibility):

Alluvium-colluvium of modern channels and floodplains

Shale with several zones of calcareous concretions Thickness (984ft)

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:

DS 1. Relic Channel (<0.10 mi, river left,)

US 1. Relic Channels (0.00-0.20 mi, river right and left, another trib. Confluence <0.10 mi US)

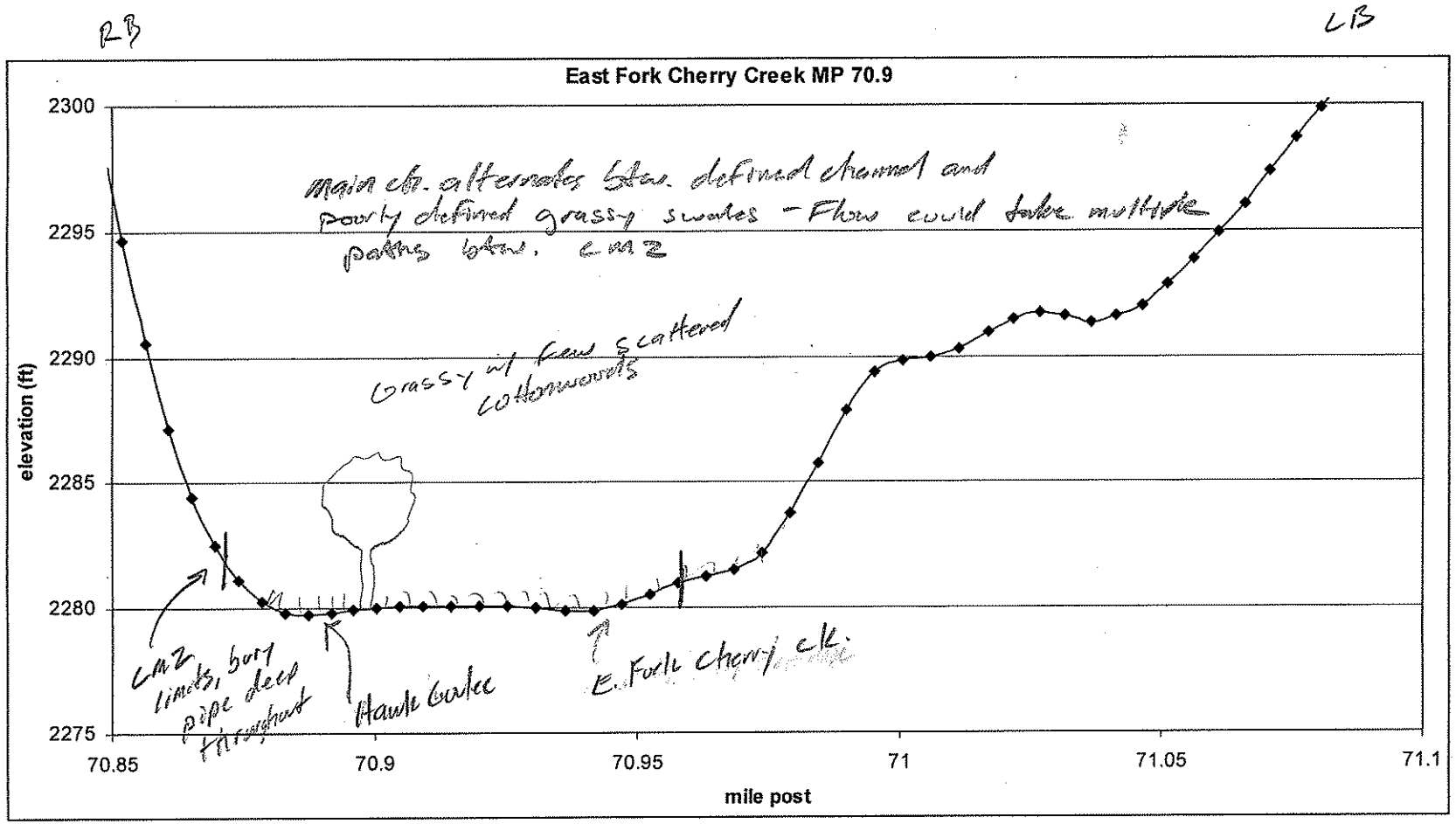
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
The elevation of the flood plain is greater than the elevation of the channel's water surface.
Unique features, exceptions, etc.
DS 1. Deep incision (0.15 mi, River right,)

Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
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.) DS 1. Road (<0.10 mi, river left, par.) 2. Residence (<0.10 mi, river left)
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.

CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM

* Note - pipeline re-route 8/6/09 - new X-ing US
This profile is the old alignment, but is used below to show CM2



LB

RB

1264000 17540000

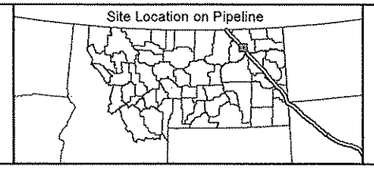
1264000

17540000

Perennial Stream Crossings
Intermittent Stream Crossings
Proposed Pipeline Route
1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

East Fork Cherry Creek- MILE POST 70.9
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 125 250 500 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

1264000

17540000

Bearpaw Shale

70.8

Alluvium-colluvium

70.9

Alluvium of modern channels and flood plains

71

E. Fork Cherry Creek

Bearpaw Shale

71.1

Bearpaw Shale

71.2

Alluvium-colluvium

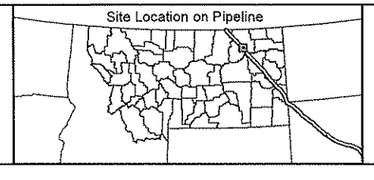
1264000

17540000

- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP
Geology: Montana Bureau of Mines & Geology

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

East Fork Cherry Creek- MILE POST 70.9
1:100,000 Geology

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Espeil Coulee MP 77.9			Surveyors	Ericsson
GPS	WP:	N:	E:	Date/Time	08/07/2009 10:45am
Flow Condition	Ponded / very low flow				
General Site Characteristics / Comments	Crossing is on slightly entrenched meandering stream with several areas of ponded water w/ cattails (meander bends). Saturated thalweg w/ rushes & sedges between ponded meanders. 25S wide valley that confines lateral migration potential				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}		Clay	
	D_{50}		Silt	
	D_{84}		1/4 mm	
	% sand		15	
	SOIL CLASS SYMBOL		OH	
Bed (sub-surface)	D_{16}			
	D_{50}		NA	
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}		NA	
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			

Banks	RIGHT BANK		LEFT BANK	
	D_{16}	clay	D_{16}	clay
	D_{50}	1/16 mm	D_{50}	silt
	D_{84}	3/4 mm	D_{84}	1/8 mm
	% sand	BNS HD	% sand	15
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	OH

Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	clay
	D_{50}	NA	D_{50}	silt
	D_{84}		D_{84}	1/10 mm
	% sand		% sand	5
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	OH

Comments: 1b - 1cm gravel @ 6"-8" depth

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 1.5'-2'			Bank Height (ft) 3'		
Bank Slope (°) 20			Bank Slope (°) 25		
Woody Cover (%) 5			Woody Cover (%) 0		
Dominant Species Salix			Dominant Species —		
Root Depth (ft) 2' Observed (Y)/N			Root Depth (ft) 2' Observed Y /(N)		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y /(N)	Potential (Y) N	Gradual Migration	Present Y /(N)	Potential Y /(N)
Slumping	Present Y /(N)	Potential Y /(N)	Slumping	Present Y /(N)	Potential Y /(N)
Landsliding	Present Y /(N)	Potential Y / (N)	Landsliding	Present Y /(N)	Potential Y /(N)
Other:	Present Y /(N)	Potential (Y)/(N)	Other:	Present Y /(N)	Potential Y /(N)
Notes: cattle movement laying back banks			Notes: up against valley wall		

RIGHT ~~LEFT~~ FLOODPLAIN PARAMETERS		LEFT ~~RIGHT~~ FLOODPLAIN PARAMETERS	
Soil Maturity		Soil Maturity moderate, organic surface 2"-3"	
Natural Levees (Y/N)		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/(N))	
Description: N/A		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft)		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H) 0	
Dominant Woody Species		Dominant Woody Species —	
Crevasse Splays (Y/N)		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/N)		Crevasse Channels (Y/(N))	
Notes:		Notes: low FP and high FP present	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 40'	Bridges (Y/N)
Bankfull Depth (ft) 3'-3.5'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) bank, veg	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 0	
	Roads (Y/N)
Incision Evidence —	(RR, LB, US, DS)
	Other Infrastructure —
Aggradation Evidence —	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) ~~~ 2'	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes: —

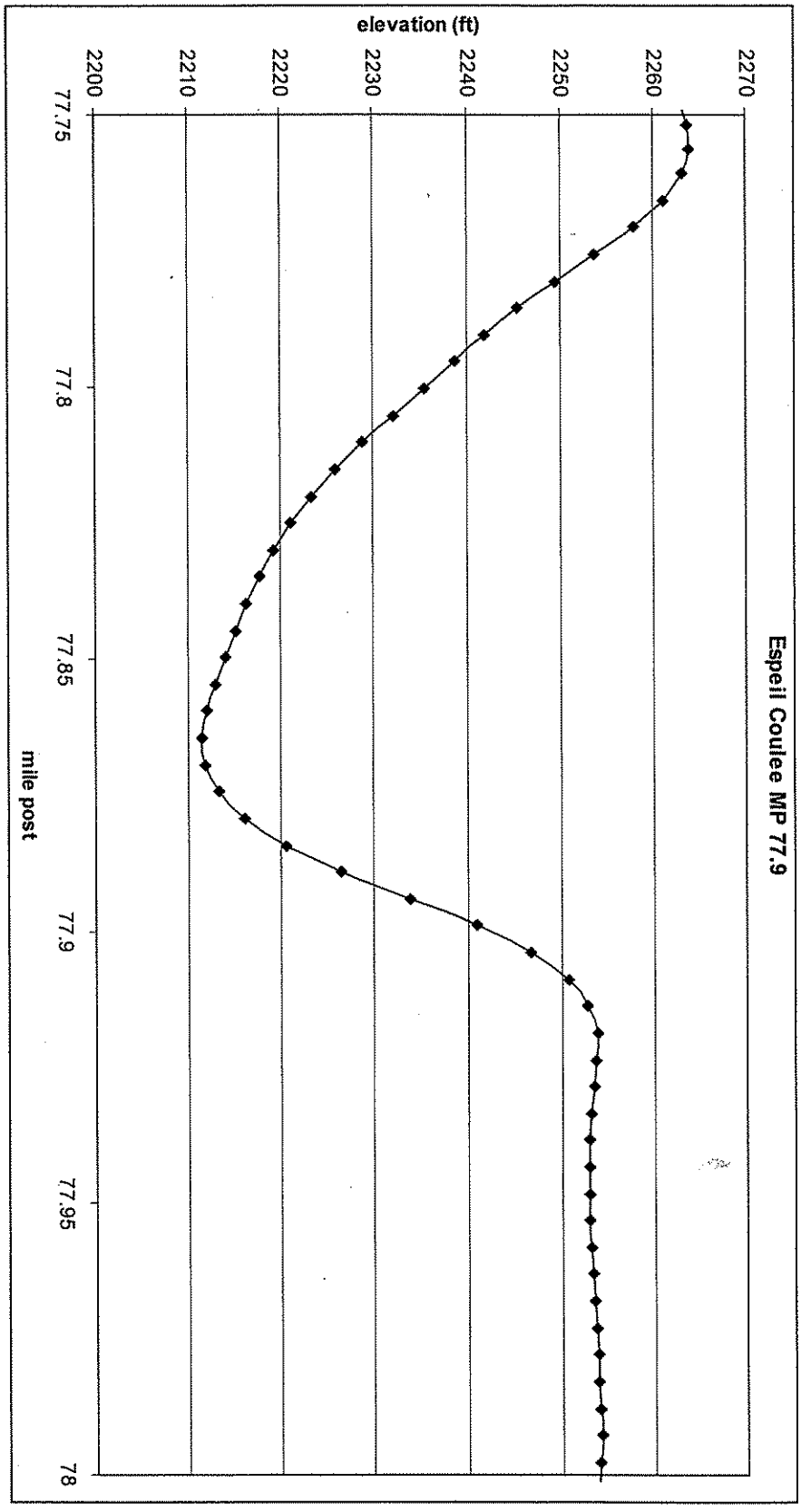
CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams NA	In-stream structures Culvert 18" approx.
	300'-400' downstream (river ~~ft~~)
Debris flow NA	
	Flow Diversion —
Landslides NA	
	Debris —
Woody debris NA	
Other: NA	Other: Cows have laid-back
	some banks

PHOTO CHECKLIST		
Site Overview	☒	331-334 panaramic starting us to ds.
Channel US Showing Both Banks	☒	324-325 panaramic
Channel DS Showing Both Banks	☒	~~324-325 panoramic~~ 330
Channel Bed Surface Alluvium	☒	315
Channel Bed Sub-Surface Alluvium	☐	NA
Bar Alluvium	☒	NA
Bars Overview	☒	NA
Islands Overview	☐	NA
Left Bank Alluvium	☒	316
Left Bank Toe Detail	☒	319
Left Bank Top of Bank Detail	☒	318
Left Bank Overview	☒	317 (looking upstream)
Left Floodplain Alluvium	☒	320
Left Floodplain Overview	☒	321 (low FP looking u.s.) 322 (low/high FP transition looking u.s.)
Left Floodplain Landforms	☒	NA 333 (high FP looking us)
Right Bank Alluvium	☒	326
Right Bank Toe Detail	☒	NA
Right Bank Top of Bank Detail	☒	329
Right Bank Overview	☒	327 328
Right Floodplain Alluvium	☒	NA
Right Floodplain Overview	☒	NA
Right Floodplain Landforms	☒	NA
Infrastructure	☐	
Disturbance/Instability	☐	

PHOTO LOG		
Photo ID	View Direction	Description

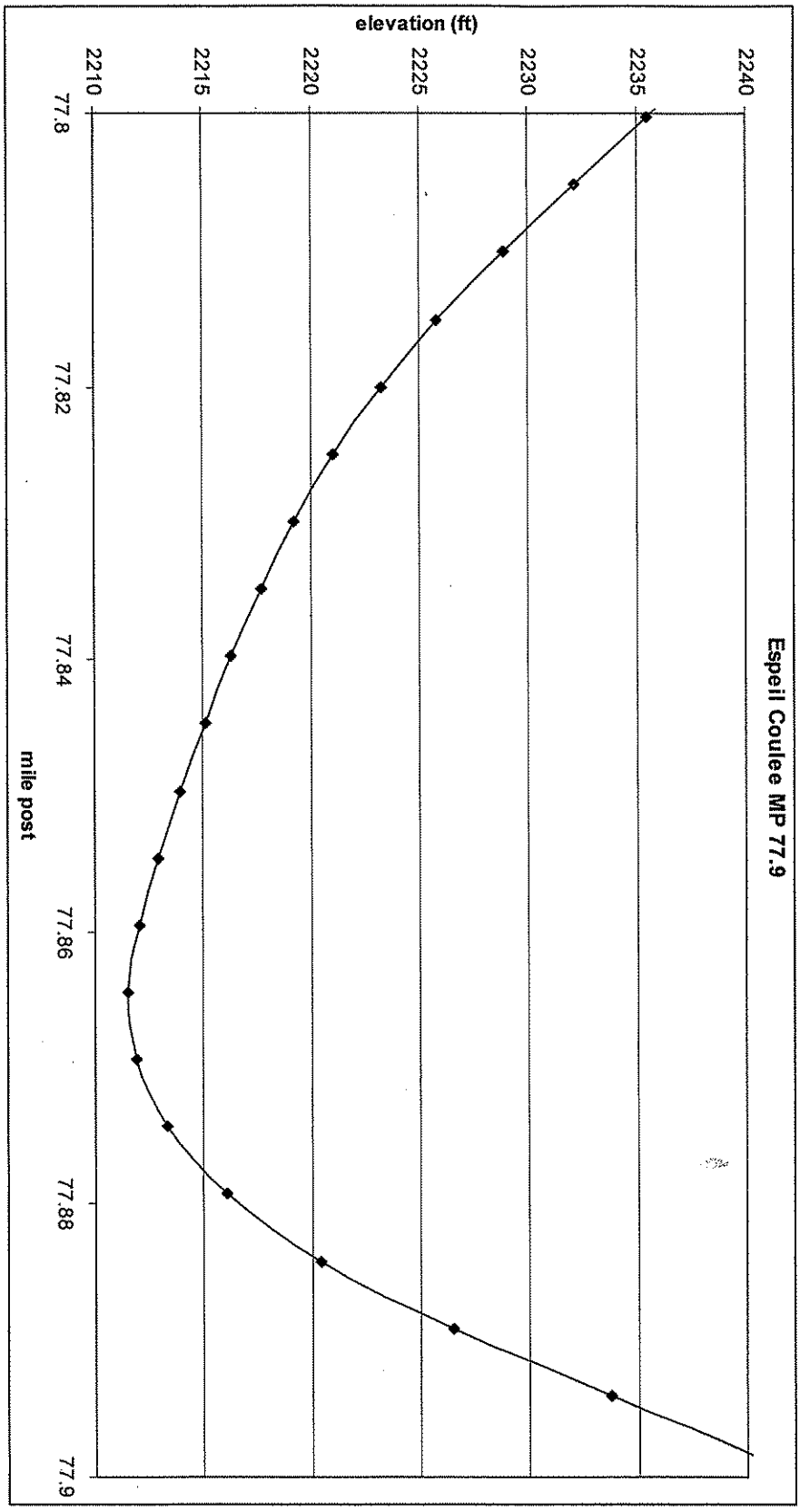
VALLEY CROSS-SECTION SKETCH

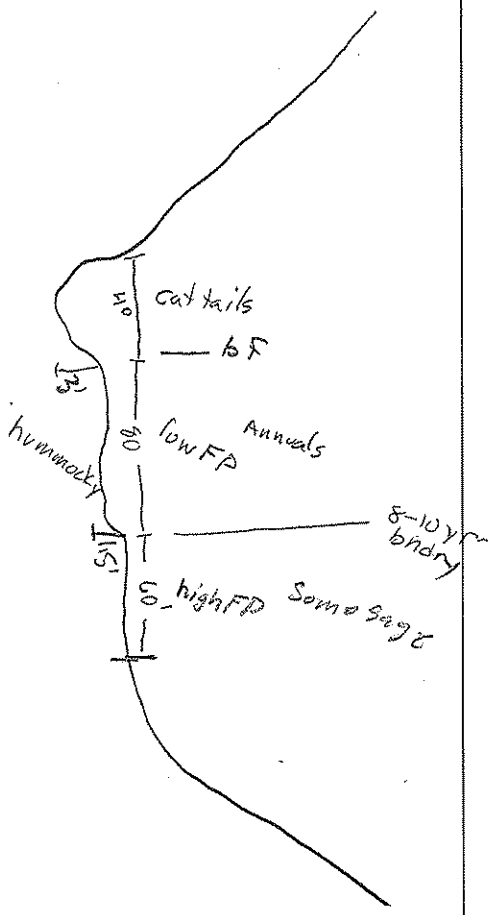
*notes – valley cross-section derived from 30 / 10 meter USGS DEM



CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM





PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	Espiel Coulee	Date	08/03/09
Done by: GF, EG	1st Review:	Final Review:	

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
Crossing Regional Regression	5.86	--	--	--	59	306	644	1,396	2,237	3,421
No Gage Station Data Available										

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: 0.0089

width	min	max	mean	stnd dev
	12	39	21	75

meander wavelength: 1033

meander amplitude: 541

Sinuosity: 1.62

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	135	370	35	232
	1713	128	155	111
	2957	382	319	49
	3729	606	572	81
	4457	86	820	482
	5909	249	1282	75

Channel form (braided, anabranching, single thread):

single

Channel confinement at crossing (W_v / W_c): 25.7

Valley

Gradient: 0.0053

width	min	max	mean	stnd dev
	344	820	579	172

describe geology (lithology, erodibility):

Alluvium,/colluvium

Bearpaw Fm: Shale with several zones of calcareous concretions, a basal zone of ferruginous concretions, and numerous thin bentonite beds. Thickness up to 984 ft

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:

0.3 mi DS

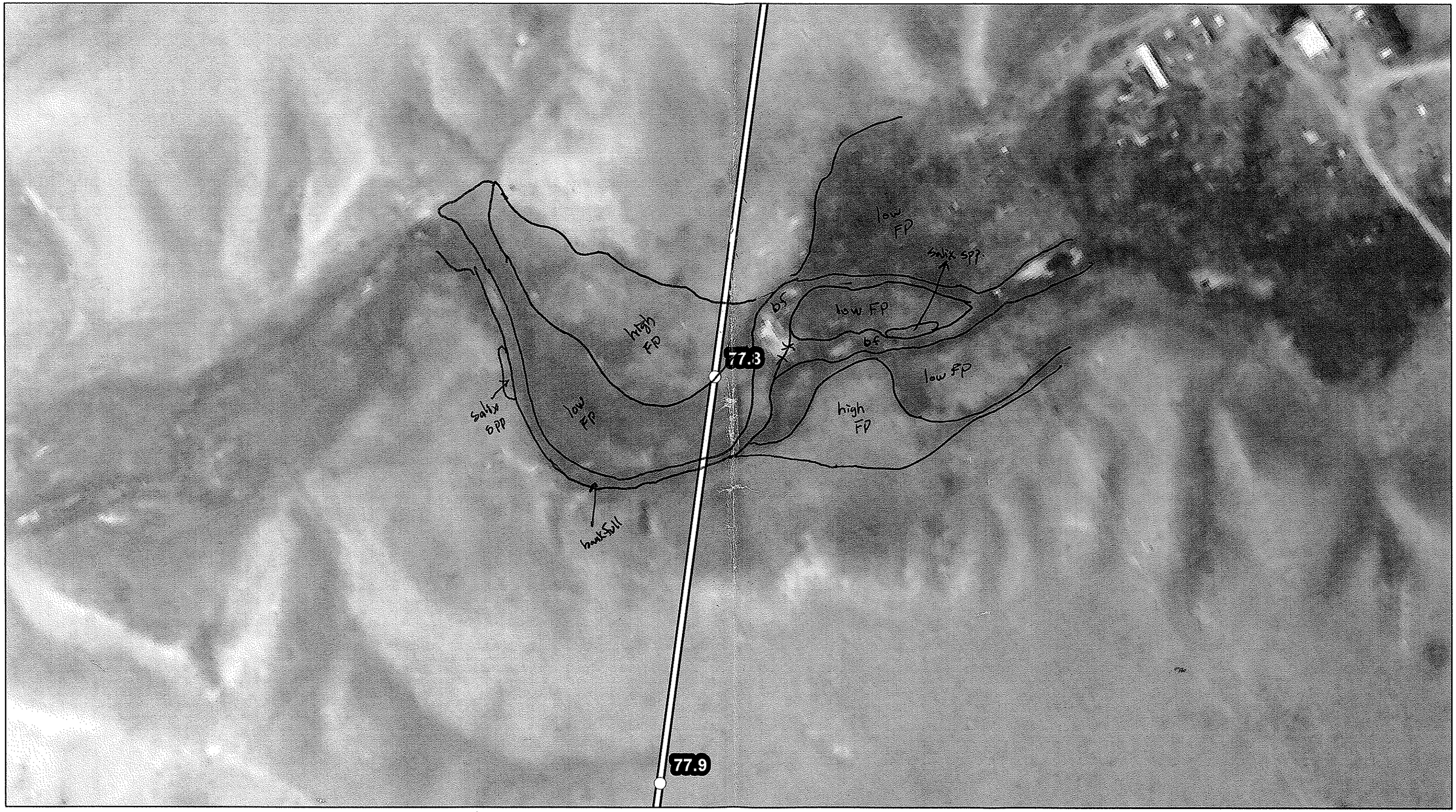
oxbows:

0.5 mi US on right bank, 0.4 mi US with stock pond

channel cut-offs:

None

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
Porcupine Creek is 2.4 miles from left bank at crossing but only 0.5 mi from pipeline route
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):
2 perpendicular roads cross .2 mi and 1.1 mi US of crossing, both have groups of buildings associated. Earthen dam 0.9 mi US near the buildings. A perpendicular road crosses at 1.5 mi DS, with 2 spur roads, one on either side. They run parallel, one on right bank for 0.5 mi, about 400 ft away from channel and on LB for 0.3 mi about 100 feet away. Both end in clusters of buildings, the right bank cluster is about 60 feet from creek. Major road 2.1 mi DS.
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None



Perennial Stream Crossings
Intermittent Stream Crossings
Proposed Pipeline Route
1/10 Mile Post
Aerial: 2005 NAIP

Site Location on Pipeline

KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Espeil Coulee - MILE POST 77.9
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
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Coordinate System: NAD 1983 UTM Zone 13 feet

0 50 100 200 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	North Fork Coal Bank Creek MP 276.1			Surveyors	Ericsson
GPS	WP:	N:	E:	Date/Time	8/10/09 10:45AM
Flow Condition	2 cfs				
General Site Characteristics / Comments	meandering single thread channel with wide bankfull channel and alternating floodplains (inside of meander), steep clay rich thalweg banks 3' high				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}			
	D_{50}			
	D_{84}		clay rich	
	% sand		< 10% sand	
	SOIL CLASS SYMBOL			
Bed (sub-surface)	D_{16}			
	D_{50}			
	D_{84}		NA	
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}			
	D_{84}		NA	
	% sand			
	SOIL CLASS SYMBOL			

		RIGHT BANK		LEFT BANK	
Banks	D_{16}		D_{16}	silt	
	D_{50}		D_{50}	1/5 mm	
	D_{84}		D_{84}	1 mm	
	% sand		% sand	90	
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	SP	

		RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
Flood-plain	D_{16}		D_{16}	~~1mm~~ silt	
	D_{50}		D_{50}	1/8 mm	
	D_{84}		D_{84}	~~1mm~~ 1 mm	
	% sand		% sand	92	
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	SP	

Comments: left bank bankfull channel SP is CH very clay rich

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 5'			Bank Height (ft) 4'		
Bank Slope (°) 50-55'			Bank Slope (°) 45°-50°		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species –			Dominant Species –		
Root Depth (ft) 1.5 Observed Y / N			Root Depth (ft) 1.5 Observed Y / N		
Undercutting (Y/N)			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / N	Potential Y / N	Gradual Migration	Present Y / N	Potential Y / N
Slumping	Present Y / N	Potential Y / N	Slumping	Present Y / N	Potential Y / N
Landsliding	Present Y / N	Potential Y / N	Landsliding	Present Y / N	Potential Y / N
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes:			Notes:		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity Young		Soil Maturity Young	
Natural Levees (Y/N)		Natural Levees (Y/N)	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H) –		Woody Riparian Plant Density (L,M,H) –	
Dominant Woody Species –		Dominant Woody Species –	
Crevasse Splays (Y/N)		Crevasse Splays (Y/N)	
Crevasse Channels (Y/N)		Crevasse Channels (Y/N)	
Notes: inside of meander immediately us of crossing		Notes: inside of meander immediately ds of meander	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 40-50'	Bridges (Y/N)
Bankfull Depth (ft) 4'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) bankL /veg	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 3'	
	Roads (Y/N) two-track
Incision Evidence NA	(RR) LB, US (DS)
	Other Infrastructure
Aggradation Evidence NA	
Bars (Y/N) inside of meanders	
Vegetated Islands (Y/N)	
Pool Depths (ft) 2'	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams —	In-stream structures —
Debris flow —	
	Flow Diversion —
Landslides —	
	Debris —
Woody debris —	
Other: —	Other: road on right bank floodplain which crosses the creek immediately ds of crossing

PHOTO CHECKLIST		
Site Overview	☒	35-37
Channel US Showing Both Banks	☒	~~45-46~~ (pan) 46-47
Channel DS Showing Both Banks	☒	~~43-44~~ (pan) 45-44
Channel Bed Surface Alluvium	☐	
Channel Bed Sub-Surface Alluvium	☐	
Bar Alluvium	☒	~~same as #3 Alluvium~~ NA
Bars Overview	☒	NA
Islands Overview	☒	NA
Left Bank Alluvium	☒	43
Left Bank Toe Detail	☐	—
Left Bank Top of Bank Detail	☐	—
Left Bank Overview	☒	41 (us) 42 (ds)
Left Floodplain Alluvium	☒	40
Left Floodplain Overview	☒	39
Left Floodplain Landforms	☒	NA
Right Bank Alluvium	☐	
Right Bank Toe Detail	☐	
Right Bank Top of Bank Detail	☐	
Right Bank Overview	☐	
Right Floodplain Alluvium	☐	
Right Floodplain Overview	☒	36
Right Floodplain Landforms	☐	
Infrastructure	☒	NA
Disturbance/Instability	☒	NA

PHOTO LOG		
Photo ID	View Direction	Description

Questions:

What is the likelihood the project will impact turbidity at the site?

unlikely (clay/fine rich bankfull channel) very turbid water present

What is the potential impact on incision and erosion?

NA

Will the project activate historical instability?

NO

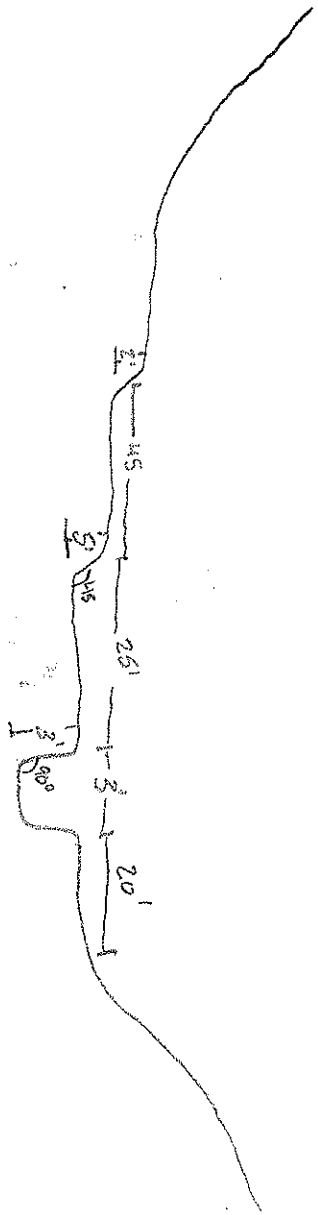
What actions or alternatives can mitigate project effects?

restore clay rich banks

Are there any cumulative effects of pipeline?

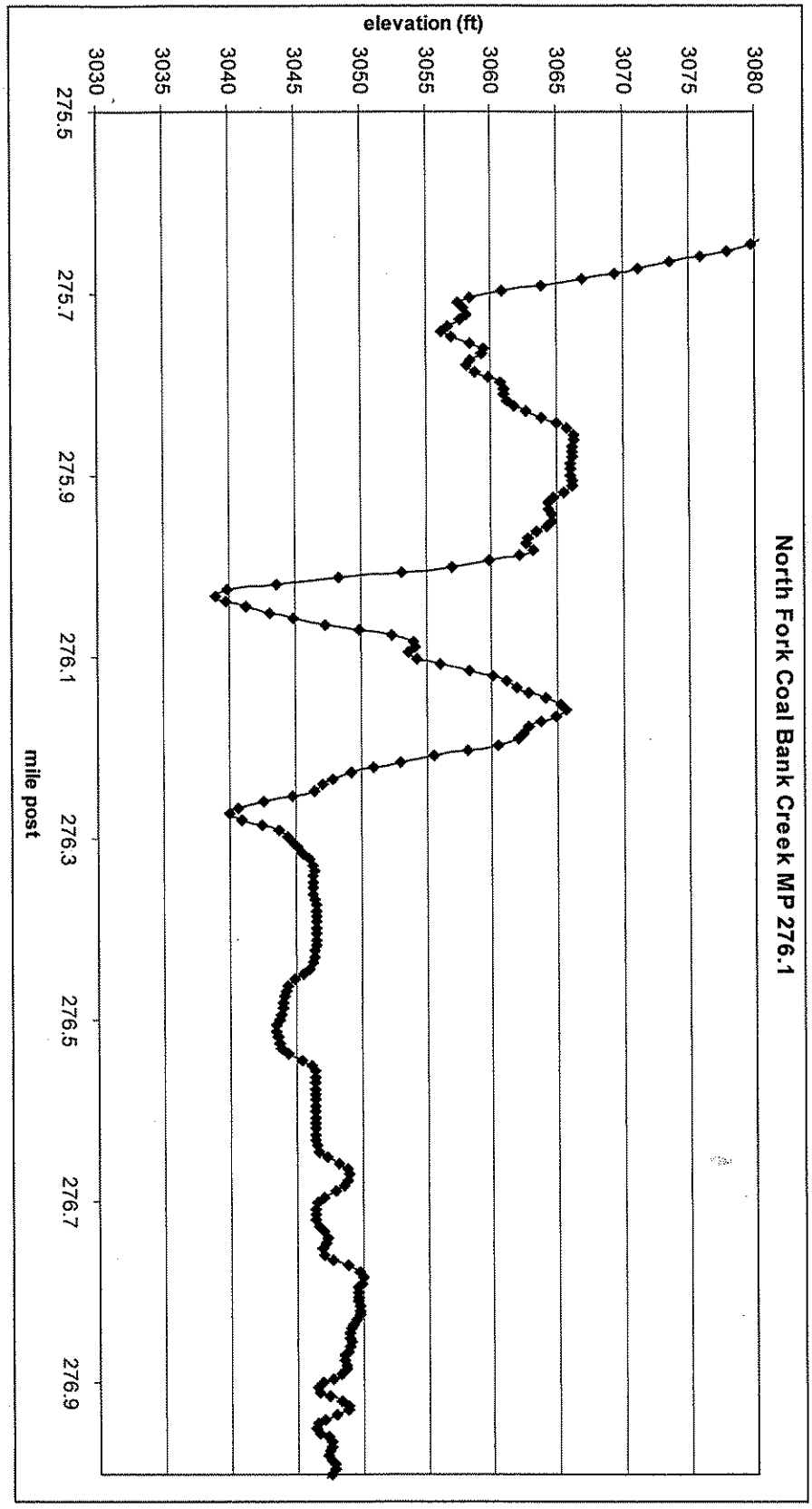
No woody riparian buffer

General Notes:



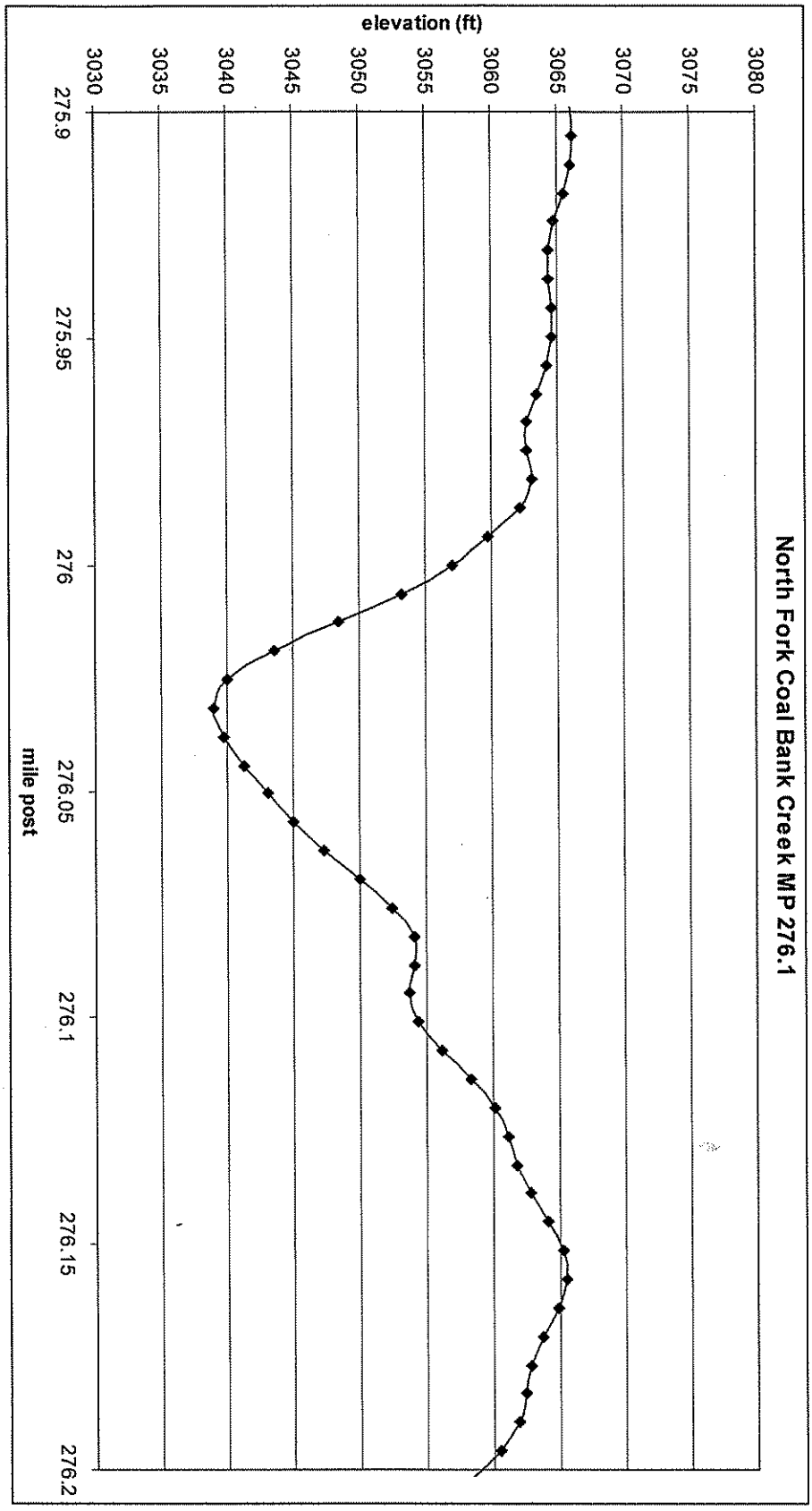
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	North Fork Coal Bank Creek	Date	08/03/09
Done by: GF, G	1st Review:	Final Review:	

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
Crossing: Regional Regression	8.97	--	--	--	1,972	4,722	6,990	10,776	13,436	19,011
No Gage Station Data Available										

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: 0.0025

width	min	max	mean	stnd dev
	6	27	11	48

meander wavelength: 1185

meander amplitude: 507

Sinuosity: 1.98

Valley

Gradient: 0.0069

width	min	max	mean	stnd dev
	377	1620	1005	390

describe geology (lithology, erodibility):

Alluvium of modern channels and floodplains

Ludlow member of the Fort Union Fm: Gray and brown shale, siltstone, silty or bentonitic claystone, sandstone and coal. Thickness to 755 ft.

Ekalaka member of the Fort Union Fm: Fi ne- to medium-grained sandstone interbedded with mudstone and thin shale and coal beds. Thickness to 180 ft.

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	591	132	103	62
	1874	156	1135	87
	2825	92	1915	102
	3847	60	2978	87
	4710	46	3573	51
	5193	49		
	6503	56		

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

possibly 1575 ft US on left bank

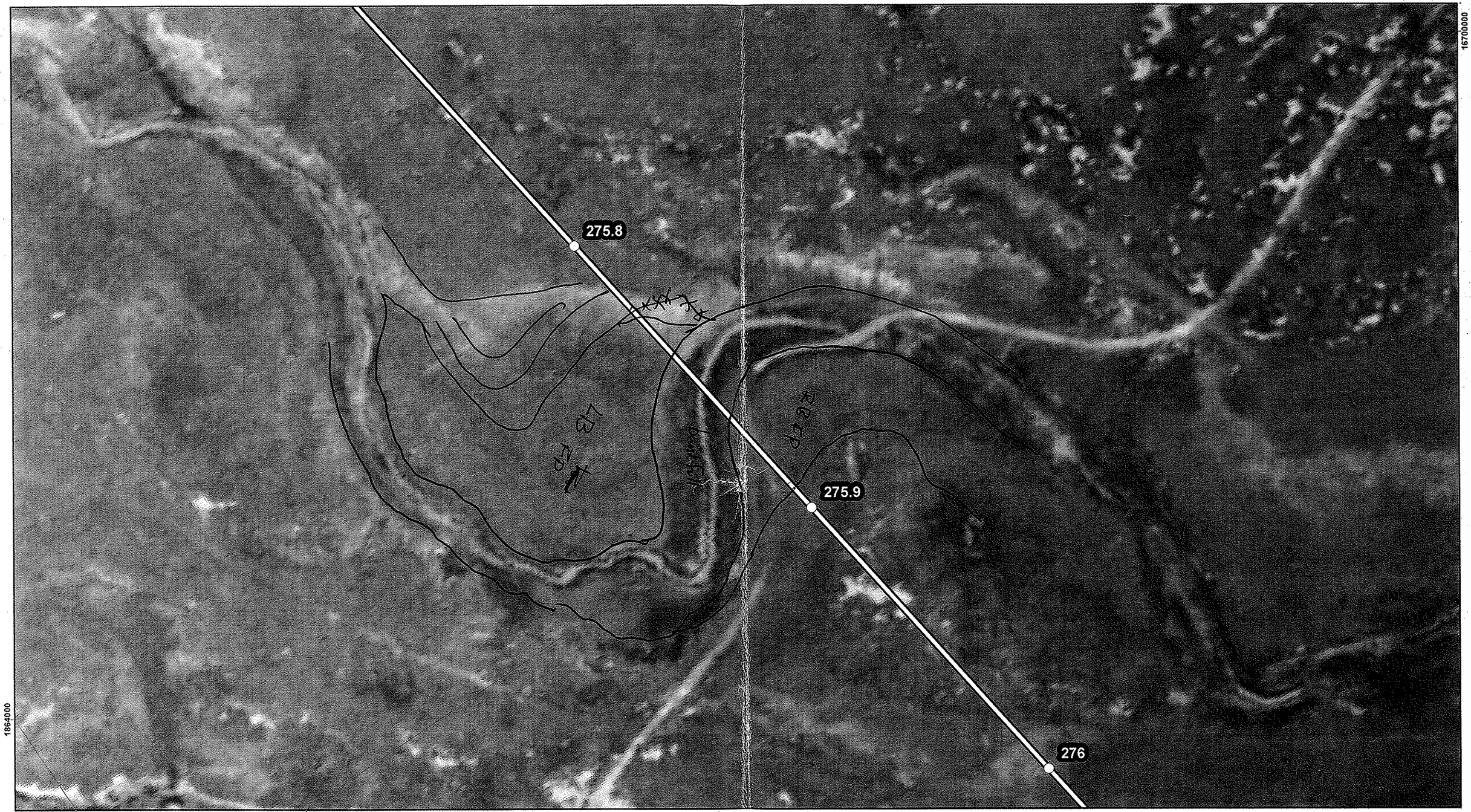
oxbows:

1443 feet DS; 400 feet US (at first meander); 2025 ft US (0.44 mi), 3450 ft US (0.66 mi)

channel cut-offs:

potential at 1733 feet DS

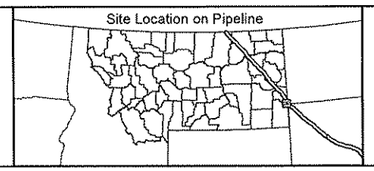
Channel form (braided, anabranching, single thread):	
Single	
Channel confinement at crossing (W_v / W_c): 79.68 .	
What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?	
Channel is 3039-3065 ft in elev and valley is 3042-3077 ft; but at 330 ft to 1130 ft (0.2 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; another unnamed creek that feeds into NF Coal has a watering pond 0.25 mi from left bank, 0.75 mi US of 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):	
A road crosses stream 235 ft DS of crossing, mostly runs perpendicular except for 250 ft US on right bank and 400 feet DS on left bank; group of buildings on this 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	



- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

North Fork Coal Bank Creek
MILE POST 276.1 - 2005 NAIP Aerial

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Seattle, WA 98119
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Coordinate System: NAD 1983 UTM Zone 13 feet

0 50 100 200 Feet

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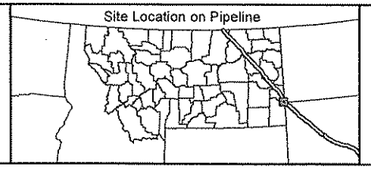
File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

- Intermittent Stream Crossings
- Perennial Stream Crossings
- SteeleCitySegmentMP
- Proposed Pipeline Route

Aerials: USGS EarthExplorer
http://edcsns17.cr.usgs.gov/EarthExplorer/

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

North Fork Coal Bank Creek
MILE POST 276.1 - 1972 Historic Aerial

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	South Fork Coal Bank Creek MP 279.2			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/8/09
Flow Condition	Very little Flow < 0.1 cfs				

General Site Characteristics / Comments

low gradient, highly sinuous, grass lined channel, gravelly sand bed
dense vegetated banks + F.P.
- stable banks
* see pipeline re-route drawn on planview map 8/18/08 to avoid trib. + steep hill

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/(N)) If Yes, enter Bed (subsurface)			
	D_{16} gravelly sand	VFS		
	D_{50}	FS to CS		
	D_{84}	16		
	% sand	60		
	SOIL CLASS SYMBOL	SP		
Bed (sub-surface)	D_{16}	same as SFC		
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}	N/A		
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK same →		LEFT BANK	
	D_{16}		D_{16}	silty sand
	D_{50}		D_{50}	VFS
	D_{84}		D_{84}	
	% sand		% sand	>50
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	SM
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}	same →	D_{16}	silty sand
	D_{50}		D_{50}	VFS
	D_{84}		D_{84}	
	% sand		% sand	>80
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	SM

Comments: Busby, gullied - Delphaf - Yamdin complex loam

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 1.5			Bank Height (ft) 1.5 - 2		
Bank Slope (°) 70 - 90			Bank Slope (°) 60 - 90		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species grass			Dominant Species grass		
Root Depth (ft) 1 - 2 Observed (Y) N			Root Depth (ft) 1 - 2 Observed (Y) N		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y /(N)	Potential (Y) N	Gradual Migration	Present Y /(N)	Potential (Y) N
Slumping	Present (Y) / N	Potential (Y) N	Slumping	Present (Y) N	Potential (Y) / N
Landsliding	Present Y /(N)	Potential Y /(N)	Landsliding	Present Y /(N)	Potential Y /(N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: landsliding @ steep outer bends US + DS reach, but not at site - minor slumping, stabilizing bank type no evidence of rapid channel migration very few unvegetated banks			Notes: ← see		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity little		Soil Maturity little	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species		Dominant Woody Species	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes:		Notes:	

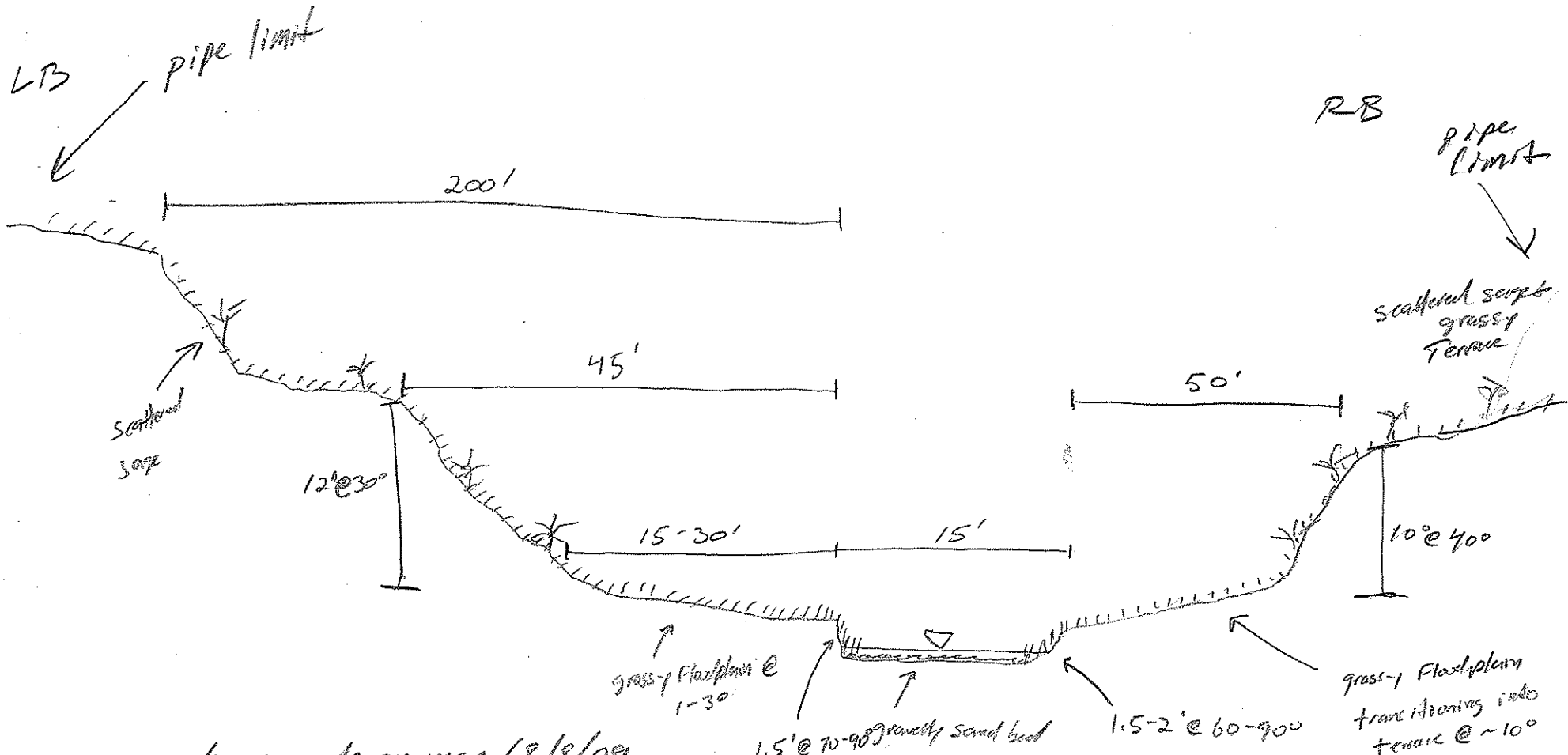
CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 15	Bridges (Y/(N))
Bankfull Depth (ft) 2.5	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) Floodplain topo	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 13	
	Roads (Y/(N))
Incision Evidence NO	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence NO	
Bars (Y/(N))	
Vegetated Islands (Y/(N))	
Pool Depths (ft) ~2' not observed	
Channel In Low Elevation of Valley Floor ((Y)/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS None - Some evidence of light cattle traffic	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

PHOTO CHECKLIST		
Site Overview	☒	89-95 US to DS
Channel US Showing Both Banks	☒	69-71
Channel DS Showing Both Banks	☒	72-74
Channel Bed Surface Alluvium	☒	75
Channel Bed Sub-Surface Alluvium	☒	75
Bar Alluvium	☒	NA
Bars Overview	☒	NA
Islands Overview	☒	NA
Left Bank Alluvium	☒	76
Left Bank Toe Detail	☒	77
Left Bank Top of Bank Detail	☒	78
Left Bank Overview	☒	79
Left Floodplain Alluvium	☒	66
Left Floodplain Overview	☒	67 DS view
Left Floodplain Landforms	☒	68 LB terrace risers
Right Bank Alluvium	☒	(same as 76
Right Bank Toe Detail	☒	80
Right Bank Top of Bank Detail	☒	81
Right Bank Overview	☒	82
Right Floodplain Alluvium	☒	same as 66
Right Floodplain Overview	☒	83-86 US to DS
Right Floodplain Landforms	☒	87 Terrace riser
Infrastructure	☒	NA
Disturbance/Instability	☒	NA

PHOTO LOG		
Photo ID	View Direction	Description

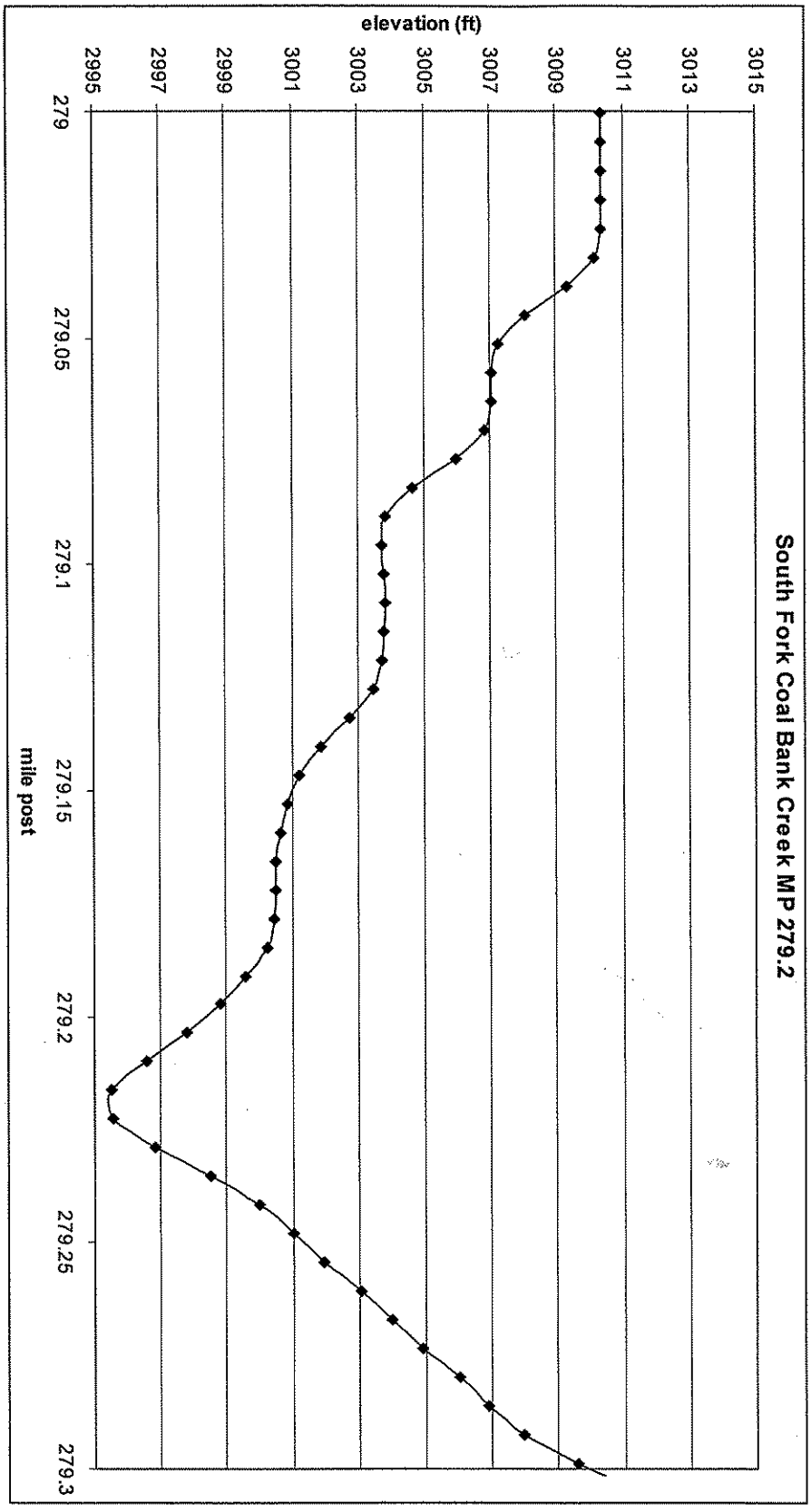
Video overview 88



- see pipeline re-route on map 18/8/09
- dense grass banks + floodplain - very stable

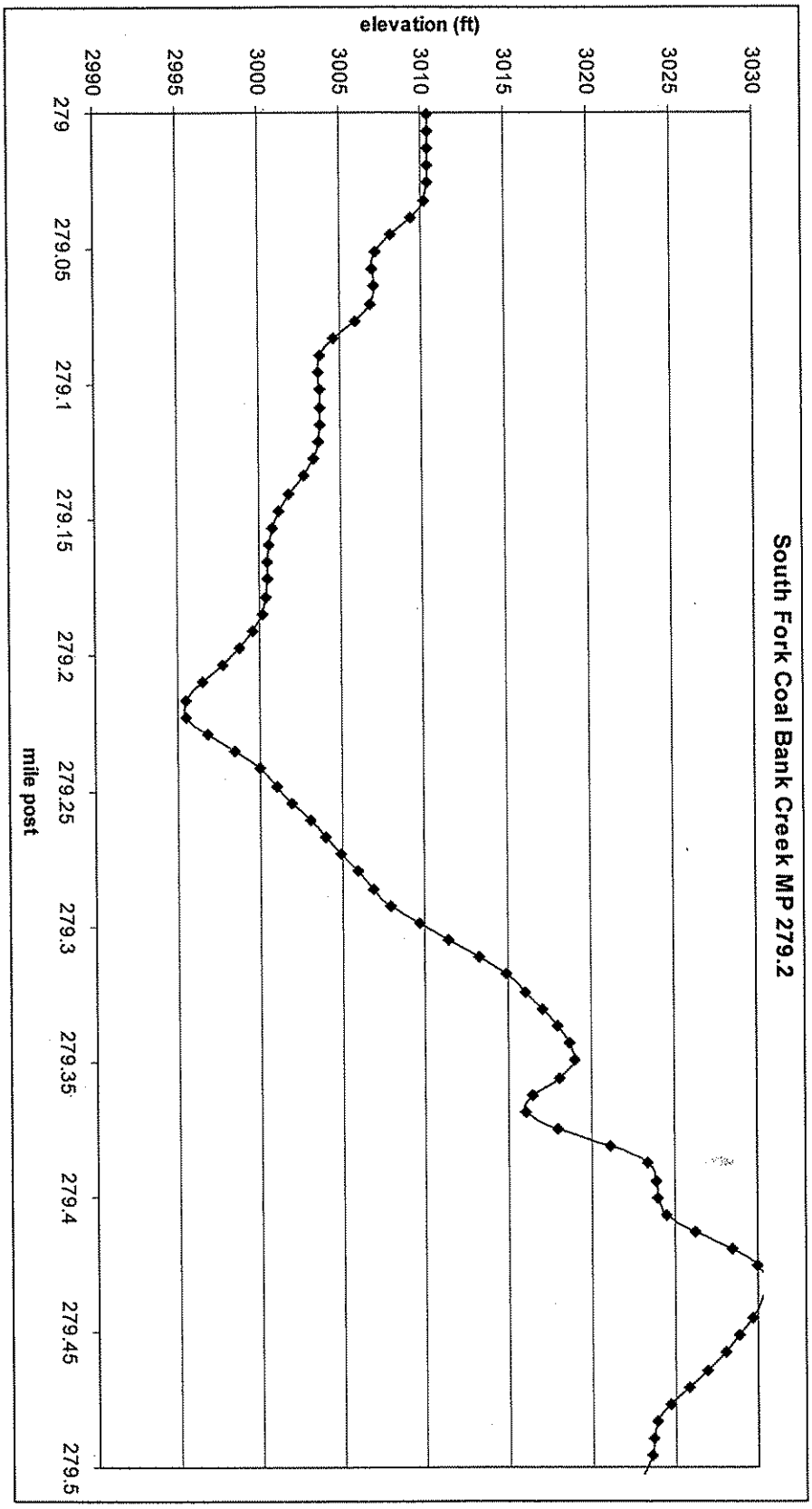
CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	South Fork Coal Bank Creek	Date	07/27/09
Done by: GF, EG	1st Review:	Final Review:	

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
Crossing: Regional Regression	13.80	–	–	–	2,463	5,850	8,627	13,249	16,455	23,277
No Gage Station Data Available										

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)

Check office forms for consistency between o/o and ft/ft →

Channel

Gradient: 0.0038

width	min	max	mean	stnd dev
	10	39	18	10

meander wavelength (ft): 453

meander amplitude (ft): 406

Sinuosity: 2.1

Valley

Gradient: 0.00019

width	min	max	mean	stnd dev
	230	1086	554	309

describe geology (lithology, erodibility):

Alluvium of modern channels and floodplains

Ludlow member of the Fort Union Fm:

Gray and brown shale, siltstone, silty or bentonitic claystone, sandstone and coal. Thickness to 755 ft.

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	564	33	46	49
	787	41	597	49
	1168	90	1253	69
	1879	46	2188	59
	2545	33	2549	49
	2988	56	3559	167

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:

1 set adjacent; 1 set US 365 ft

oxbows:

US at 1157ft; S at 724 ft, 1163, and 1962 ft

channel cut-offs:

US at 475 ft; DS at 2030 ft

Channel form (braided, anabranching, single thread):

Single

Channel confinement at crossing (W_v / W_c): 106.8

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
Stream elev. is 2972-2997 feet while valley is about 3004-3005 ft. 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
Possibly some incision further downstream, about 2000 feet from crossing, based on DEM.
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 crosses stream at 2,120 ft, then runs parallel US; a perpendicular road crosses at 3,010 ft US of crossing.
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

16688000

16688000

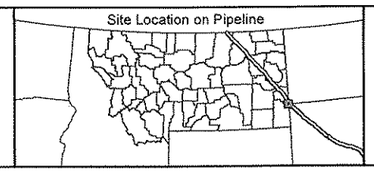
279

279.1

- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

South Fork Coal Bank Creek
MILE POST 279.2 - 2005 NAIP Aerial

ENTRIX

200 1st Ave W Ste 500
Seattle, WA 98119

ph (206) 269-0104
fx (206) 269-0098

www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

N W E S

0 50 100 200 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

1876000

1872000

279.4

279.3

279.2

279.1

279

278.9

8/8/09 Pipeline re-route

Flow

16688000

16688000

1876000

1872000

Perennial Stream Crossings

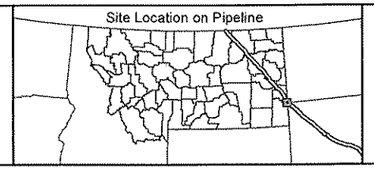
Intermittent Stream Crossings

Proposed Pipeline Route

1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

South Fork Coal Bank Creek
MILE POST 279.2 - 2005 NAIP Aerial

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Coordinate System: NAD 1983 UTM Zone 13 feet

S E W N

0 150 300 600 Feet

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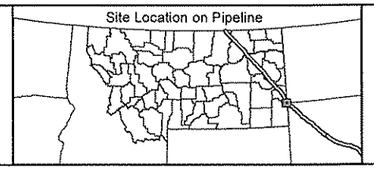
File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

- Intermittent Stream Crossings
- Perennial Stream Crossings
- SteeleCitySegmentMP
- Proposed Pipeline Route

Aerials: USGS EarthExplorer
http://edcsns17.cr.usgs.gov/EarthExplorer/

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

South Fork Coal Bank Creek
MILE POST 279.2 - 1972 Historic Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Hay Coulee MP 38			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/5/09
Flow Condition	No Flow, dry, likely only flows Spring runoff				
General Site Characteristics / Comments					
Boulder bed coulee in till plains - very stable, little potential for migration or scour					

ALLUVIUM / SUBSTRATE

	Armored (Y/N) If Yes, enter Bed (subsurface)			
Bed (surface)	D_{16}			
	D_{50} small to medium boulders w/ cobble			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bed (sub-surface)	D_{16}			
	D_{50} same as sfc			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50} NA			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}	same as ~~D50~~ - till deposits		
	D_{84}		D_{84}	
	% sand		% sand	
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}	NA	D_{50}	
	D_{84}		D_{84}	
	% sand		% sand	
	SOIL CLASS SYMBOL		SOIL CLASS SYMBOL	

Comments: Boulder & cobble till deposits
Soils mapped as clay loam in till plains

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 70'-100			Bank Height (ft) 70 – 100'		
Bank Slope (°) 10 – 30			Bank Slope (°) 10 – 30		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species grasses			Dominant Species grasses		
Root Depth (ft) ~1-2 Observed Y /(N)			Root Depth (ft) ~1-2 Observed Y /(N)		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y /(N)	Potential Y /(N)	Gradual Migration	Present Y /(N)	Potential Y /(N)
Slumping	Present Y /(N)	Potential Y /(N)	Slumping	Present Y /(N)	Potential Y / N
Landsliding	Present Y /(N)	Potential Y /(N)	Landsliding	Present Y /(N)	Potential Y /(N)
Other:	Present Y /(N)	Potential Y /(N)	Other:	Present Y /(N)	Potential Y /(N)
Notes: Coarse grained, stable banks			Notes: Coarse grained, stable banks		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity No floodplain		Soil Maturity No floodplain	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels NA		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species		Dominant Woody Species	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes:		Notes:	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 42	Bridges (Y/N)
Bankfull Depth (ft) 8-15	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) Slight break in topo	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 0	
	Roads (Y/N)
Incision Evidence None	(RR, LB, US, DS)
	Other Infrastructure None
Aggradation Evidence None	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) No pools	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS None	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

PHOTO CHECKLIST		
Site Overview	☒	175 D/S, 176 RB, 177 U/S, 178 LB
Channel US Showing Both Banks	☒	179, 180
Channel DS Showing Both Banks	☒	181, 182
Channel Bed Surface Alluvium	☒	183, 184
Channel Bed Sub-Surface Alluvium	☒	185
Bar Alluvium	☒	N/A
Bars Overview	☒	N/A
Islands Overview	☒	N/A
Left Bank Alluvium	☒	186, 194
Left Bank Toe Detail	☒	187
Left Bank Top of Bank Detail	☒	188
Left Bank Overview	☒	189
Left Floodplain Alluvium	☒	N/A
Left Floodplain Overview	☒	N/A
Left Floodplain Landforms	☒	N/A
Right Bank Alluvium	☒	190, 194
Right Bank Toe Detail	☒	191
Right Bank Top of Bank Detail	☒	192
Right Bank Overview	☒	193
Right Floodplain Alluvium	☒	N/A
Right Floodplain Overview	☒	N/A
Right Floodplain Landforms	☒	N/A
Infrastructure	☒	N/A
Disturbance/Instability	☒	N/A

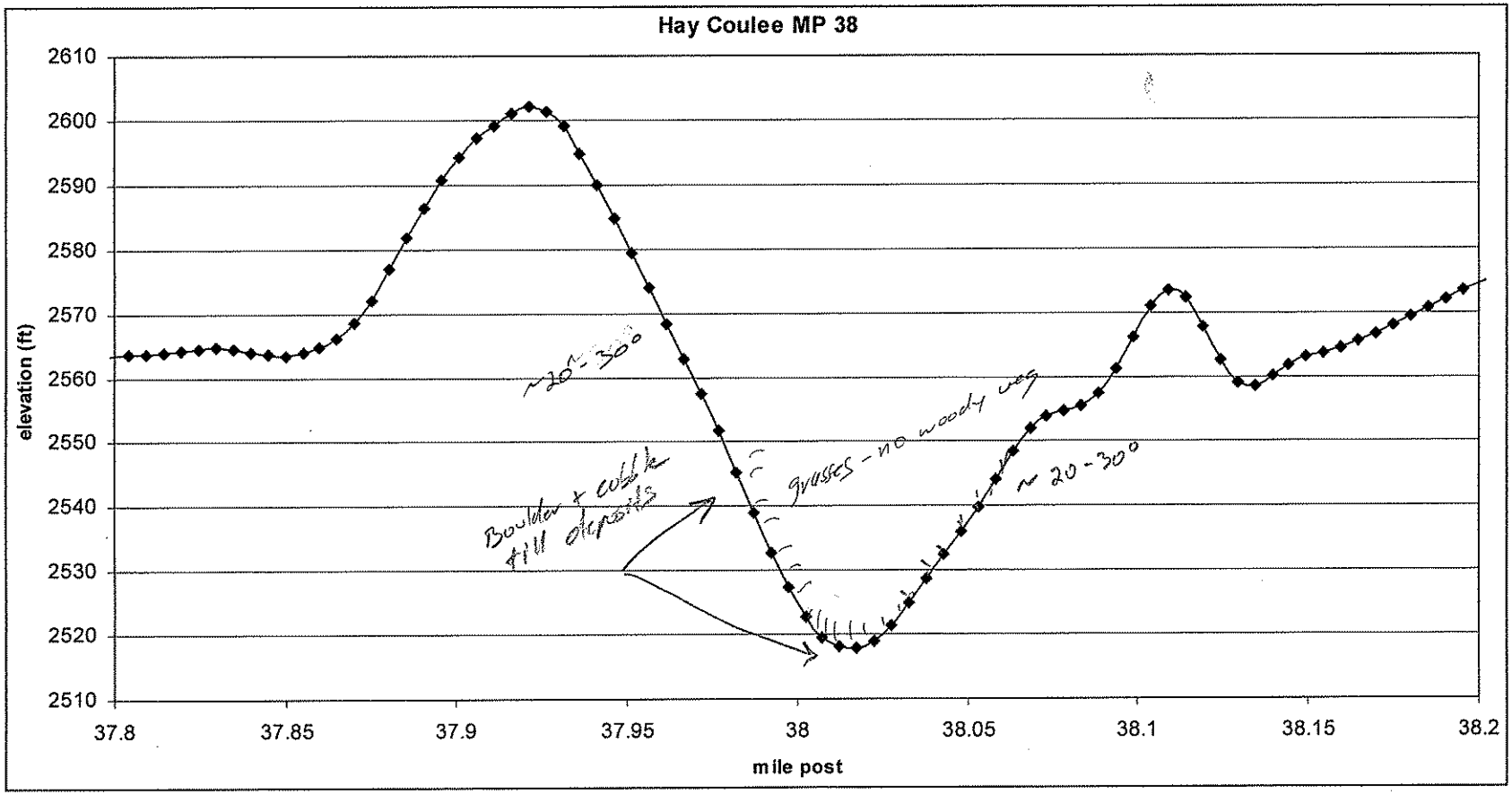
PHOTO LOG		
Photo ID	View Direction	Description
196	DS	overview from LB hillslope
197	RD	overview " "
198	US	" "

195 Video - Site Overview from channel
196 Video - " " from LB hillslope

VALLEY CROSS-SECTION SKETCH

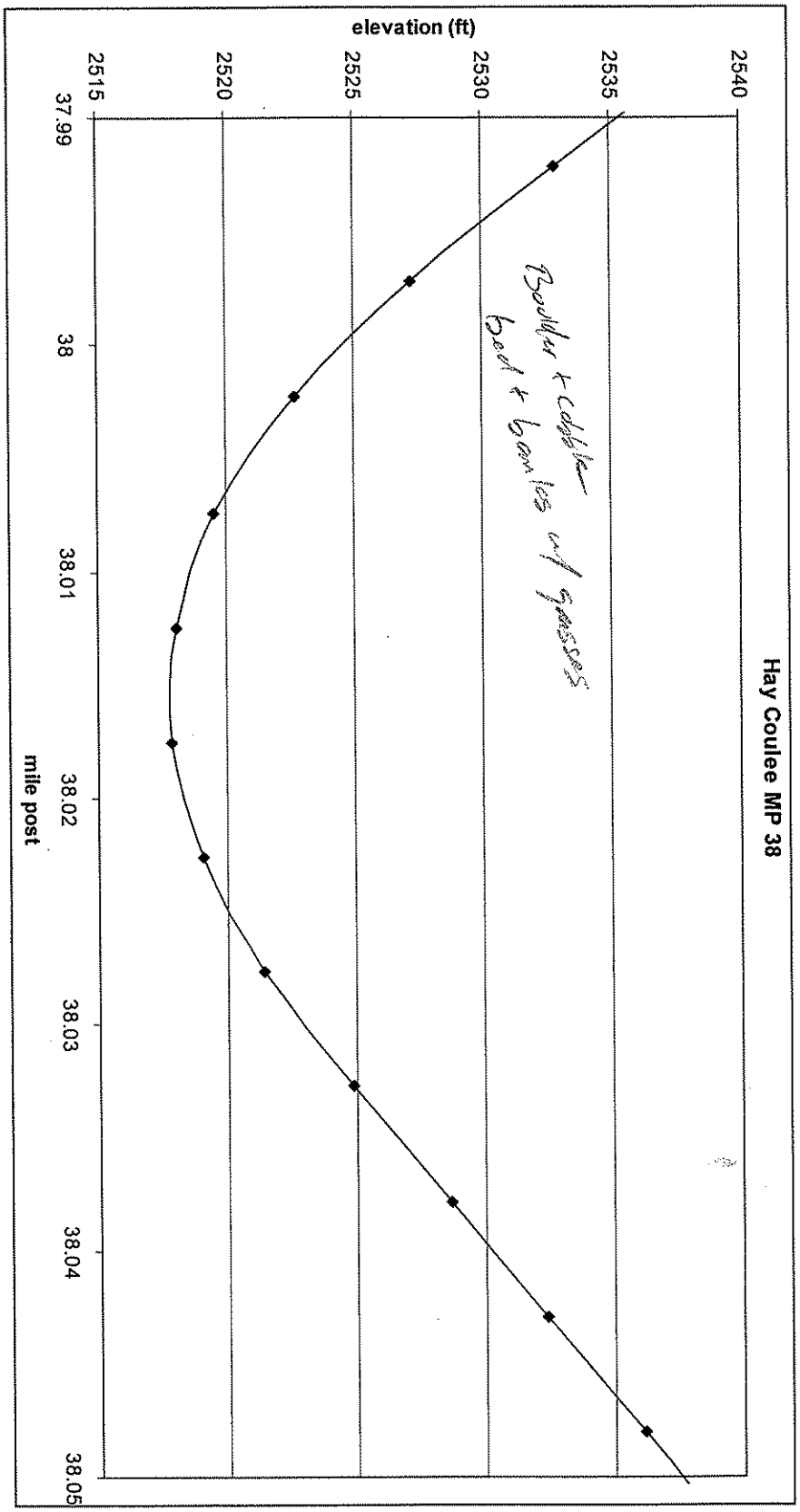
*notes -- valley cross-section derived from 30 / 10 meter USGS DEM

little to no scour or migration potential



CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

Hay Coulee

Questions:

What is the likelihood the project will impact turbidity at the site? None - no flow during construction

What is the potential impact on incision and erosion? none

Will the project activate historical instability? no

What actions or alternatives can mitigate project effects? NA

Are there any cumulative effects of pipeline? None known

General Notes: very stable intermittent drainage

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	Hay Coulee	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing Regional Regression	1.68	--	--	--	24	125	267	582	935	1,431
No Gage Station Data Available										

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: 1.6

Width (ft)	min	max	mean	stnd dev
	14	22	17	3

meander wavelength (ft) 954

meander amplitude (ft)135

Sinuosity 1.30

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	377	338	413	315
	751	247	647	279
	1502	397	1045	239
	2073	443	1265	220

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 7.29

Valley

Gradient: 2.1

width	min	max	mean	stnd dev
	526	240	331	114

describe geology (lithology, erodibility):

Alluvium from modern channels and flood plains.

likely till instead of alluvium

Sandstone with interbeds of shale. Thickness 1000ft.

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

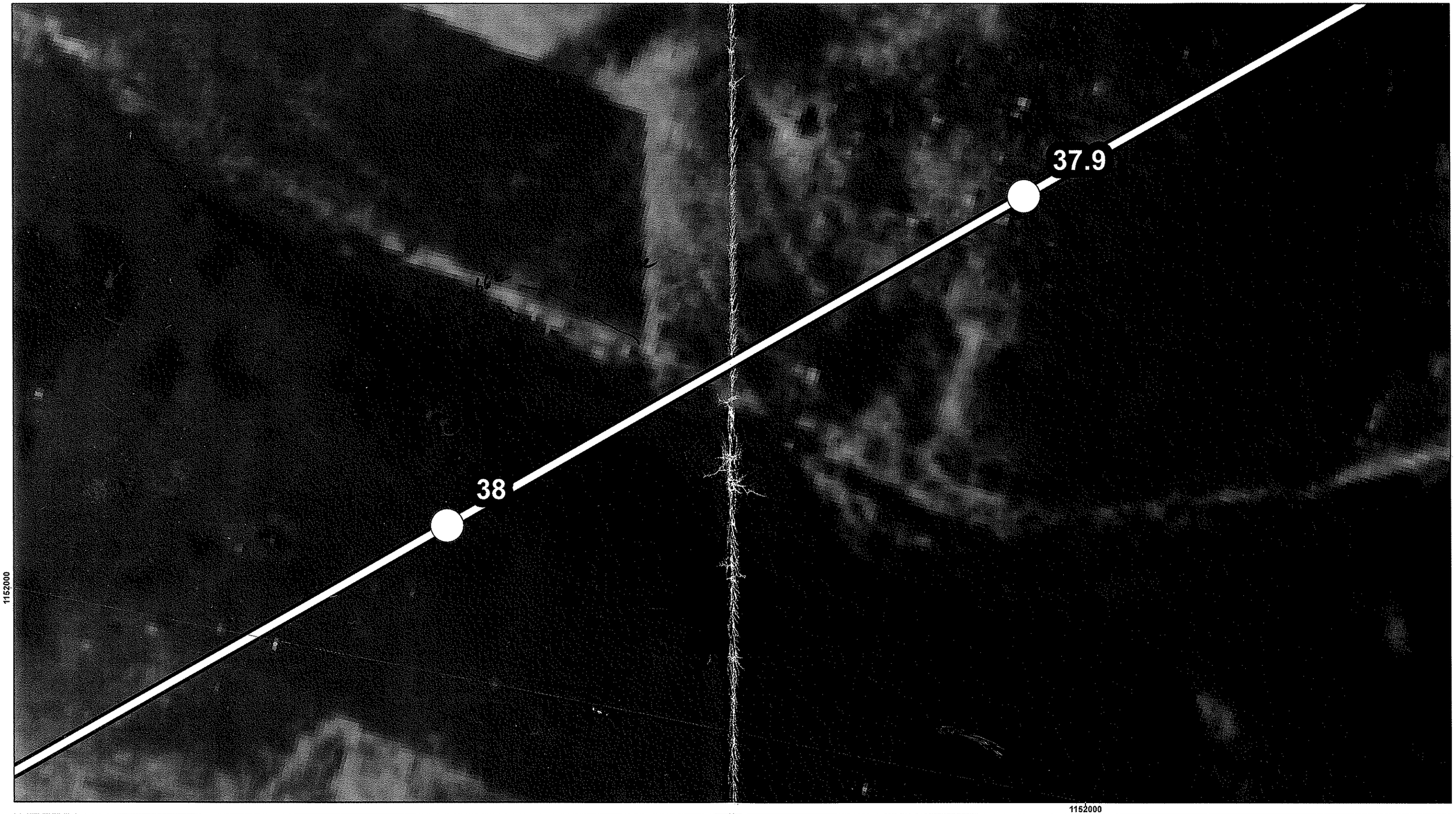
oxbows: None

channel cut-offs:

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

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

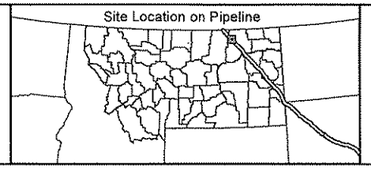
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
No town or county roads present.
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



- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Hay Coulee - MILE POST 38.0
2005 NAIP Aerial

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0 25 50 100 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Lime Creek MP 44.9			Surveyors	
GPS	WP:	N:	E:	Date/Time	8/5/09
Flow Condition	NO water - Dry				
General Site Characteristics / Comments	meandering, moderately steep channel w/ gravel bed + sand banks, grass growing in gravel bed - no woody veg Rick - channel X-ing location will have to be moved as it doesn't go in between 55' gaps at meander neck - too narrow for ROW, and too much potential for meander cut-off (though not likely to happen soon) - more X-ing ~125' US - see map				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)	
	D_{16}	2 mm
	D_{50}	32 mm
	D_{84}	64 mm
	% sand	50
	SOIL CLASS SYMBOL	GW
Bed (sub-surface)	D_{16}	2
	D_{50}	32
	D_{84}	64
	% sand	50
	SOIL CLASS SYMBOL	GW
Bars	D_{16}	
	D_{50}	
	D_{84}	
	% sand	60
	SOIL CLASS SYMBOL	SC

Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}	FS-MS	D_{50}	FS-MS
	D_{84}		D_{84}	
	% sand	>70	% sand	>70
	SOIL CLASS SYMBOL	SM	SOIL CLASS SYMBOL	SM

Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	60	% sand	
	SOIL CLASS SYMBOL	SM	SOIL CLASS SYMBOL	SM

Comments: Ustic Torrifluvents soils 75

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

* artificial channel plug ~100' DS of new proposed crossing - may've been constructed to pond water for cattle, and to cross the channel + more sand + fines in channel US of plug

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 4-5			Bank Height (ft) 4-5		
Bank Slope (°) lower 3' 40°, upper 2' 90°			Bank Slope (°) 40-50		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species grasses + see photo			Dominant Species grasses + see photo		
Root Depth (ft) 2 Observed Y/N			Root Depth (ft) 2 Observed Y/N		
Undercutting (Y/N)			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / N	Potential Y / N	Gradual Migration	Present Y / N	Potential Y / N
Slumping	Present Y / N	Potential Y / N	Slumping	Present Y / N	Potential Y / N
Landsliding	Present Y / N	Potential Y / N	Landsliding	Present Y / N	Potential Y / N
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: cohesive bank material ~50-75% vegetated			Notes: ← see		
no evidence of recent instability					

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity little		Soil Maturity little	
Natural Levees (Y/N)		Natural Levees (Y/N)	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species		Dominant Woody Species	
Crevasse Splays (Y/N)		Crevasse Splays (Y/N)	
Crevasse Channels (Y/N)		Crevasse Channels (Y/N)	
Notes: see map		Notes: NO Frequently inundated R FP - Sage, likely terrace	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 30	Bridges (Y/N)
Bankfull Depth (ft) 4-5	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) alluvial flat on LB to	Associated Instability (Y/N)
fringe RB	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) no water	
20-25' when flowing	Roads (Y/N)
Incision Evidence none	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence fines deposition from channel	
plug DS	
Bars (Y/N) not well defined + vegetated	
Vegetated Islands (Y/N)	
Pool Depths (ft) 5-6	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams	In-stream structures artificial ch. plug - see
	p. 2 notes + photos
Debris flow	
	Flow Diversion
Landslides steep RB US + DS of	
x-ing, but not at x-ing.	Debris
Woody debris	
Other:	Other:

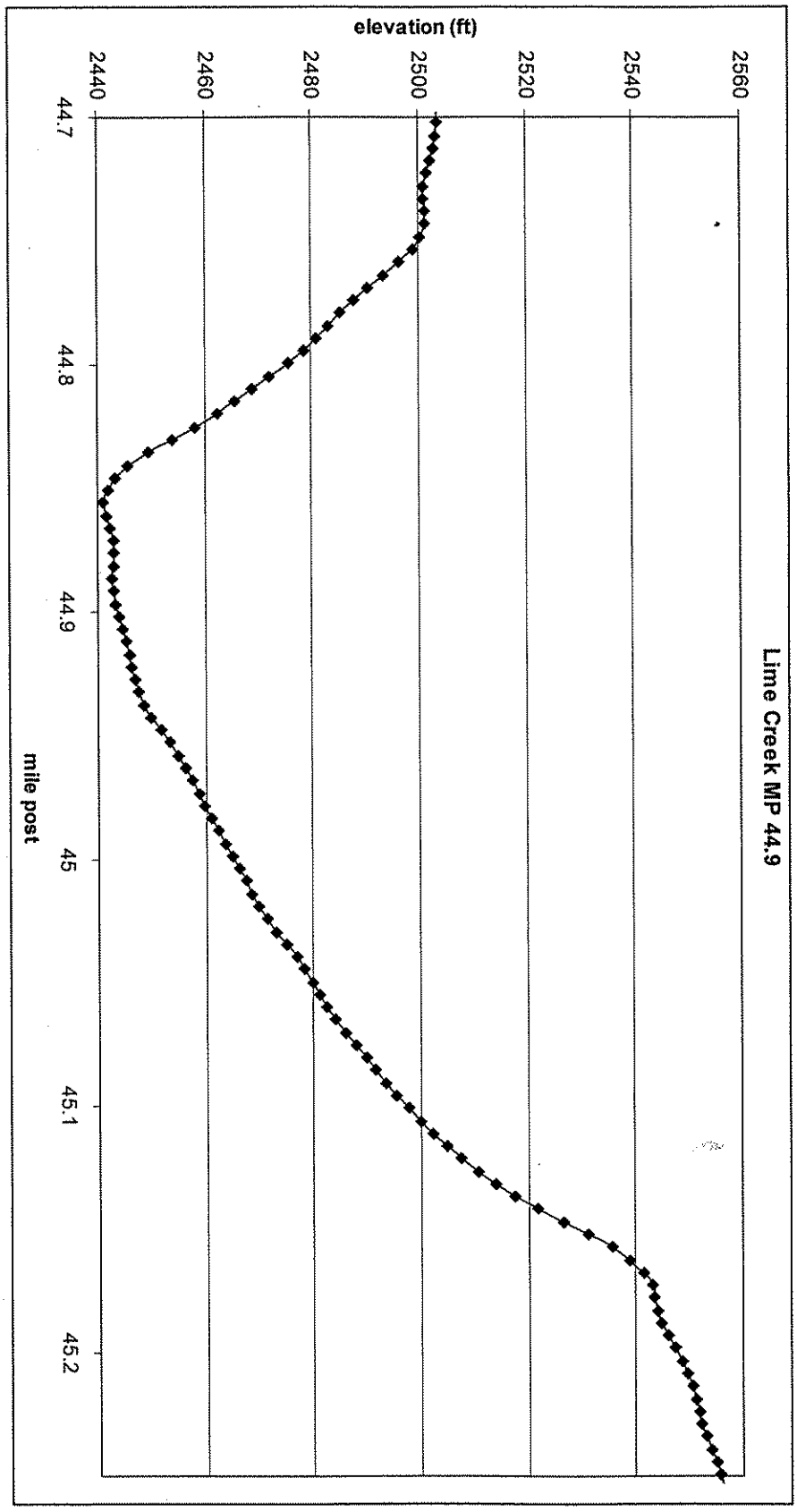
PHOTO CHECKLIST		
Site Overview	☒	318-323 DS to US order
Channel US Showing Both Banks	☒	297-299
Channel DS Showing Both Banks	☒	294-296
Channel Bed Surface Alluvium	☒	292
Channel Bed Sub-Surface Alluvium	☒	293
Bar Alluvium	☒	290
Bars Overview	☒	291
Islands Overview	☒	NA
Left Bank Alluvium	☒	300
Left Bank Toe Detail	☒	301
Left Bank Top of Bank Detail	☒	302
Left Bank Overview	☒	303
Left Floodplain Alluvium	☒	313, 314
Left Floodplain Overview	☒	315-317 DS to US order
Left Floodplain Landforms	☒	NA
Right Bank Alluvium	☒	304
Right Bank Toe Detail	☒	305
Right Bank Top of Bank Detail	☒	306
Right Bank Overview	☒	307
Right Floodplain Alluvium	☒	311, 312
Right Floodplain Overview	☒	308-310 DS to US
Right Floodplain Landforms	☒	NA
Infrastructure	☒	NA
Disturbance/Instability	☐	

PHOTO LOG		
Photo ID	View Direction	Description
324	LB	typical LB species
326-328	US, RB, DS	channel plug @ original X-ing, now ~100' DS of new X-ing

325 site overview video

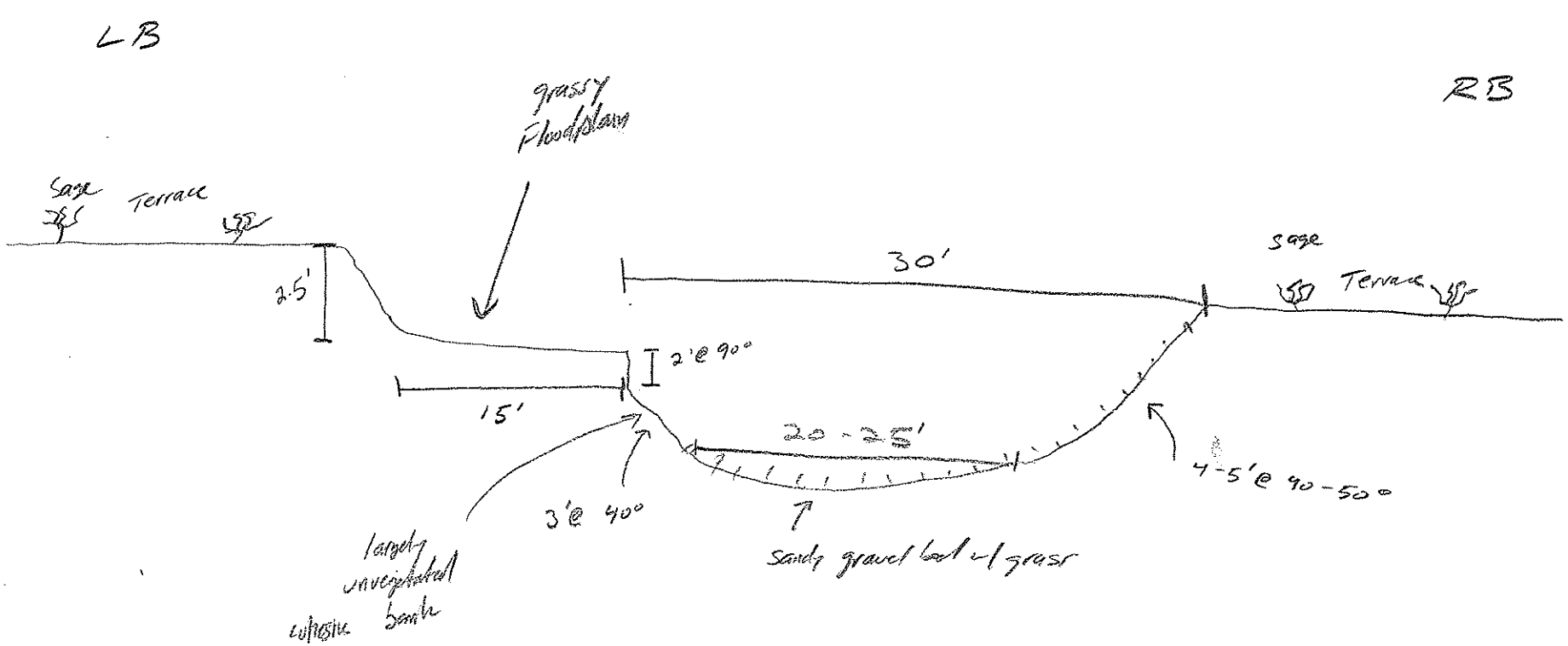
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



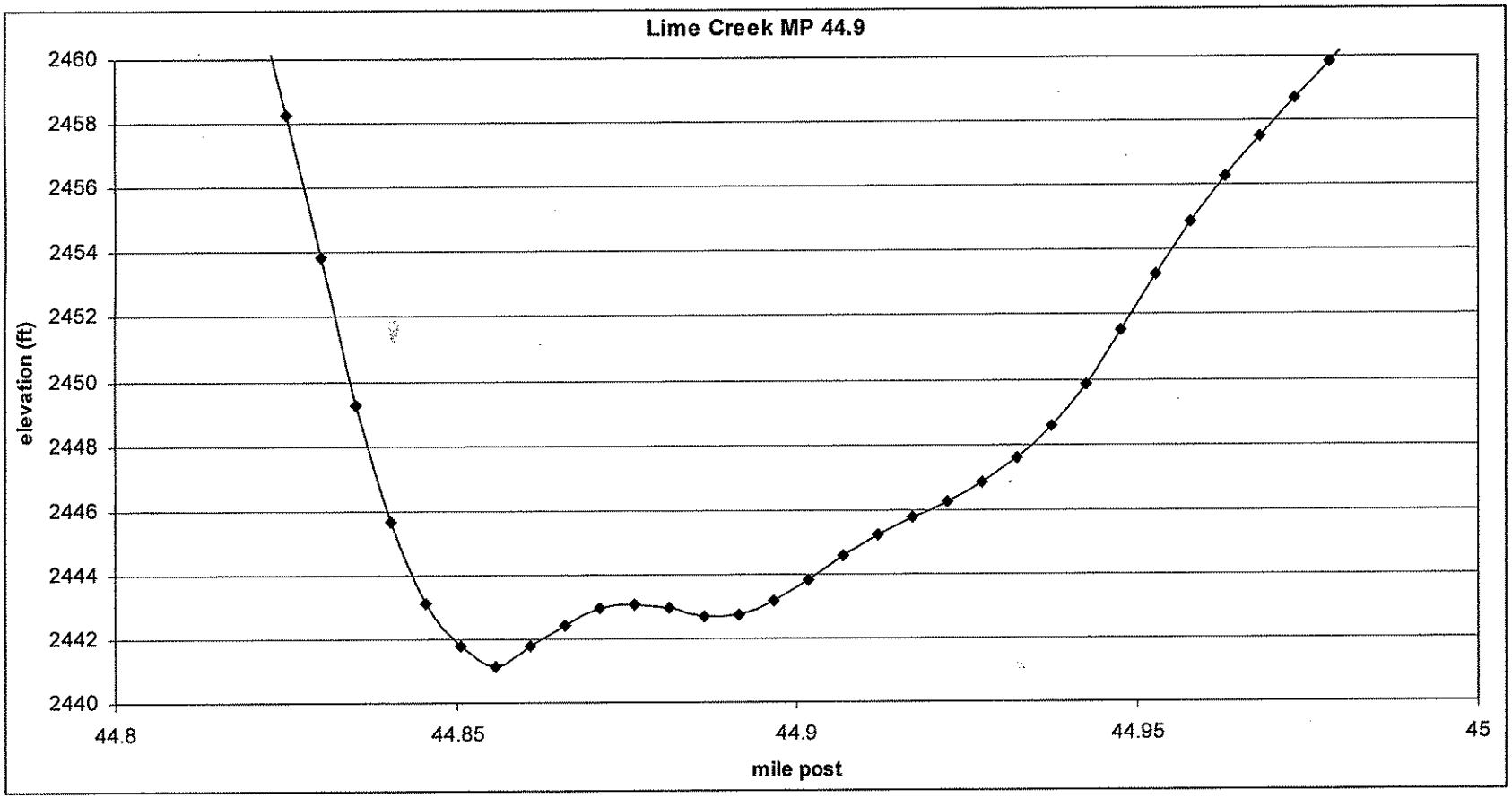
PLANVIEW MAP

*notes – image background date:


LB
RB
grassy Floodplain
Sage
Terrace
2.5'
30'
Sage
Terrace
2'@ 90°
15'
20-25'
3'@ 40°
4-5'@ 90-50°
largely unvegetated colluvial talus
Sandy gravel bed w/ grass

CHANNEL CROSS-SECTION SKETCH

*notes -- channel cross-section derived from 30 / 10 meter USGS DEM



KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	Lime Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing Regional Regression	8.89	--	--	--	76	372	768	1,623	2,565	3,866
No Gage Station Data Available										

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: 0.4

Width (ft)	min	max	mean	stnd dev.
	9	15	12	2

meander wavelength (ft) 551

meander amplitude (ft) 179

Sinuosity 1.81

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	172	330	535	262
	587	449	1348	144
	1174	528	1729	285
	1774	459	1988	151

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 47.72

Valley

Gradient: 0.5

width	min	max	mean	stnd dev.
	107	584	278	154.0

describe geology (lithology, erodibility):

Fine to coarse sandstone with interbeds with shale, and thin coal. Thickness 1,000 ft.

Sand and Gravel

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:

Scour Holes present, could be oxbow

channel cut-offs:

US 1. Avulsions (0.04 , 0.10mi, 0.20 river right) 2. Scour Holes (0.04,0.10mi river right) DS Avulsions (0.00-0.20 mi, river right) 2. Scour Holes (0.06 mi river right)

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
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 (0.05 river right) (0.20 mi 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):
None
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.

Lime CK

Questions:

What is the likelihood the project will impact turbidity at the site?

None - no flow

What is the potential impact on incision and erosion?

little

Will the project activate historical instability?

NO

What actions or alternatives can mitigate project effects?

None

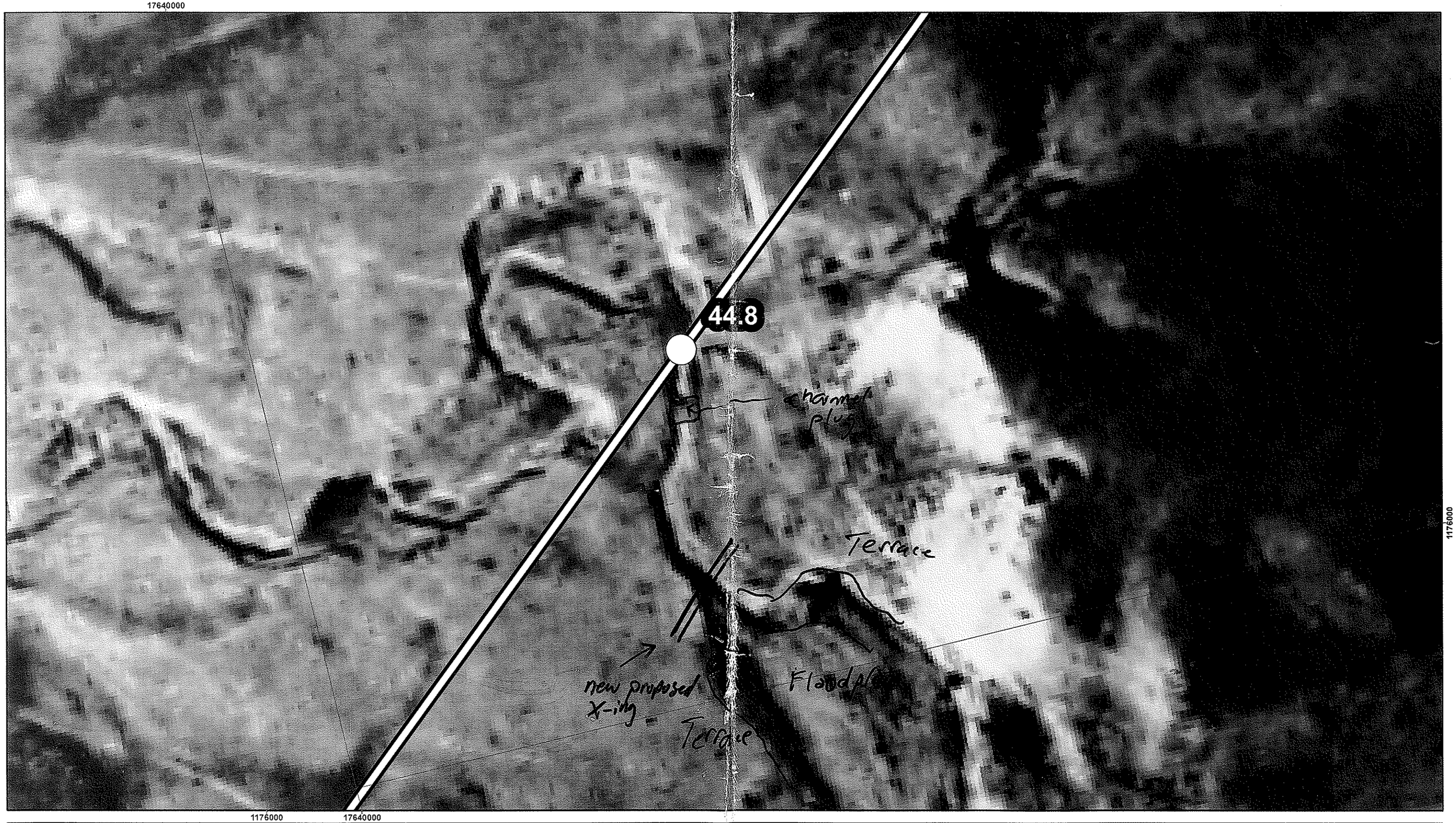
Are there any cumulative effects of pipeline?

no

General Notes:

Dry channel

17640000



1176000

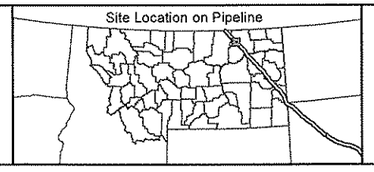
1176000

17640000

- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Lime Creek - MILE POST 44.9
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 25 50 100 Feet

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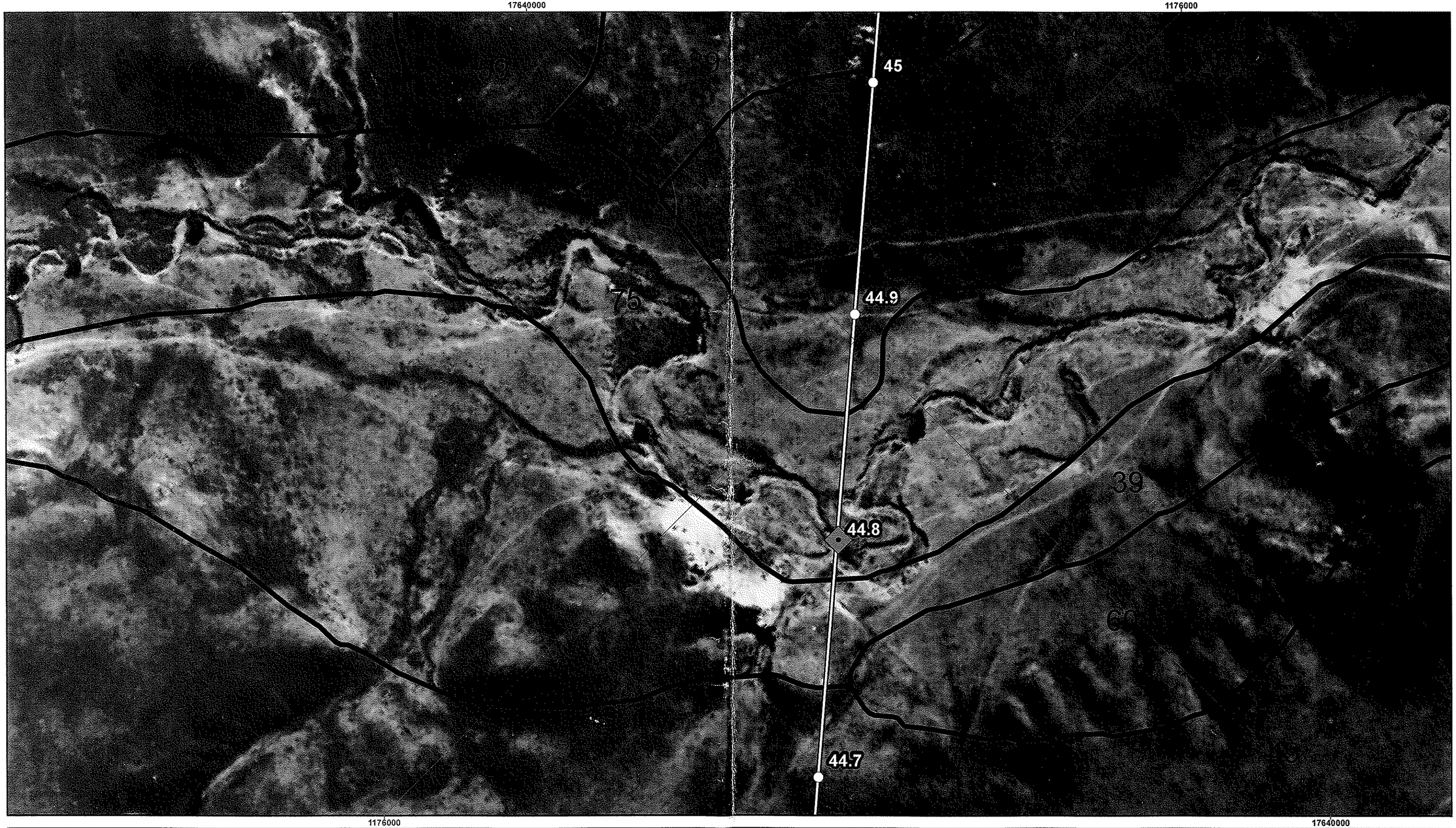
File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

1764000

1176000



1176000

1764000

Perennial Stream Crossings

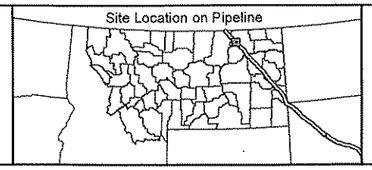
Intermittent Stream Crossings

Proposed Pipeline Route

1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Lime Creek - MILE POST 44.9
NRCS Ssurgo Soils

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
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Coordinate System: NAD 1983 UTM Zone 13 feet

0 100 200 400 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Brush Fork MP 51.1			Surveyors	Ericsson
GPS	WP:	N:	E:	Date/Time	8/6/2009 8:30AM
Flow Condition	no flow present				
General Site Characteristics / Comments	single thread intermittent meandering river flowing along the western margin of valley (200m wide) ; pool-riffle channel w/ 4-6' elevation change from pools (meander bends) to riffles (transition). Bed grain size is dictated by location (pool = cobble/gravel riffle = coarse sand)				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/(N)) If Yes, enter Bed (subsurface)			
	D_{16}	1/4 mm		
	D_{50}	2 mm		
	D_{84}	8 cm		
	% sand	55		
	SOIL CLASS SYMBOL	GW		
Bed (sub-surface)	D_{16}			
	D_{50}	NA		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}			
	D_{50}	NA		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}	clay	D_{16}	clay
	D_{50}	1/4 mm	D_{50}	1/5 mm
	D_{84}	1 mm	D_{84}	3/4 mm
	% sand	85	% sand	85
	SOIL CLASS SYMBOL	SC	SOIL CLASS SYMBOL	SC
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}	clay	D_{16}	clay
	D_{50}	1/10 mm	D_{50}	1/8 mm
	D_{84}	1/2 mm	D_{84}	1/2 mm
	% sand	75	% sand	80
	SOIL CLASS SYMBOL	SC	SOIL CLASS SYMBOL	SC

Comments:

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) ≈ 1-1.5'			Bank Height (ft) 2'		
Bank Slope (°) 35			Bank Slope (°) 70		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species NA			Dominant Species NA		
Root Depth (ft) 1	Observed Y / (N)		Root Depth (ft) 1	Observed (Y) / N	
Undercutting (Y/N)			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / (N)	Potential (Y) / N	Gradual Migration	Present Y / (N)	Potential (Y) / N
Slumping	Present Y / (N)	Potential Y / (N)	Slumping	Present Y / (N)	Potential (Y) / N
Landsliding	Present Y / (N)	Potential Y / (N)	Landsliding	Present Y / (N)	Potential Y / (N)
Other:	Present Y / (N)	Potential Y / (N)	Other:	Present Y / (N)	Potential Y / (N)
Notes: on inside bend of minor arc in transition between meanders			Notes: on outside bend of minor arc in transition between meanders		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity young / little to no dark surface, sub-angular peds		Soil Maturity young / little to no dark surface, sub-angular peds	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H) 0		Woody Riparian Plant Density (L,M,H) 0	
Dominant Woody Species NA		Dominant Woody Species NA	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes: low floodplain w/ annuals? high floodplain w/ sage		Notes: low floodplain w/ annuals? high floodplain w/ sage	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 20	Bridges (Y/(N))
Bankfull Depth (ft) 2	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) bank, more grass and less annuals than floodplain	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 3-6'	
	Roads (Y/(N))
Incision Evidence NA	(RR, LB, US, DS)
	Other Infrastructure NA
Aggradation Evidence NA	
Bars (Y/(N))	
Vegetated Islands (Y/(N))	
Pool Depths (ft) NA	
Channel In Low Elevation of Valley Floor ((Y)N)	
Notes:	Notes:

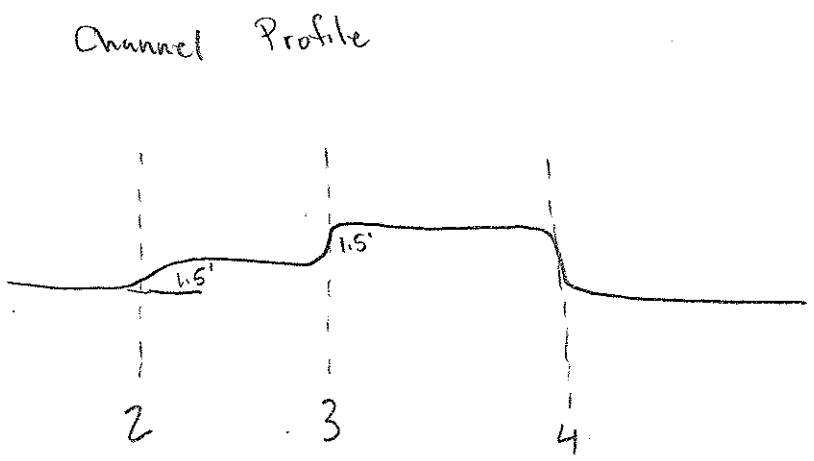
CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams NA	In-stream structures NA
Debris flow NA	
	Flow Diversion NA
Landslides NA	
	Debris NA
Woody debris NA	
Other:	Other:

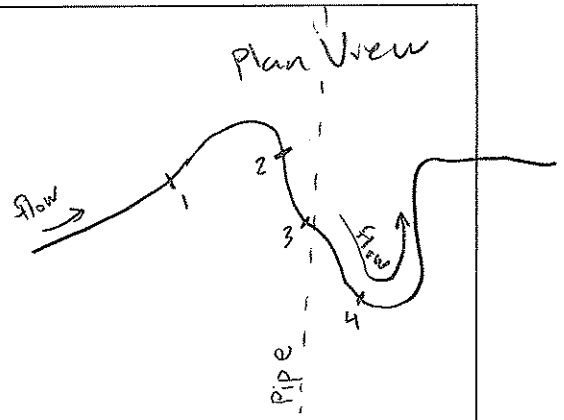
PHOTO CHECKLIST		
Site Overview	☒	365 – 368 panaramic
Channel US Showing Both Banks	☒	356
Channel DS Showing Both Banks	☒	357
Channel Bed Surface Alluvium	☒	358
Channel Bed Sub-Surface Alluvium	☐	NA
Bar Alluvium	☐	NA
Bars Overview	☐	NA
Islands Overview	☐	NA
Left Bank Alluvium	☒	359
Left Bank Toe Detail	☒	360
Left Bank Top of Bank Detail	☒	361
Left Bank Overview	☒	362
Left Floodplain Alluvium	☒	364
Left Floodplain Overview	☒	363
Left Floodplain Landforms	☒	NA
Right Bank Alluvium	☒	351
Right Bank Toe Detail	☒	353
Right Bank Top of Bank Detail	☒	352
Right Bank Overview	☒	354
Right Floodplain Alluvium	☒	350
Right Floodplain Overview	☒	355
Right Floodplain Landforms	☒	NA
Infrastructure	☒	NA
Disturbance/Instability	☒	NA

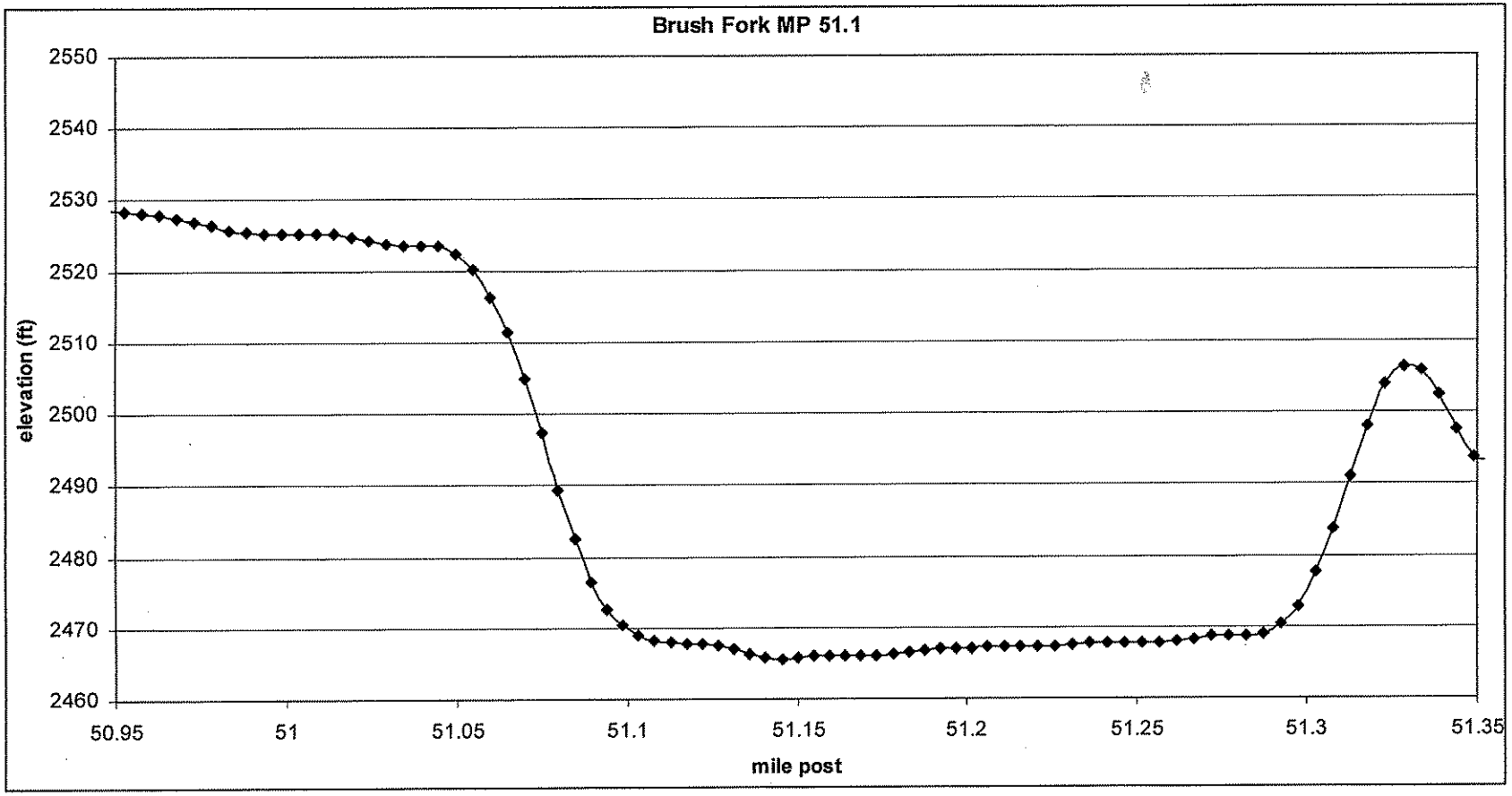
PHOTO LOG		
Photo ID	View Direction	Description
369		Upstream meander pool
370		looking at crossing from upstream looking downstream
371		right floodplain (high FP left, low FP right)

VALLEY CROSS-SECTION SKETCH

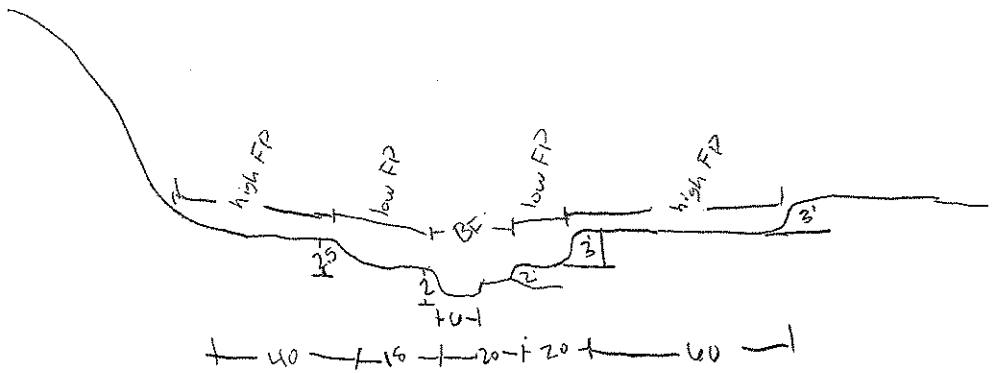
*notes -- valley cross-section derived from 30 / 10 meter USGS DEM

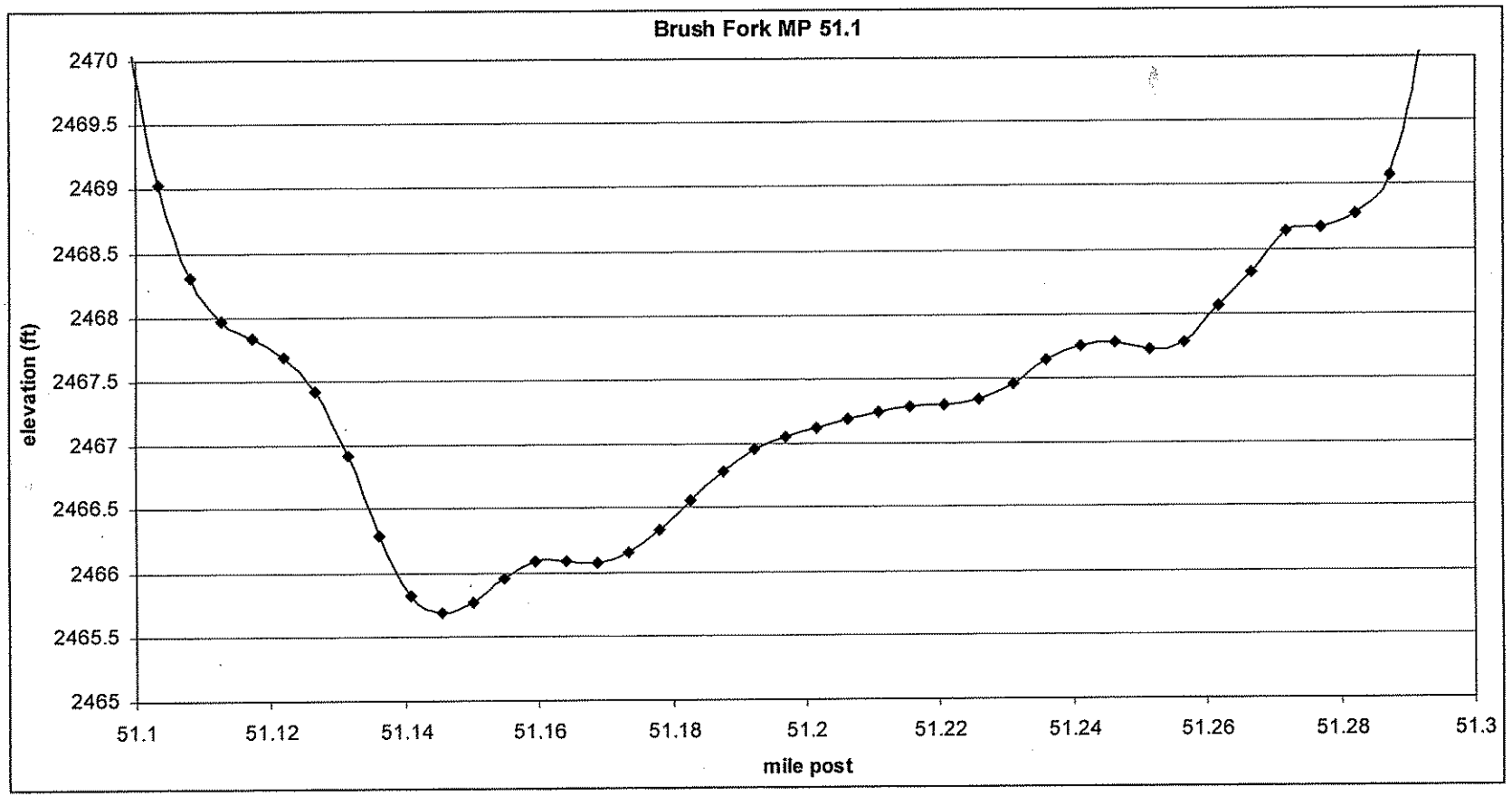






CHANNEL CROSS-SECTION SKETCH





*notes – channel cross-section derived from 30 / 10 meter USGS DEM

PLANVIEW MAP

*notes – image background date:

- clay % is ~15% on average for the site. Intermittent crossing.

- ensure that cobble substrate is restored in the new channel thalweg.

- where the channel is reconstructed, re-build the channel profile elevations, else may lead to instability.

- extend the minimum 5' cover depth to the limits of the low FP (ie CMZ)

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	**Brush Fork**	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing Regional Regression	7.13	--	--	--	64	314	648	1,367	2,159	3,249
No Gage Station Data Available										

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: 0.5

Width (ft)	Min	max	mean	stnd dev.
	8	16	11	3

meander wavelength (ft) 324

meander amplitude (ft) 82

Sinuosity 1.93

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	79	220	109	175
	417	203	227	109
	866	220	571	183
	699	200		
	1545	176		
	1747	221		

Channel form (braided, anabranching, single thread):

Single thread

Channel confinement at crossing (W_v / W_c): 75.56

Valley

Gradient: 1.20

width	min	max	mean	stnd dev.
	508	774	648	102

Describe geology (lithology, erodibility):

Alluvium of modern channels and floodplains

Dark Gray shale with zones of concretions. Thickness (984ft)

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:

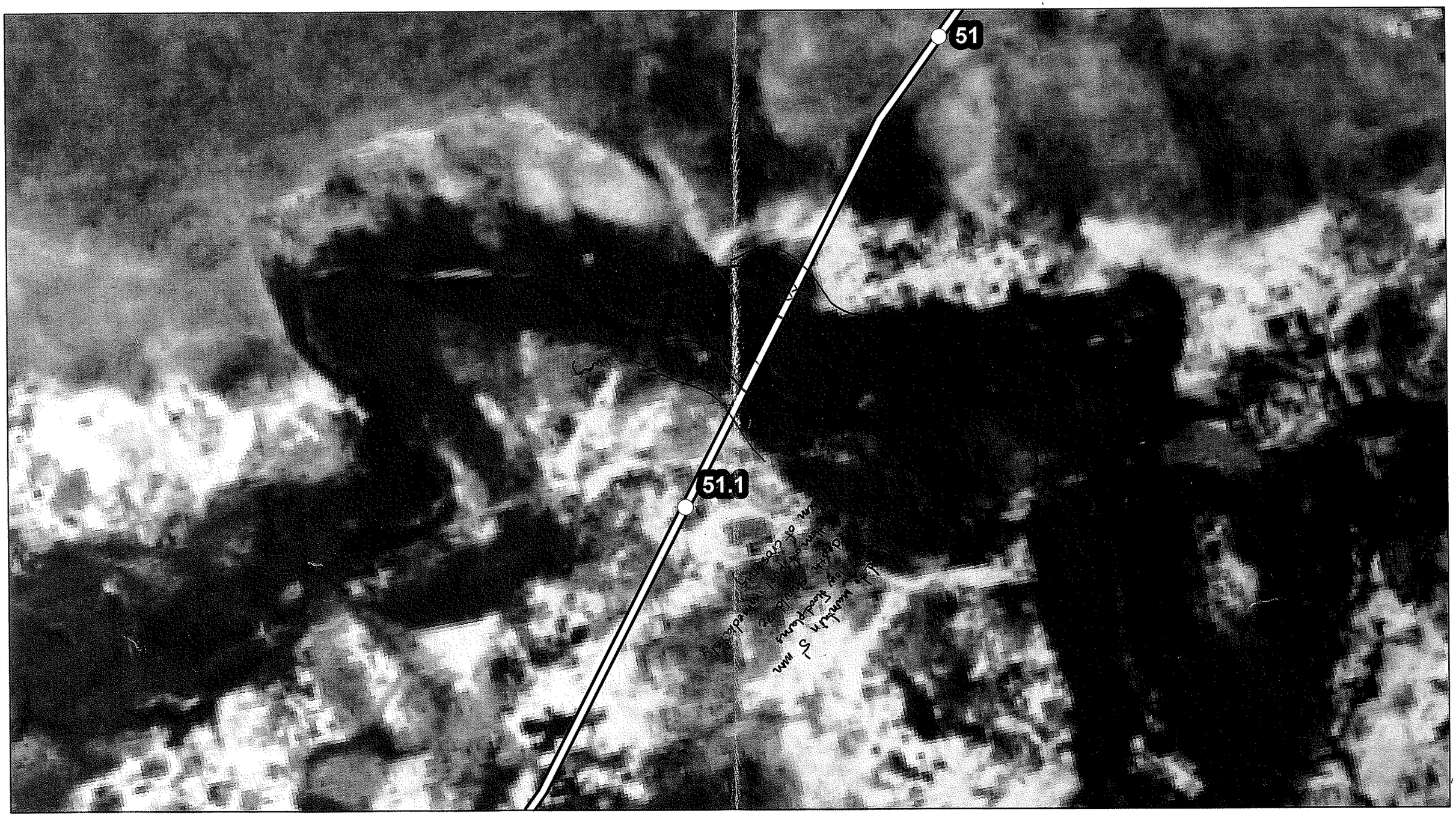
US 0.10 mi river right

channel cut-offs:

US Avulsions (0.00-0.07 mi river right)

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: None

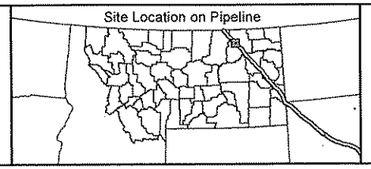
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
US (0.0-0.10 mi, river right, minor sloughing of material appears to exist)
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
DS 1. Bridge or culvert (0.40 miles, perp.)
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.



- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Brush Fork - MILE POST 51.1
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 37.5 75 150 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Bear Creek MP 52.3			Surveyors	Ericsson
GPS	WP:	N:	E:	Date/Time	08/06/2009 11am
Flow Condition	No Flow				
General Site Characteristics / Comments	Wide (40'-60') active FP (10yr) with an 0'-15' unvegetated thalweg. Thalweg substrate varies from cobbles in low spots to sands in high spots. >10yr terrace is present w/ sage. Valley width is only ~180-220' wide with variable slopes of all <30°.				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/(N)) If Yes, enter Bed (subsurface)			
	D_{16}		clay	
	D_{50} ~~Median~~		1/10 mm	
	D_{84}		4cm	
	% sand		30	
	SOIL CLASS SYMBOL		ML	
Bed (sub-surface)	D_{16}			
	D_{50}		NA	
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}		NA	
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		~~LEFT BANK~~ RT FP	
	D_{16}	silt	D_{16}	silt/clay
	D_{50}	1/3 mm	D_{50}	1/16 mm
	D_{84}	2cm	D_{84}	1.5 cm
	% sand	75	% sand	60
	SOIL CLASS SYMBOL	GW	SOIL CLASS SYMBOL	~~SM~~
Flood-plain	~~RIGHT FLOODPLAIN~~ LB.		LEFT FLOODPLAIN	
	D_{16}	clay	D_{16}	1cm (>4" deep)
	D_{50}	1/8 mm	D_{50}	1/4 mm
	D_{84}	3/4 mm	D_{84}	1/2cm clay
	% sand	60	% sand	80
	SOIL CLASS SYMBOL	SC	SOIL CLASS SYMBOL	SW

Comments:

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 21			Bank Height (ft) 31		
Bank Slope (°) 15			Bank Slope (°) 35		
inside of meander			outside of meander		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species —			Dominant Species —		
Root Depth (ft) 1.5 Observed Y / (N)			Root Depth (ft) 1.5' Observed Y / (N)		
Undercutting (Y/(N))			Undercutting (Y/(N))		
Bank Failure			Bank Failure		
Gradual Migration	Present Y /(N)	Potential (Y) / N	Gradual Migration	Present Y /(N)	Potential (Y)/ N
Slumping	Present Y /(N)	Potential Y /(N)	Slumping	Present (Y)/ N	Potential Y /(N)
Landsliding	Present Y /(N)	Potential Y /(N)	Landsliding	Present Y /(N)	Potential Y /(N)
Other:	Present Y /(N)	Potential Y /(N)	Other:	Present Y /(N)	Potential Y /(N)
Notes:			Notes:		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity Immature		Soil Maturity Immature	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/(N))	Relic/Abandoned (Y/(N))	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H) —		Woody Riparian Plant Density (L,M,H) 0	
Dominant Woody Species —		Dominant Woody Species —	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes: low floodplain no side channels but abundant swales and headcuts immediately upstream		Notes: high Floodplain	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 25'	Bridges (Y/N)
Bankfull Depth (ft) 2.5-2.75'	Distance from Crossing (ft) — U.S. / D.S. —
Bankfull Indicator(s) bank	Associated Instability (Y/N) —
	Pier Scour Present (Y/N) — If yes, depth: —
Unvegetated Channel Width (ft) 0-(4'-3')	
	Roads (Y/N)
Incision Evidence active headcuts immediately	(RR, LB, US, DS) —
downstream of crossing	
	Other Infrastructure —
Aggradation Evidence NA	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) 2-2.5'	
Channel in Low Elevation of Valley Floor (Y/N)	
Notes: thalweg elevation varies (pool-riffle)	Notes: —
approx 3' from pools to riffles	

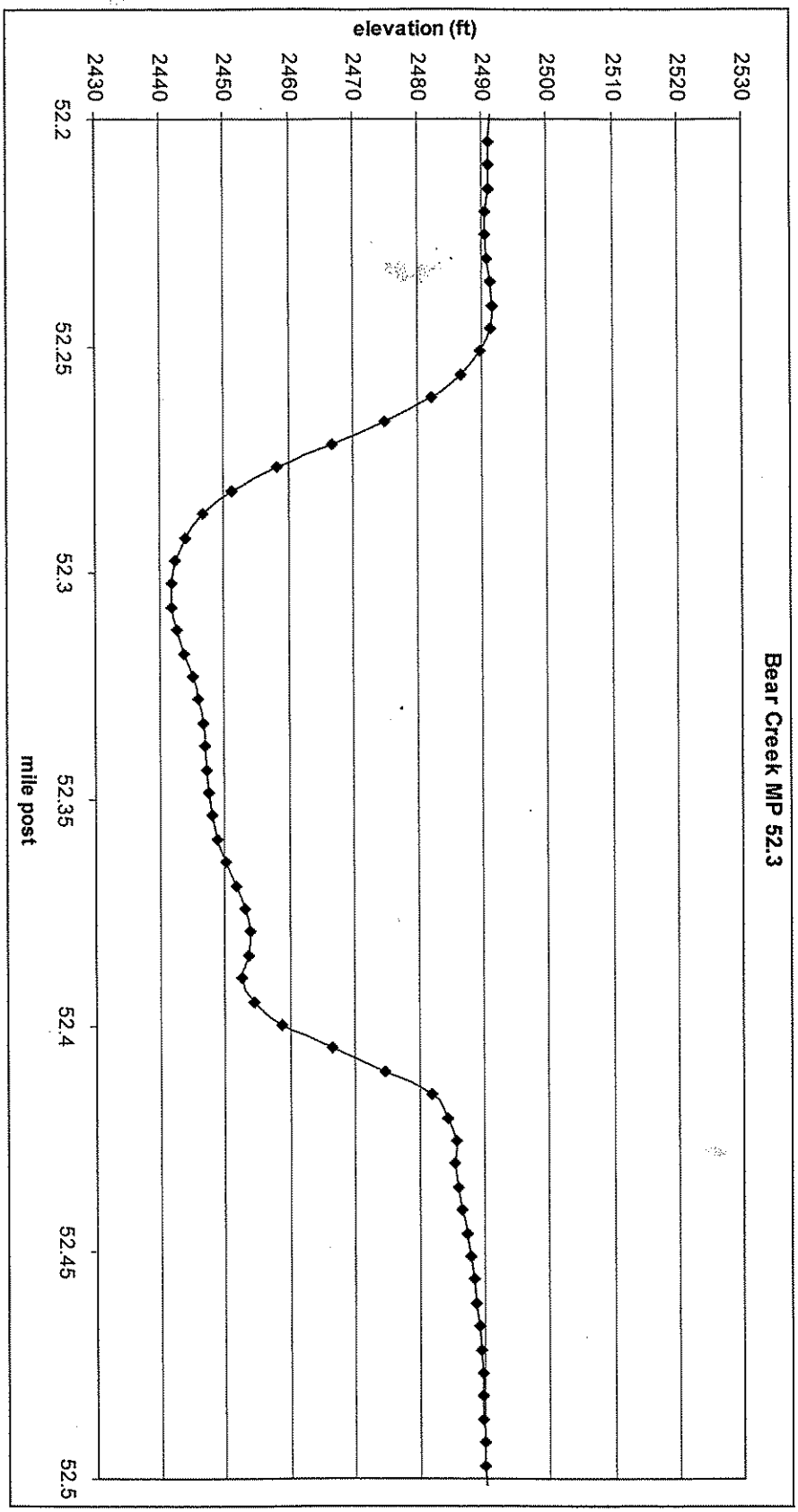
CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams NA	In-stream structures NA
Debris flow NA	
	Flow Diversion NA
Landslides NA	
	Debris NA
Woody debris NA	
Other: head cuts immediately downstream of crossing. High flow swales through left bank floodplain connect to headcuts (4'+ high)	Other: NA

PHOTO CHECKLIST		
Site Overview	☐	393-395
Channel US Showing Both Banks	☒	373-374 panaramic
Channel DS Showing Both Banks	☒	372
Channel Bed Surface Alluvium	☒	377
Channel Bed Sub-Surface Alluvium	☐	NA
Bar Alluvium	☐	NA
Bars Overview	☐	NA
Islands Overview	☐	NA
Left Bank Alluvium	☐	392
Left Bank Toe Detail	☐	—
Left Bank Top of Bank Detail	☐	—
Left Bank Overview	☐	391
Left Floodplain Alluvium	☐	384
Left Floodplain Overview	☐	385
Left Floodplain Landforms	☐	386 (swale)
Right Bank Alluvium	☐	378
Right Bank Toe Detail	☐	379
Right Bank Top of Bank Detail	☐	380
Right Bank Overview	☐	381
Right Floodplain Alluvium	☐	382
Right Floodplain Overview	☐	383
Right Floodplain Landforms	☐	NA
Infrastructure	☐	NA
Disturbance/Instability	☐	387 (headcut 3'-3.5' high)

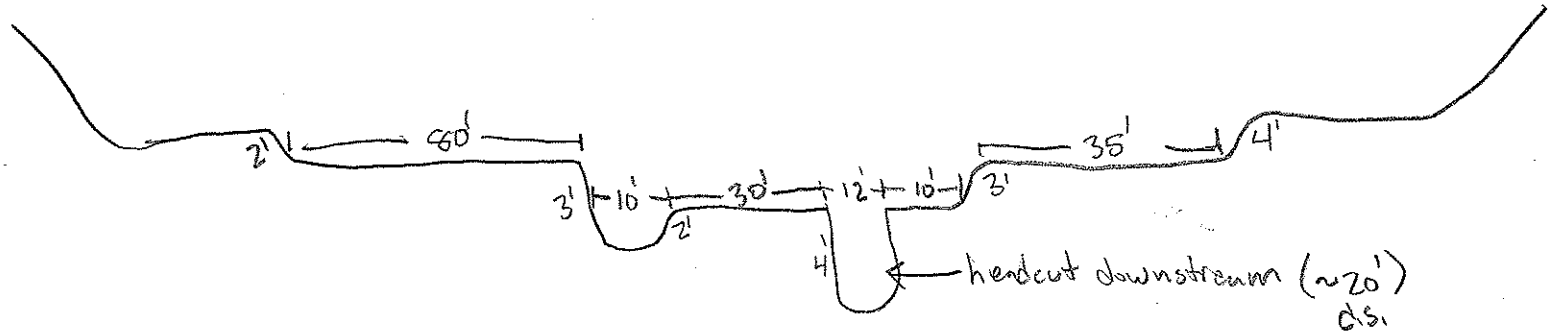
PHOTO LOG		
Photo ID	View Direction	Description
		388-390 headcut panaramic looking upstream

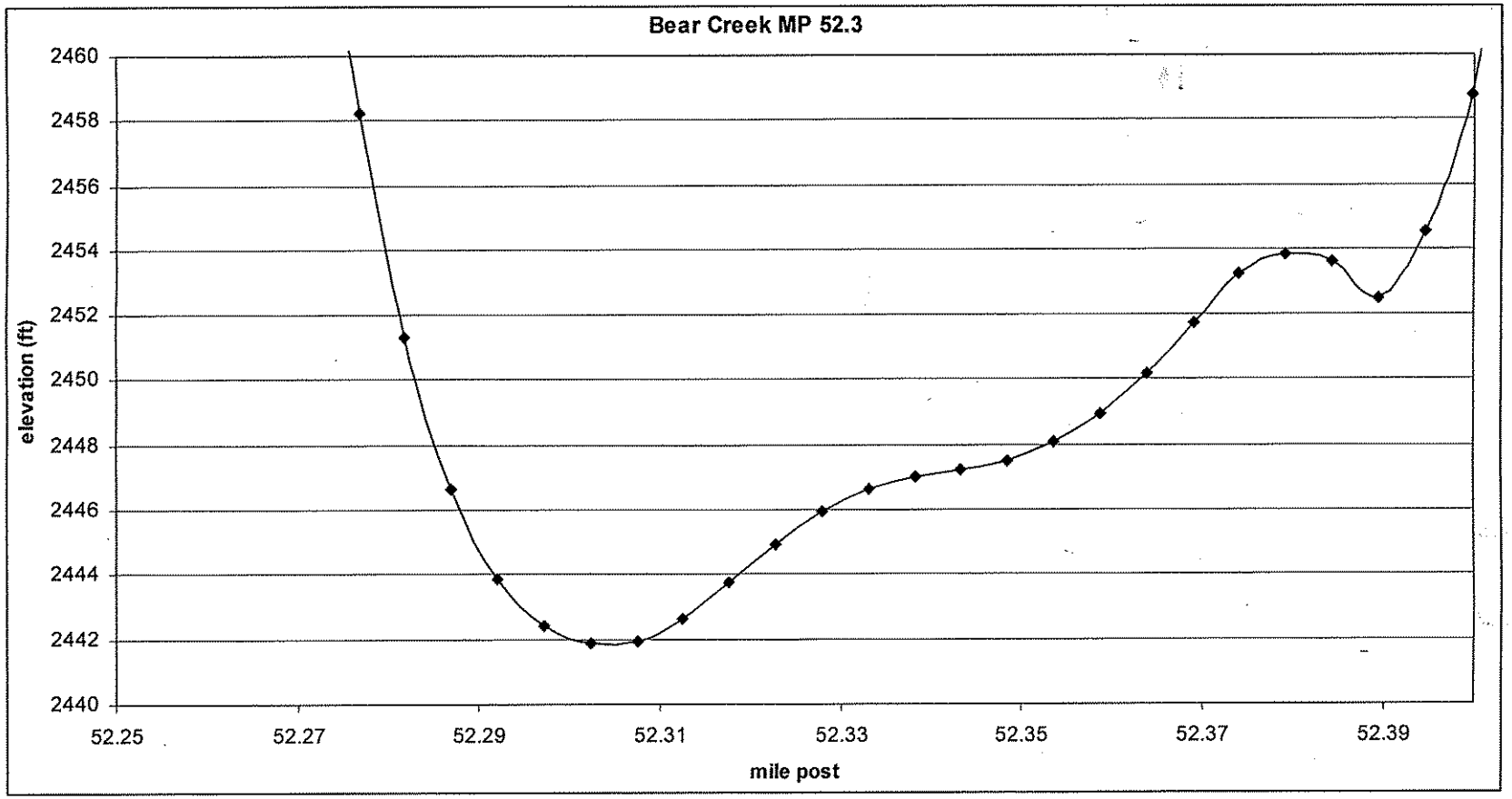
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



CHANNEL CROSS-SECTION SKETCH





*notes – channel cross-section derived from 30 / 10 meter USGS DEM

PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	**Bear Creek**	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing: Regional Regression	4.49	–	–	–	46	230	478	1,015	1,608	2,427
No Gage Station Data Available										

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:: 0.8

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

meander wavelength (ft) 359

meander amplitude (ft) 224

Sinuosity 1.61

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	310	164	11	153
	554	189	333	120
	873	502	686	194
	1519	322	1089	176
	213	162		

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 16.75

Valley

Gradient: 1.4

	min	max	mean	stnd dev
width	179	394	257	86

describe geology (lithology, erodibility):

Alluvium of modern channels and floodplains

Shale with several zones of concreations. Thickness (984 ft)

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: None

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:
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
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
None
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.

17612000

17608000

52.6

52.5

52.4

52.3

52.2

52.1

52

51.9

51.8

51.7

1200000

1200000

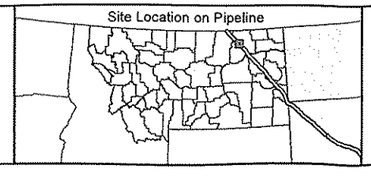
17612000

17608000

- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Bear Creek - MILE POST 52.3
1:100,000 Geology

ENTRIX

200 1st Ave W Ste 500
Seattle, WA 98119

ph (206) 269-0104
fx (206) 269-0098

www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 175 350 700 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Unger Coulee MP 53.3			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/7/09
Flow Condition	No Flow - Dry				
General Site Characteristics / Comments	moderately steep, meandering, pool + riffle channel w/ sand + silt pools + gravel riffles. Grassy banks. Some trampling of banks by cattle. No evidence of recent channel migration				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/(N)) If Yes, enter Bed (subsurface)			
	D_{16}	silty clay		
	D_{50}	silty clay		
	D_{84}	22		
	% sand	<2		
	SOIL CLASS SYMBOL	CL		
Bed (sub-surface)	D_{16}	same as SFC		
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}	vegetated point bars / FP		
	D_{50}			
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}	silty clay	D_{16}	silty clay
	D_{50}	silty clay	D_{50}	silty clay
	D_{84}	22	D_{84}	22
	% sand	<2	% sand	<2
	SOIL CLASS SYMBOL	CL	SOIL CLASS SYMBOL	CL
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}	silty clay	D_{50}	VFS
	D_{84}		D_{84}	
	% sand		% sand	80
	SOIL CLASS SYMBOL	CL	SOIL CLASS SYMBOL	SM

Comments: Absher - Vaeda complex soil 2
silty clay

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 2 4-6'@ some cut banks			Bank Height (ft) 2 4-6'@ some cut banks		
Bank Slope (°) varies 10° (vegetated pt. bar / F.P.) to 90°			Bank Slope (°) varies 10° (veg. pt. bar + FP) to 90°		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species grass + shrubs			Dominant Species grass + shrubs		
Root Depth (ft) 1	Observed (Y)/ N		Root Depth (ft) 1	Observed (Y)/ N	
Undercutting (Y/N) < 0.5'			Undercutting (Y/N) < 0.5'		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / (N)	Potential (Y) / N	Gradual Migration	Present Y / (N)	Potential (Y) / N
Slumping	Present (Y) / N	Potential (Y) / N	Slumping	Present (Y) / N	Potential (Y) / N
Landsliding	Present Y / (N)	Potential Y / (N)	Landsliding	Present Y (N)	Potential Y / (N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: cantelivar bank failure dominant			Notes: ← see		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity minimal		Soil Maturity minimal	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/(N))	Ephemeral (Y/(N))	Perennial (Y/(N))	Ephemeral (Y/(N))
Intermittent (Y/(N))	Relic/Abandoned ((Y)/N)	Intermittent (Y/(N))	Relic/Abandoned (Y/(N))
Not active, or potentially active			
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species		Dominant Woody Species	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes:		Notes:	

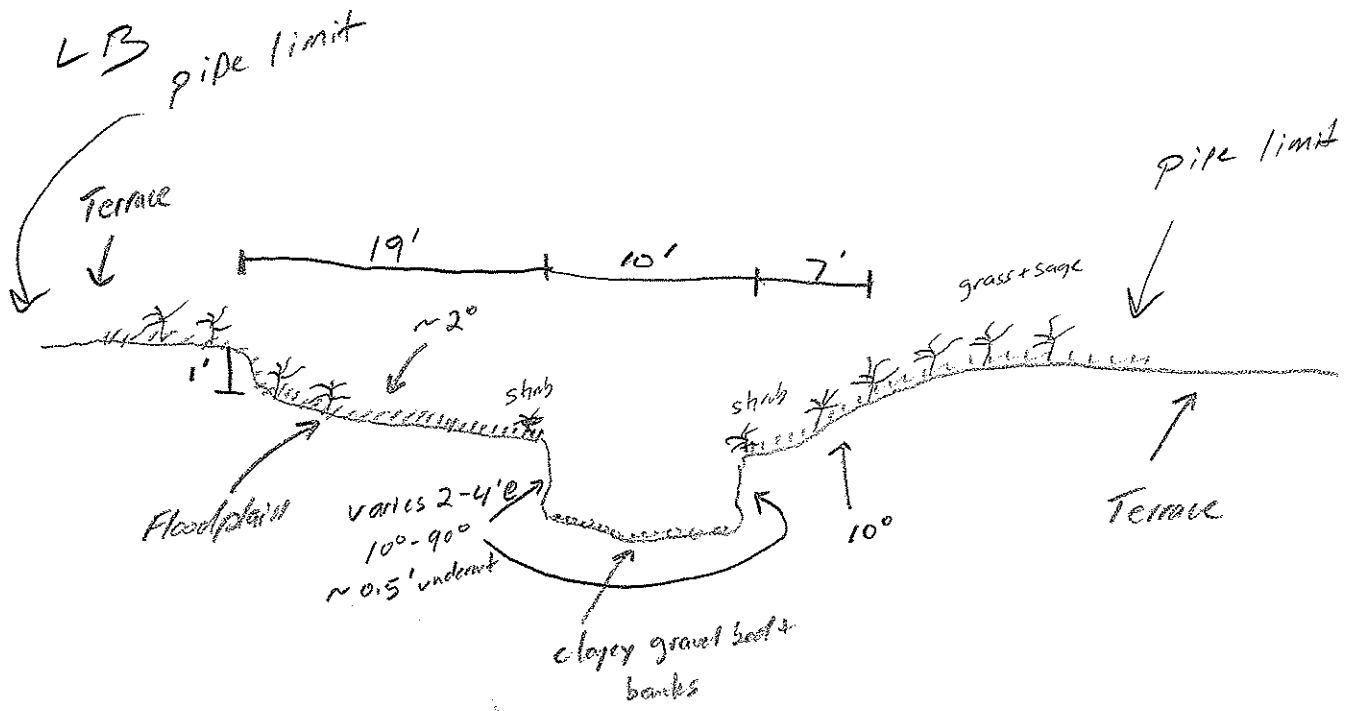
CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 5-7'	Bridges (Y/N)
Bankfull Depth (ft) 2.5'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) topography	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 2-5'	
	Roads (Y/N)
Incision Evidence no	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence no	
Bars (Y/N) Vegetated pt. bars / F.P.	
Vegetated Islands (Y/N)	
Pool Depths (ft) 2.5'	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other: Some trampling of bed + banks by cattle	Other:

PHOTO CHECKLIST		
Site Overview	☑	94-99 US to DS
Channel US Showing Both Banks	☑	100
Channel DS Showing Both Banks	☑	101
Channel Bed Surface Alluvium	☐	102-103
Channel Bed Sub-Surface Alluvium	☑	104
Bar Alluvium	☑	105
Bars Overview	☑	106 DS
Islands Overview	☐	NA
Left Bank Alluvium	☑	107
Left Bank Toe Detail	☑	108
Left Bank Top of Bank Detail	☑	109
Left Bank Overview	☑	110
Left Floodplain Alluvium	☑	111
Left Floodplain Overview	☑	112
Left Floodplain Landforms	☐	N/A
Right Bank Alluvium	☑	113
Right Bank Toe Detail	☑	114
Right Bank Top of Bank Detail	☑	115
Right Bank Overview	☑	116
Right Floodplain Alluvium	☑	117
Right Floodplain Overview	☑	118
Right Floodplain Landforms	☐	N/A
Infrastructure	☐	N/A
Disturbance/Instability	☑	119

PHOTO LOG		
Photo ID	View Direction	Description

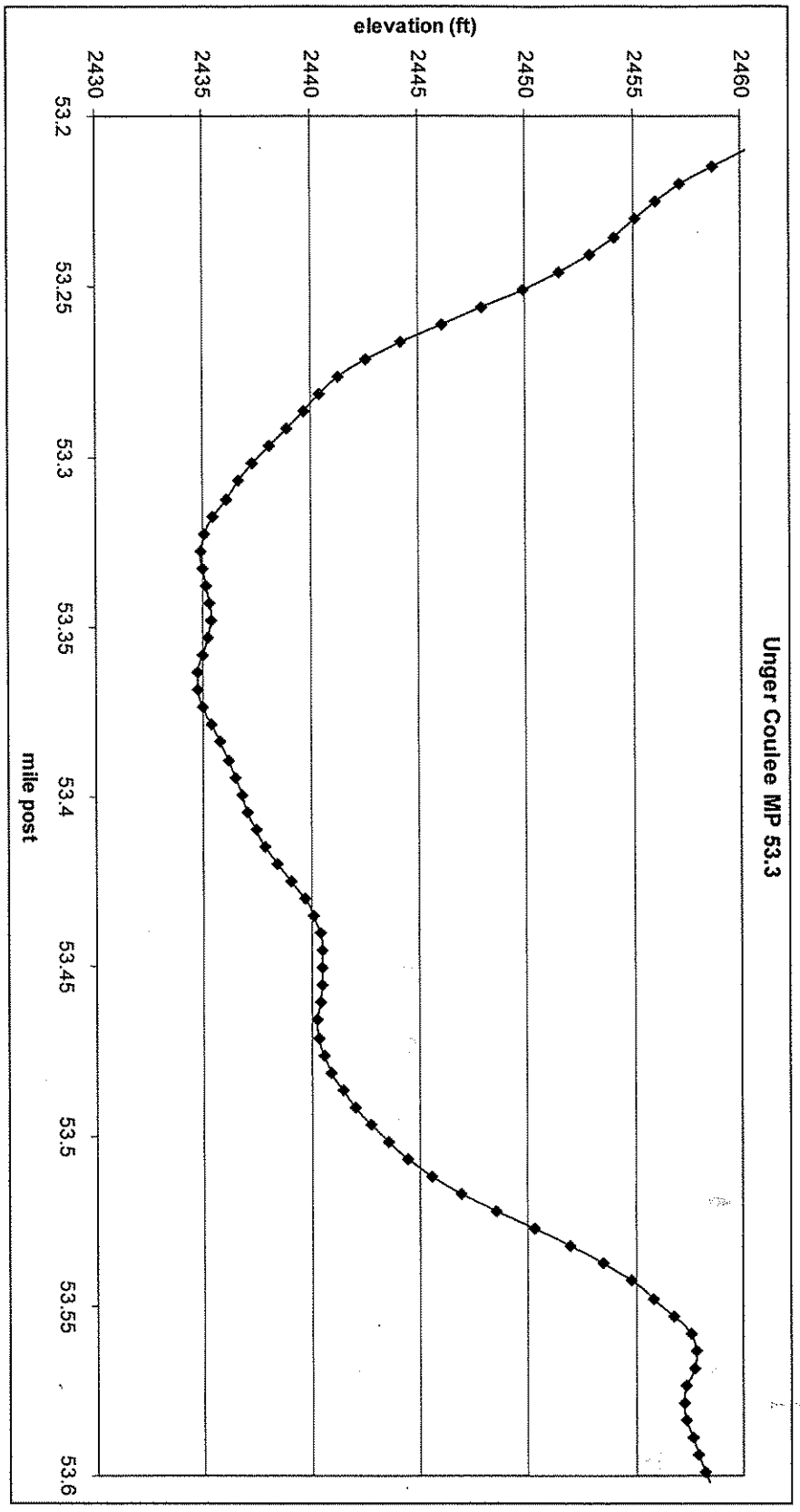
* 120 Video



- Some undercutting of (<0.5') of clayey gravel banks
  channel doesn't show evidence of planform change or widening

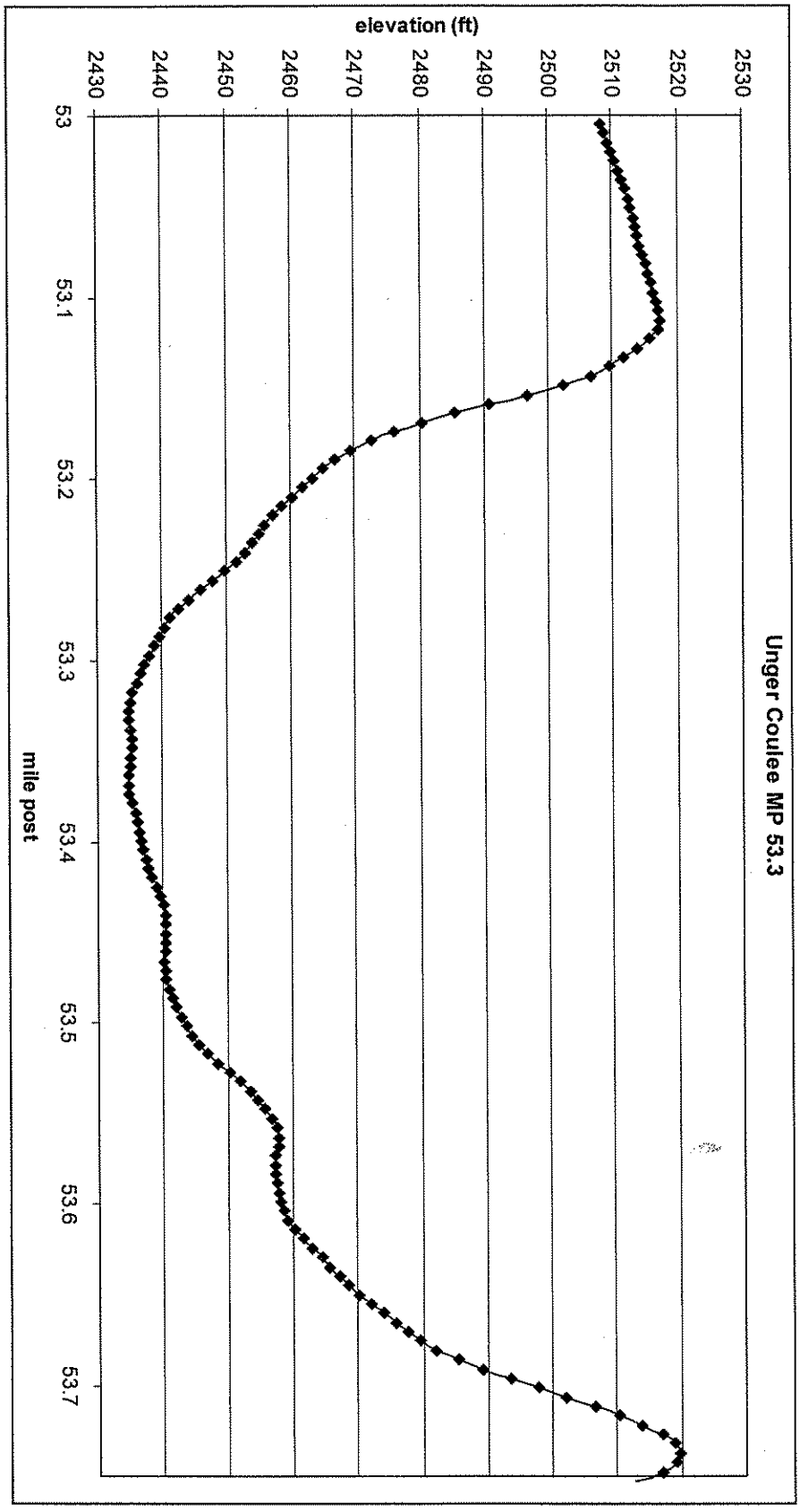
CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	Unger Coulee	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing Regional Regression	4.45	--	--	--	47	234	487	1,041	1,653	2,503
No Gage Station Data Available										

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: 0.7

Width (ft)	min	max	mean	stnd dev.
	7	13	10	1

meander wavelength (ft) 282

meander amplitude (ft) 90

Sinuosity 1.66

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	1179	156	163	127
	918	136	295	118
	688	89	499	133
	71	59	685	88
	210	100		
	355	89		

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 36.79

Valley

Gradient: 1.2

width	min	max	mean	stnd dev.
	289	463	365	58

describe geology (lithology, erodibility):

Alluvium of modern channel and floodplains

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:

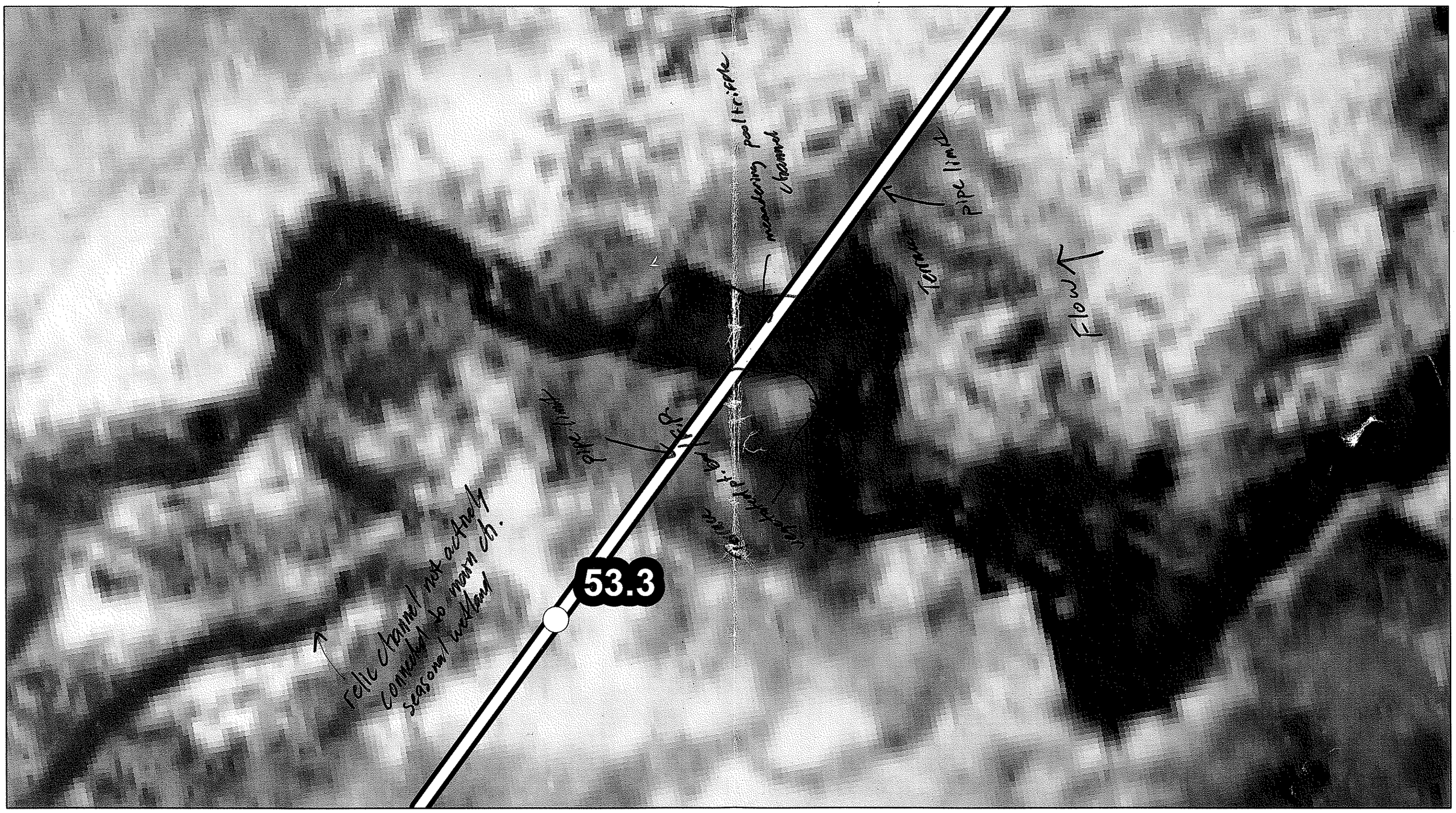
US Scour Holes (0.00-0.25 mi, river center).

channel cut-offs:

DS relic channel (<0.10 mi, river left)

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
None

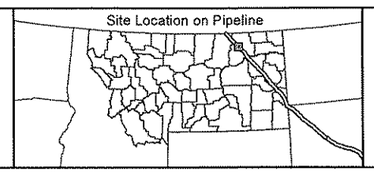
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
None
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
None
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.



- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Unger Coulee - MILE POST 53.3
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
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fx (206) 269-0098
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Coordinate System: NAD 1983 UTM Zone 13 feet

0 25 50 100 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Buggy Creek MP 55.3			Surveyors	Ericsson
GPS	WP:	N:	E:	Date/Time	08/06/2009
Flow Condition	No Flow at time of ~~crossing~~ inspection				
General Site Characteristics / Comments	High gradient cobble bed river w/ evidence (ground + historic photo) of recent avulsion. Channel and <50yr floodplain is confined into an incised network. Abundant Cottonwood ~~ranging from~~ two distinct age stands, one >50 yrs on <30 yrs. Younger trees are on lower floodplains and ~~were~~ relic channel locations (from 1976 air photo)				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	1 mm		
	D_{50}	4 ~~5~~ cm		
	D_{84}	6 ~~8~~ cm		
	% sand	10		
	SOIL CLASS SYMBOL	GW		
Bed (sub-surface)	D_{16}			
	D_{50}	NA		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Bars	D_{16}	1/2 mm		
	D_{50}	7.5mm		
	D_{84}	3 cm		
	% sand	35		
	SOIL CLASS SYMBOL	GP		
Banks	RIGHT BANK		LEFT BANK	
	D_{16}	silt	D_{16}	clay
	D_{50}	1/16mm	D_{50}	1/10mm
	D_{84}	1/4 mm	D_{84}	1/4 mm
	% sand	75	% sand	~~0~~ 75
	SOIL CLASS SYMBOL	SM	SOIL CLASS SYMBOL	SM
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}	silt	D_{16}	clay
	D_{50}	1/4 mm	D_{50}	1/12 mm
	D_{84}	1mm	D_{84}	1/5 mm
	% sand	70	% sand	65
	SOIL CLASS SYMBOL	SC	SOIL CLASS SYMBOL	SC

Comments:

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 4			Bank Height (ft) 2		
Bank Slope (°) 35-40			Bank Slope (°) 35		
Woody Cover (%) 5			Woody Cover (%) 2		
Dominant Species Cottonwood			Dominant Species Cottonwood		
Root Depth (ft) 2+ Observed Y/N			Root Depth (ft) 2 Observed Y / N		
Undercutting (Y/N)			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / N	Potential Y / N	Gradual Migration	Present Y / N	Potential Y / N
Slumping	Present Y / N	Potential Y / N	Slumping	Present Y / N	Potential Y / N
Landsliding	Present Y / N	Potential Y / N	Landsliding	Present Y / N	Potential Y / N
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: One slump present at crossing			Notes:		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity Young- very poorly developed dark surface		Soil Maturity Young	
Natural Levees (Y/N)		Natural Levees (Y/N)	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Woody Riparian Buffer Width (ft) 4 discontinuous		Woody Riparian Buffer Width (ft) 4 discontinuous	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species Cottonwood		Dominant Woody Species Cottonwood	
Crevasse Splays (Y/N)		Crevasse Splays (Y/N)	
Crevasse Channels (Y/N)		Crevasse Channels (Y/N)	
Notes: Old Cottonwood tree, side channels undulating topography		Notes: relic channel deposits, multiple side channels	

CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 75'	Bridges (Y/N)
Bankfull Depth (ft) 5'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) Bank, stacked wood along margin	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) 40'	
	Roads (Y/N)
Incision Evidence Current channel is lower (~2ft) than the 1976 channel	(RR, LB, US, DS)
	Other Infrastructure —
Aggradation Evidence NA	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) NA	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes: Actively migrating system, high energy confined system. Multiple side channels present at different elevations above the thalweg	Notes: —

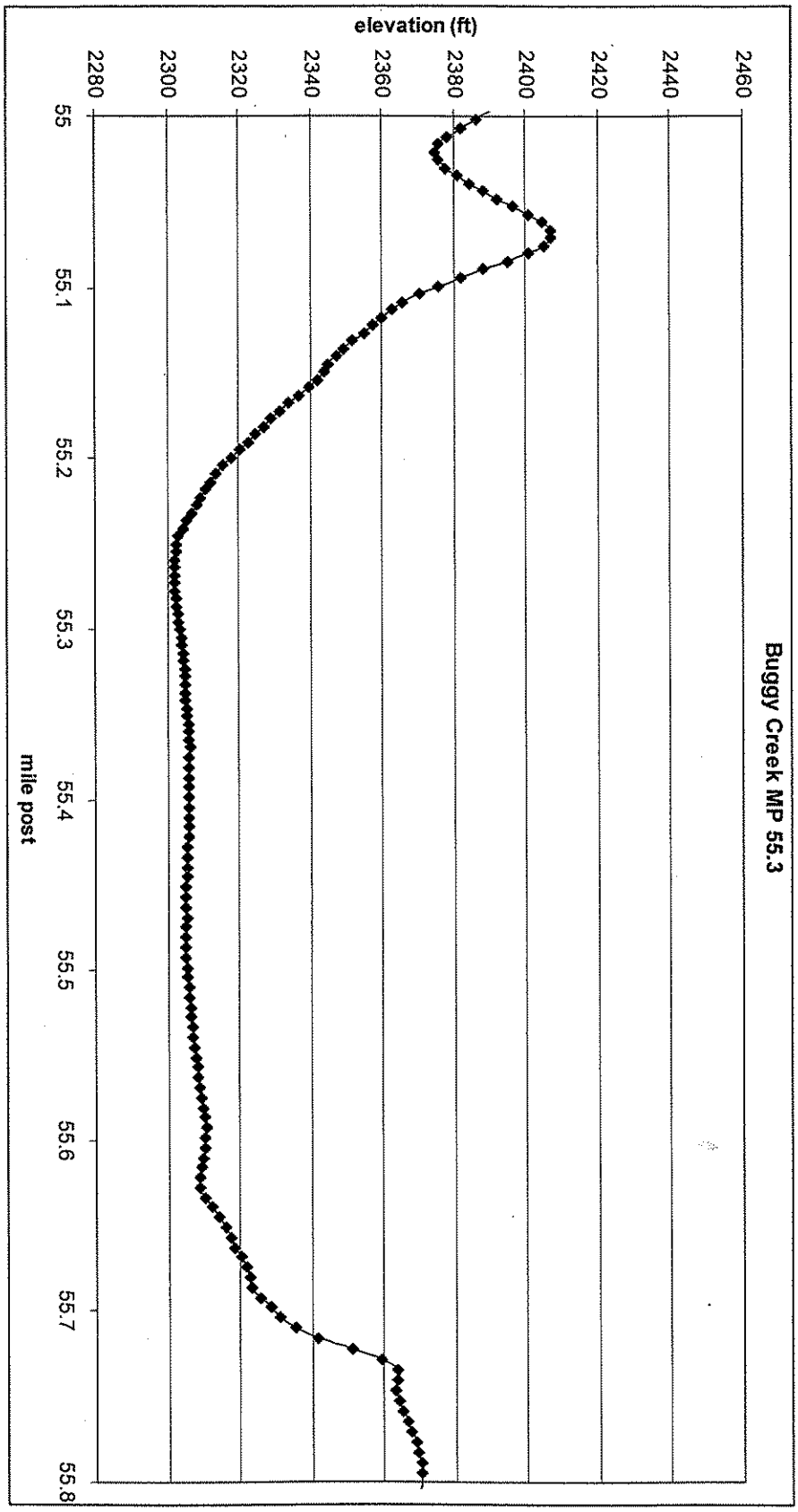
CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams NA	In-stream structures —
Debris flow NA	
	Flow Diversion —
Landslides NA	
	Debris —
Woody debris Some transient wood, small and not forcing channel	
Other:	Other: —

PHOTO CHECKLIST		
Site Overview	☐	
Channel US Showing Both Banks	☒	410 + 411 panaramic
Channel DS Showing Both Banks	☒	416 + 415 panaramic
Channel Bed Surface Alluvium	☒	414
Channel Bed Sub-Surface Alluvium	☒	NA
Bar Alluvium	☒	413
Bars Overview	☒	412 looking downstream
Islands Overview	☒	NA
Left Bank Alluvium	☒	~~410~~ 417
Left Bank Toe Detail	☒	~~417~~ 418
Left Bank Top of Bank Detail	☒	~~418~~ 419
Left Bank Overview	☒	~~419~~ 420
Left Floodplain Alluvium	☒	~~423~~ 424
Left Floodplain Overview	☒	422 (downstream) 423 (upstream)
Left Floodplain Landforms	☒	side channel @ low/high left floodplain) 425
Right Bank Alluvium	☒	398
Right Bank Toe Detail	☒	399
Right Bank Top of Bank Detail	☒	400
Right Bank Overview	☒	401
Right Floodplain Alluvium	☒	396, 397
Right Floodplain Overview	☒	402 (upstream) 403 (downstream)
Right Floodplain Landforms	☒	404 (hfc at boundary of low/high right floodplain)
Infrastructure	☐	NA
Disturbance/Instability	☐	see overview

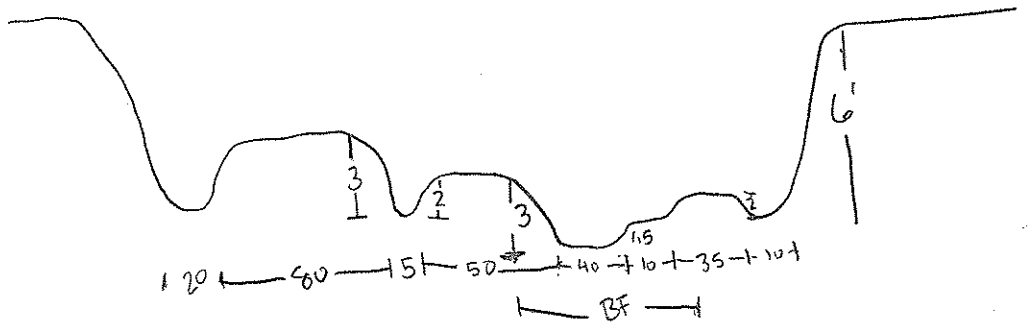
PHOTO LOG		
Photo ID	View Direction	Description
405	upstream	high right floodplain
406	surface	high rt floodplain surficial sediment
407	upstream	hfc at extent of high rt f.p.
408	"	"
409	downstream	racked wood along bankfull boundary (r.b.)
420	upstream	beaver?
426 427	upstream	high lb floodplain panaramic w/ hfc @ margin

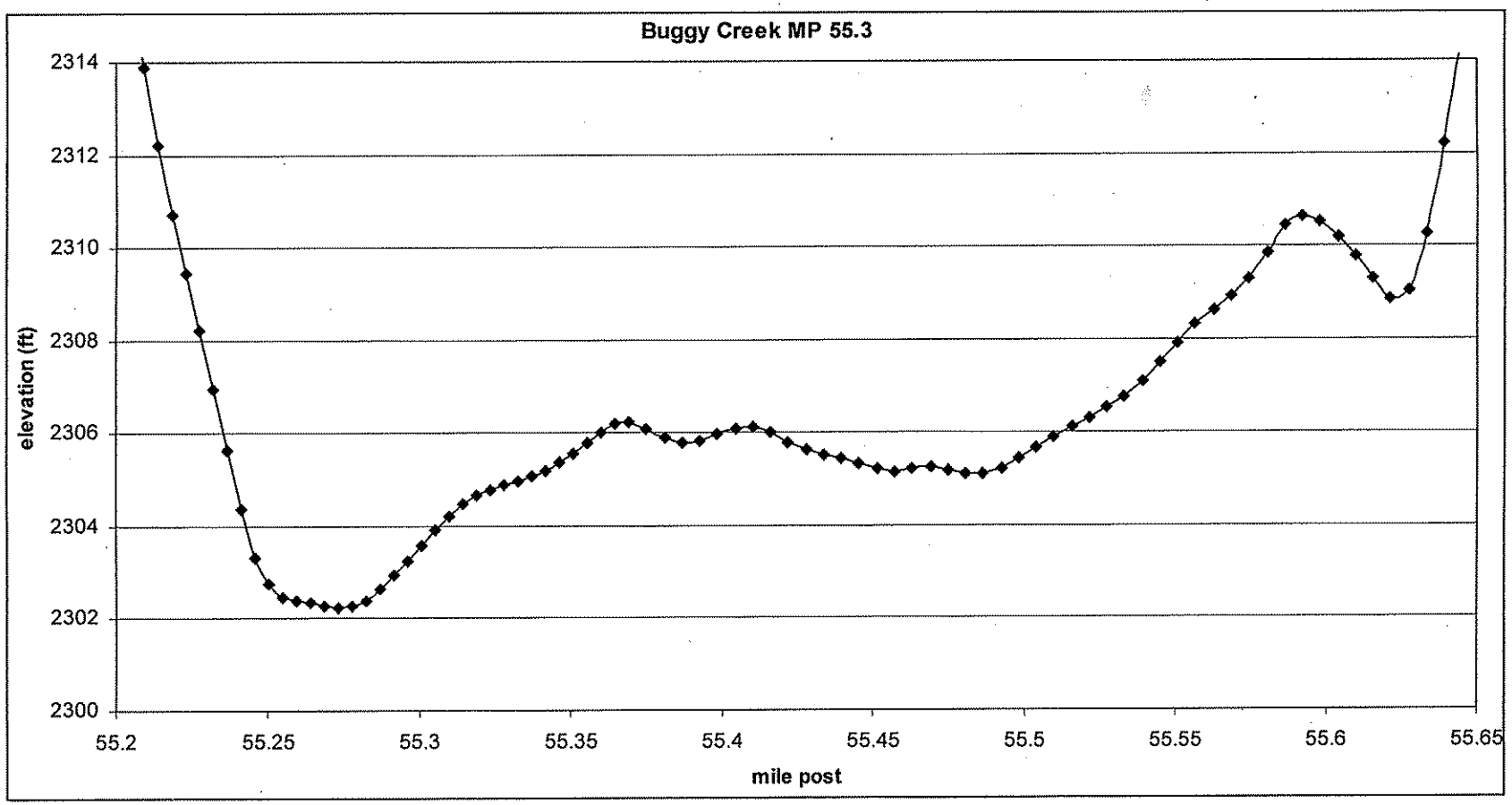
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



CHANNEL CROSS-SECTION SKETCH





*notes – channel cross-section derived from 30 / 10 meter USGS DEM

PLANVIEW MAP

*notes – image background date:

- <10% fines, low impact from turbidity
- could propagate head-cuts if cobble bed is not re-established
  - high energy system/high gradient
- system is currently unstable
- avoidance, maintain 8-10 ft cover below thalweg to the outer extents of the lb+rb high floodplain (300')
- many cottonwoods would be lost (habitat)

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	Buggy Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Regional Regression	92.1	–	–	–	371	1,630	3,179	6,346	9,741	14,250
06172200 Buggy Creek near Tampico MT	105	DS	5.41	10 (1957-1967)	607	2,886	5,248	7,792	11,069	13,326

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: 0.50

Width (ft)	min	max	mean	std dev
	9	14	11	2

meander wavelength (ft) 669

meander amplitude (ft) 176

Sinuosity 1.47

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	55	313	438	226
	1807	725	758	210
	2601	541	1214	380
	3218	361	1597	482
	3418	285	2135	351
	3979	302		

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 40.98

Valley

Gradient 1.1

width	min	max	mean	stnd dev
	381	977	719	208

describe geology (lithology, erodibility):

Alluvium of modern channels and floodplains.

Shale with several zones of calcareous concretions Thickness (984ft)

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:

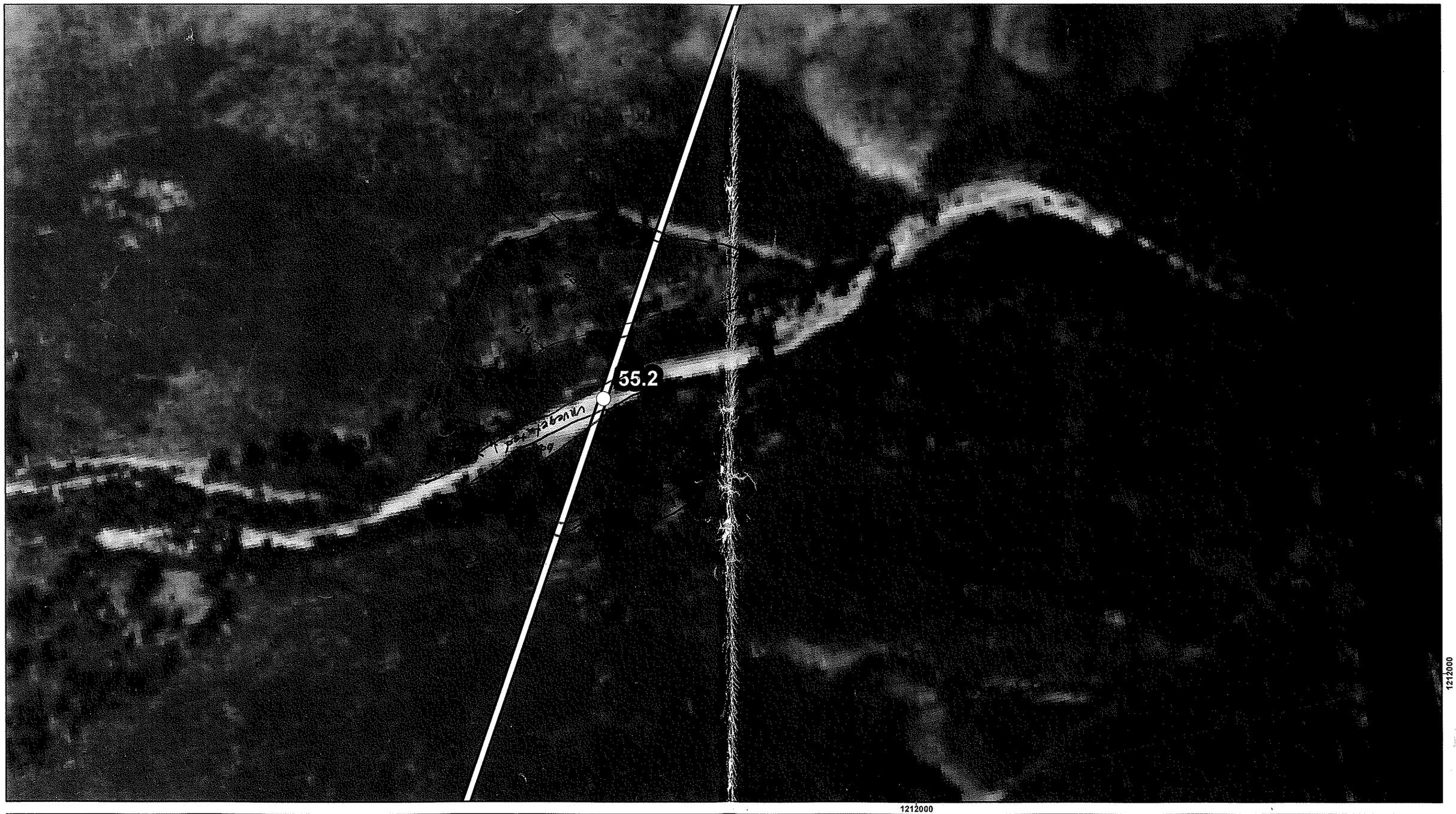
None

channel cut-offs:

US. 1. 4*Relic Channels (0.00-0.35mi river left)

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
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.

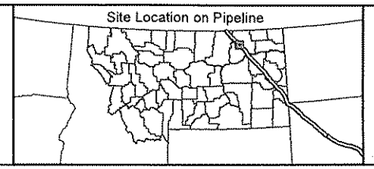
Evidence of landslides upstream or downstream along valley margins (Upstream/downstream? Straight line distance to pipeline along valley axis?):
1. US (0.50 mi, downstream of confluence, river left) there is a steep embankment possible mass wasting.
Describe any infrastructure (bridges, roads, buildings, powerlines, etc) (upstream/downstream with distance to pipeline, if linear feature, right or left bank, perpendicular or parallel):
DS 1. Road (0.30 mi, perp. River Left)
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.



- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Buggy Creek - MILE POST 55.3
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500, Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 50 100 200 Feet

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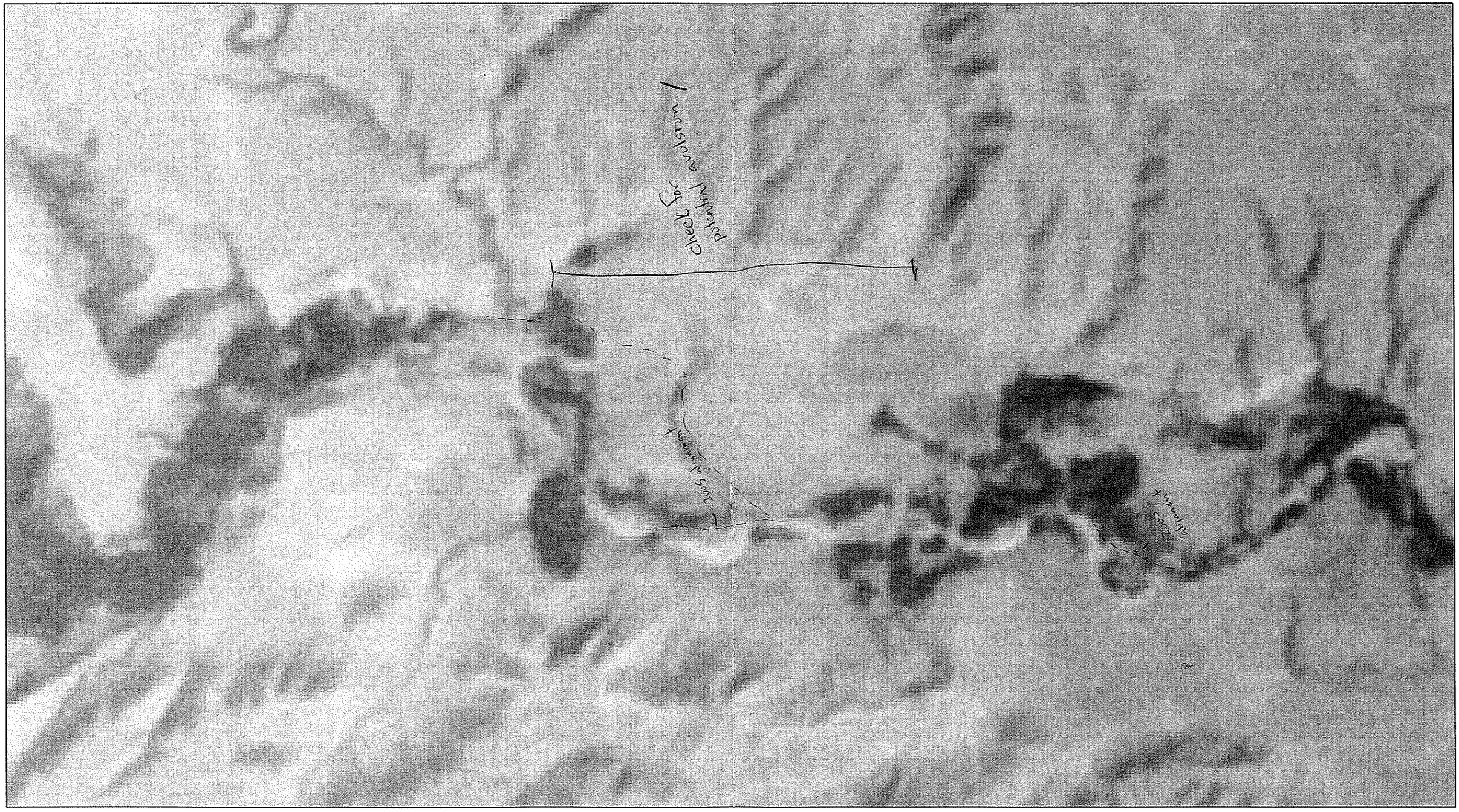
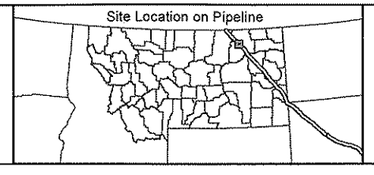
File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd



- Intermittent Stream Crossings
- Perennial Stream Crossings
- SteeleCitySegmentMP
- Proposed Pipeline Route

Aerials: USGS EarthExplorer
http://edcsns17.cr.usgs.gov/EarthExplorer/

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Buggy Creek - MILE POST 55.3
1976 Historic Aerial

ENTRIX
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Seattle, WA 98119
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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Spring Creek MP 59.8			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/6/09
Flow Condition	No Flow - Dry				
General Site Characteristics / Comments	low gradient, meandering, dry channel w/ gravel + sand in bed + banks - minor drainage				
	undulating channel w/ gravel + cobble in some pools separated by				
	sandy topographic high - seasonally low flow path				

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	< 2		
	D_{50}	16 some medium gravel		
	D_{84}	32		
	% sand	<10		
	SOIL CLASS SYMBOL	CG		
Bed (sub-surface)	D_{16}	< 2		
	D_{50}	16		
	D_{84}	32		
	% sand	<10		
	SOIL CLASS SYMBOL	CG		
Bars	D_{16}			
	D_{50}	NA		
	D_{84}			
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	20	% sand	20
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	CL
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	20	% sand	20
	SOIL CLASS SYMBOL	ML	SOIL CLASS SYMBOL	CM

Comments: Aquic Ustifluvents, saline cohesive soils

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 3			Bank Height (ft) 3		
Bank Slope (°) 20			Bank Slope (°) 30		
Woody Cover (%) 0			Woody Cover (%) 0		
Dominant Species grass			Dominant Species grass		
Root Depth (ft) 1.5 Observed (Y) / N			Root Depth (ft) 1.5 Observed (Y) / N		
Undercutting (Y/N) Minor - not recent			Undercutting (Y/N) minor - not recent		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / (N)	Potential (Y) / N	Gradual Migration	Present Y / N	Potential Y / N
Slumping	Present Y / (N)	Potential Y / (N)	Slumping	Present Y / (N)	Potential Y / (N)
Landsliding	Present Y / (N)	Potential Y / (N)	Landsliding	Present Y / (N)	Potential Y / (N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: cohesive bank soils			Notes: cohesive bank soils		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity fine - alluvial deposits		Soil Maturity silt	
Natural Levees (Y/(N))		Natural Levees (Y/(N))	
Description:		Description	
Artificial Levees (Y/(N))		Artificial Levees (Y/(N))	
Description:		Description:	
Side Channels N/A		Side Channels N/A	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/N)	Relic/Abandoned (Y)/N	Intermittent (Y/N)	Relic/Abandoned (Y)/N
~30 ft from LB, ~ 75' US X-ing		~ 20' right of RBE X-ing	
Woody Riparian Buffer Width (ft) 0		Woody Riparian Buffer Width (ft) 0	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species grass + sage		Dominant Woody Species grass + sage	
Crevasse Splays (Y/(N))		Crevasse Splays (Y/(N))	
Crevasse Channels (Y/(N))		Crevasse Channels (Y/(N))	
Notes:		Notes:	

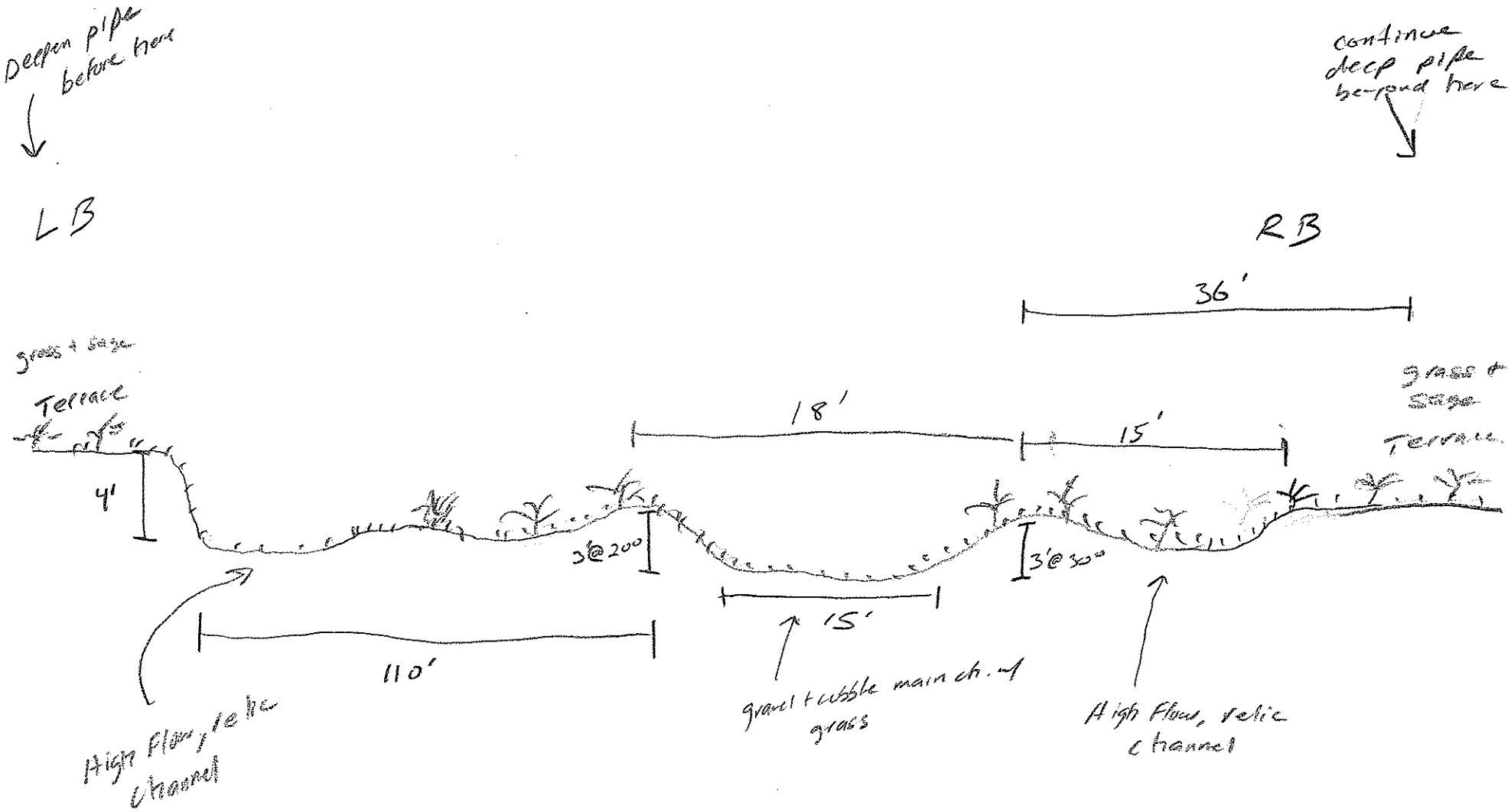
CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 18	Bridges (Y/N)
Bankfull Depth (ft) 3-4'	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) topography	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) most of ch. is	
grassy - bottom width ~ 15'	Roads (Y/N)
Incision Evidence no	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence no	
Bars (Y/N) Vegetated point bars - not	
well defined	
Vegetated Islands (Y/N) - poorly defined flow	
path	
Pool Depths (ft) 2-3	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes:	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

PHOTO CHECKLIST		
Site Overview	☒	D/S 329, 330, 331 - U/S 332, 333, 334, 335, 336
Channel US Showing Both Banks	☒	337
Channel DS Showing Both Banks	☒	338
Channel Bed Surface Alluvium	☒	339 in a pole / 340 bed surface riffle
Channel Bed Sub-Surface Alluvium	☒	341 pole / 342 riffle
Bar Alluvium	☒	N/A
Bars Overview	☒	N/A
Islands Overview	☒	N/A
Left Bank Alluvium	☒	343
Left Bank Toe Detail	☒	344
Left Bank Top of Bank Detail	☒	345
Left Bank Overview	☒	346
Left Floodplain Alluvium	☒	347
Left Floodplain Overview	☒	348
Left Floodplain Landforms	☒	N/A
Right Bank Alluvium	☒	349
Right Bank Toe Detail	☒	350
Right Bank Top of Bank Detail	☒	351
Right Bank Overview	☒	352
Right Floodplain Alluvium	☒	353
Right Floodplain Overview	☒	354
Right Floodplain Landforms	☒	N/A
Infrastructure	☒	N/A
Disturbance/Instability	☒	N/A

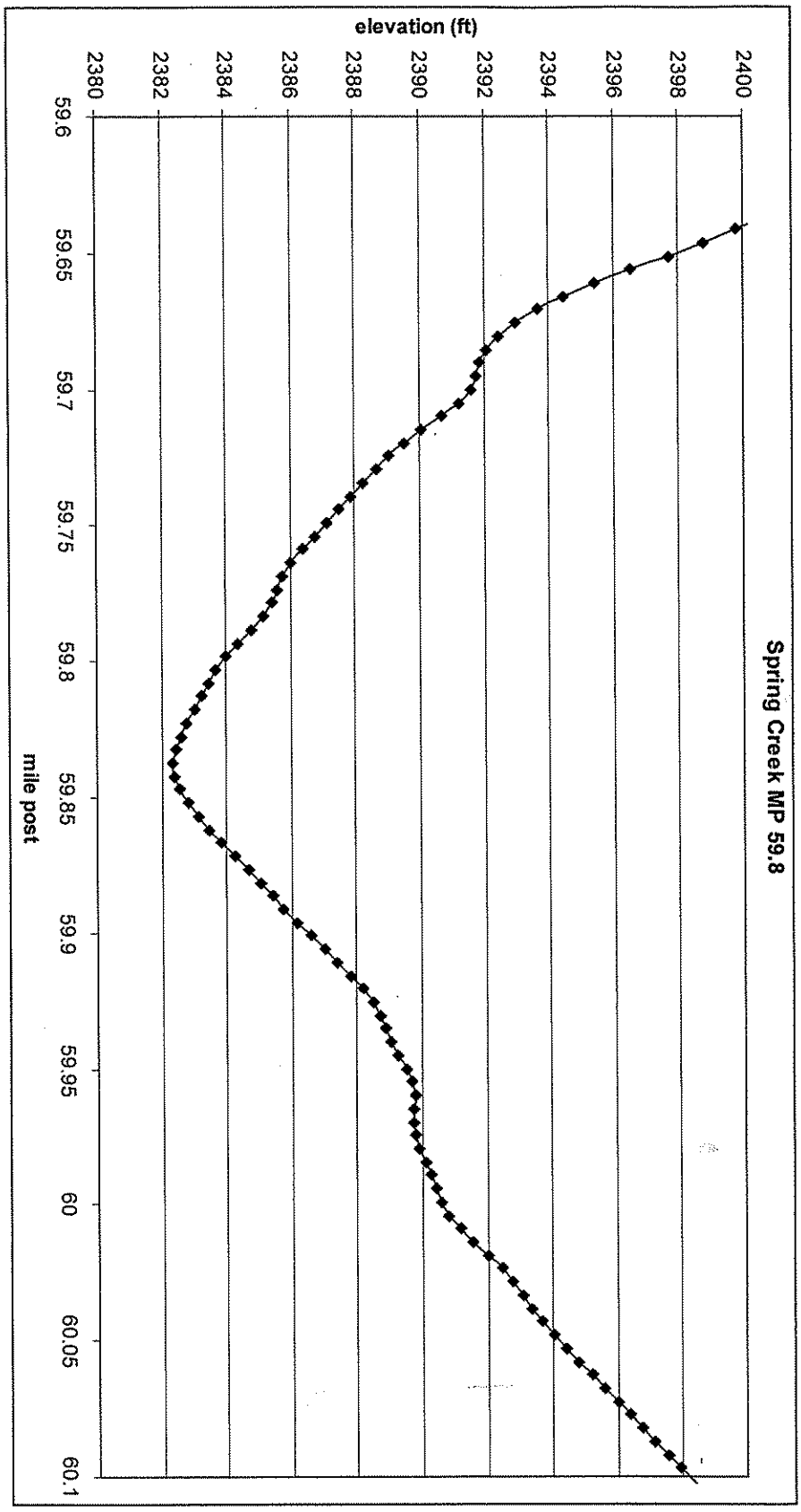
PHOTO LOG		
Photo ID	View Direction	Description

355 - Video Overview


Deepen pipe before here
continue deep pipe beyond here
LB
RB
36'
grass + sage
Terrace
4'
18'
15'
3'@20°
3'@30°
15'
110'
High flow, relic channel
gravel + cobble main ch.
grass
High flow, relic channel

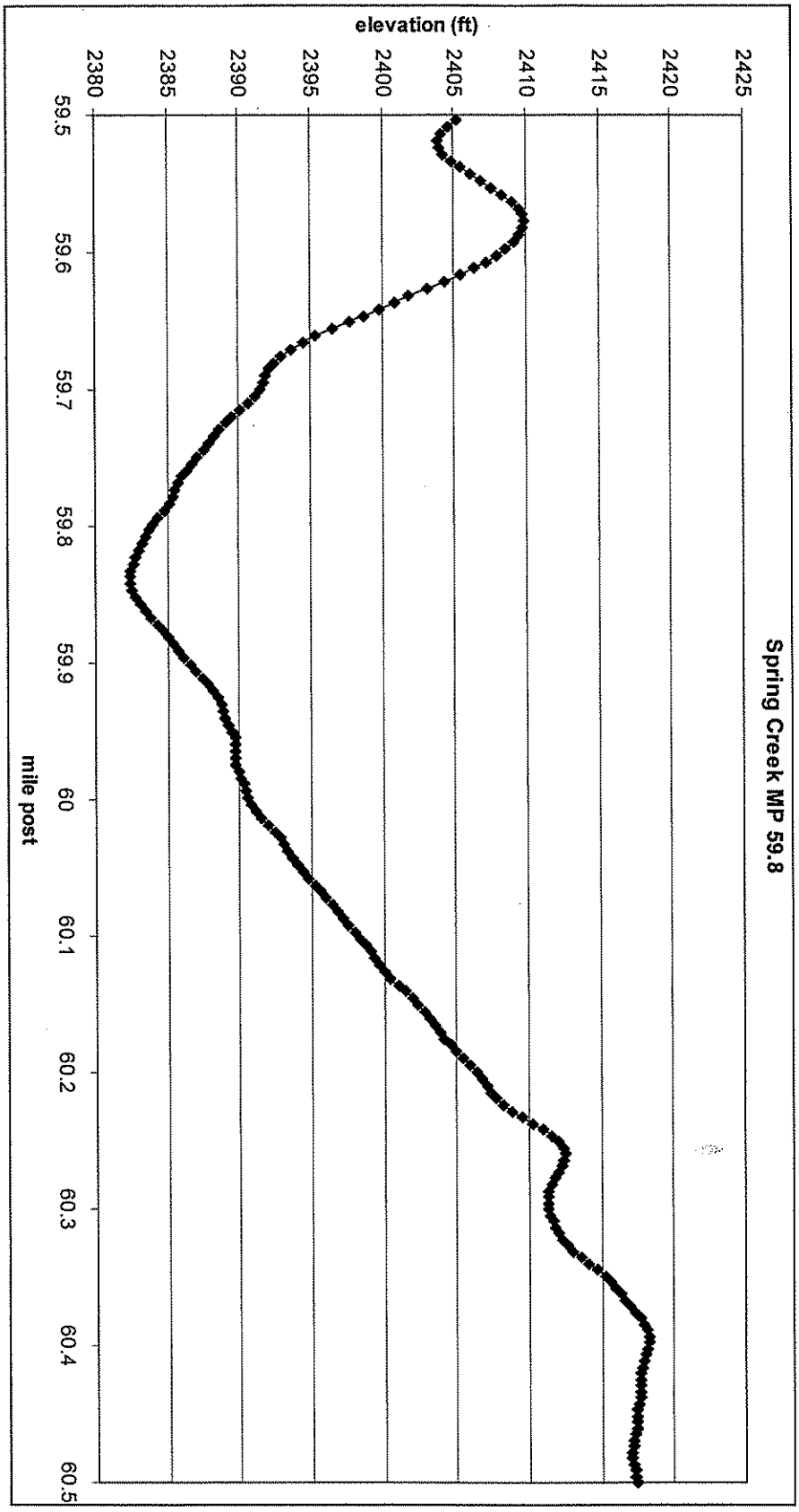
CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

Spring Ck

Questions:

What is the likelihood the project will impact turbidity at the site?

None - no flow

What is the potential impact on incision and erosion?

little

Will the project activate historical instability?

no

What actions or alternatives can mitigate project effects?

deepen pipe excavation depth through cmz - as drawn on mgs

Are there any cumulative effects of pipeline?

no

General Notes:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	**Spring Creek**	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Crossing Regional Regression	10.7	–	–	–	85	412	844	1,769	2.783	4,176
No Gage Station Data Available										

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 : 0.6

Width (ft)	min	max	mean	stnd. dev
	8	12	10	2

meander wavelength (ft) 374

meander amplitude (ft) 163

Sinuosity 1.43

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	97	89	221	168
	489	177	495	205
	817	184	738	222
	1348	157	1076	157

Channel form (braided, anabranching, single thread):

Single thread

Channel confinement at crossing (W_v / W_c):

Valley

Gradient: 0.9

Width (ft)	min	max	mean	stnd dev.
	492	1099	7756	253

describe geology (lithology, erodibility):

Alluvium of modern channels and flood plains

Shale with several zones of calcareous concretions Thickness 984ft

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:

US Oxbow or scour pool (0.00, river right , 0.35 river right)

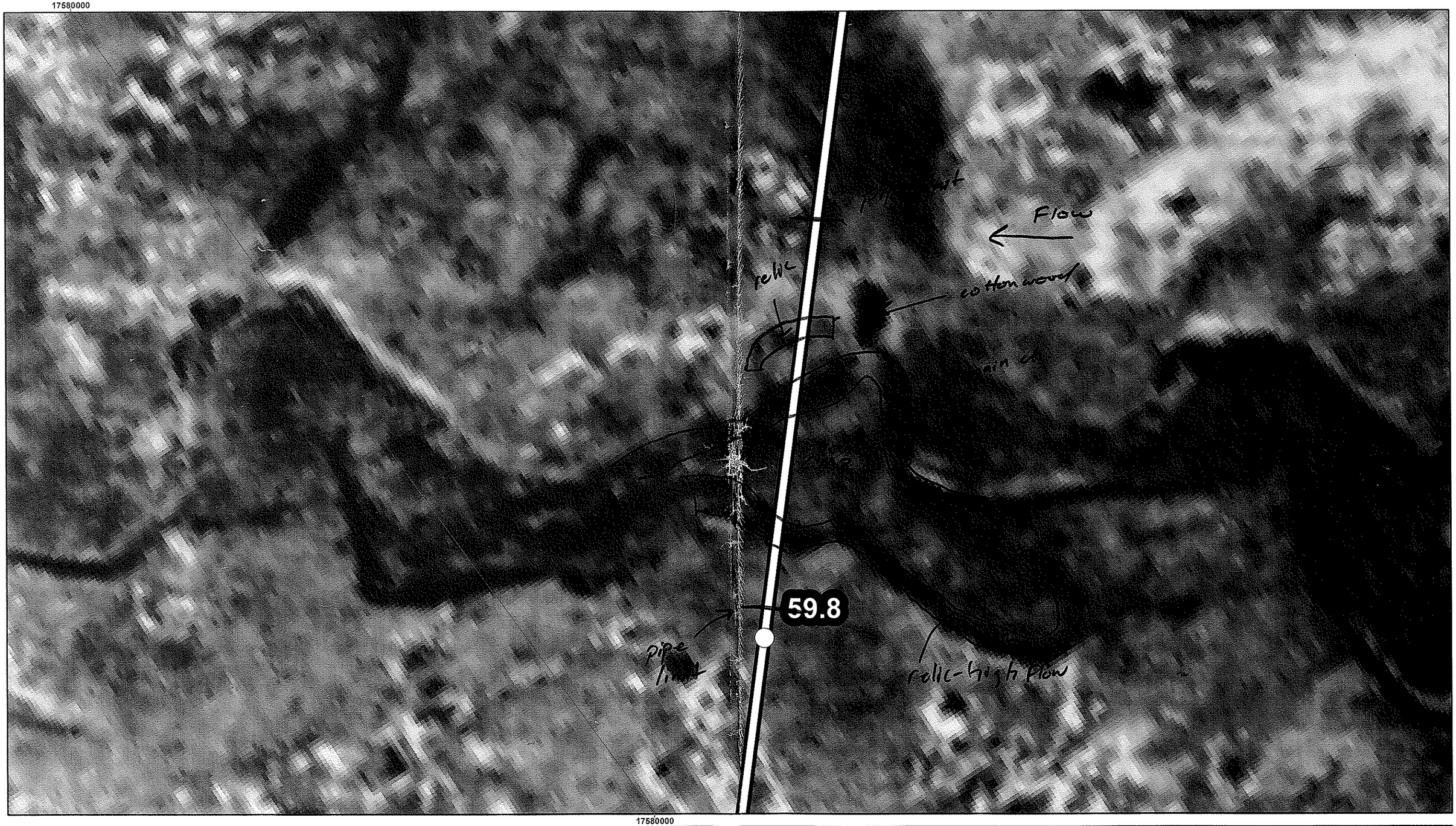
channel cut-offs:

US 1. Avulsion (0.05 mi, river right Due north of crossing) 2. Avulsion (0.34 mi river right, just DS of Oxbow)

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
There is a large relic channel beginning DS of the Oxbow pond (river right)

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. Dam (0.62 mi NNE on different channel)
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
None

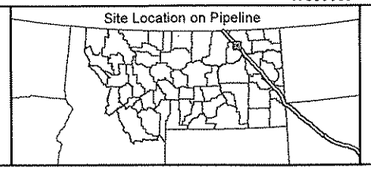
17580000



17580000

Perennial Stream Crossings
Intermittent Stream Crossings
Proposed Pipeline Route
1/10 Mile Post

Aerial: 2005 NAIP



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Spring Creek - MILE POST 59.8
2005 NAIP Aerial

ENTRIX
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Coordinate System: NAD 1983 UTM Zone 13 feet

0 25 50 100 Feet

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File: \\Geomorph\GIS\Keystone-MT Stream Crossing\mxd

KEYSTONE PIPELINE XL GEOMORPHOLOGY FIELD DATA SHEET

Site	Cherry Creek MP 66.9			Surveyors	BB
GPS	WP:	N:	E:	Date/Time	8/6/09
Flow Condition					

General Site Characteristics / Comments: Dry channel, meandering gravel bed pool + riffle channel w/ grasses in bed. Dense grass cover on stable banks trees line banks (see photos), mostly grassy FP

- Discontinuous swales/depressions on LB Floodplain - no risk for channel avulsion

- see pipeline re-route on MAP

ALLUVIUM / SUBSTRATE

Bed (surface)	Armored (Y/N) If Yes, enter Bed (subsurface)			
	D_{16}	8		
	D_{50}	32		
	D_{84}	128		
	% sand	<5		
	SOIL CLASS SYMBOL	GW		
Bed (sub-surface)	D_{16}	2		
	D_{50}	8		
	D_{84}	32		
	% sand	GM		
	SOIL CLASS SYMBOL			
Bars	D_{16}	NA		
	D_{50}	will be inundated		
	D_{84}	with flow = riffles		
	% sand			
	SOIL CLASS SYMBOL			
Banks	RIGHT BANK		LEFT BANK	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	<5	% sand	<5
	SOIL CLASS SYMBOL	CL	SOIL CLASS SYMBOL	CL
Flood-plain	RIGHT FLOODPLAIN		LEFT FLOODPLAIN	
	D_{16}		D_{16}	
	D_{50}		D_{50}	
	D_{84}		D_{84}	
	% sand	<5	% sand	<5
	SOIL CLASS SYMBOL	CL	SOIL CLASS SYMBOL	CL

Comments: Mostly Ustic Torrifluvents soils 75

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	
	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

LEFT BANK PARAMETERS			RIGHT BANK PARAMETERS		
Bank Height (ft) 3-5, if riffle or pool			Bank Height (ft) 3-5 if riffle or pool		
Bank Slope (°) 20 to 90° on outer bends			Bank Slope (°) 15-20 to 90° on outer bends		
Woody Cover (%) 20			Woody Cover (%) 20		
Dominant Species see photos			Dominant Species		
Root Depth (ft) 1-2 grasses Observed (Y) N tree root depth?			Root Depth (ft) 1-2 grasses Observed (Y) N Tree root dpth?		
Undercutting (Y/N)			Undercutting (Y/N)		
Bank Failure			Bank Failure		
Gradual Migration	Present Y / (N)	Potential (Y) N	Gradual Migration	Present Y / (N)	Potential (Y) N
Slumping	Present Y / (N)	Potential (Y) N	Slumping	Present Y / (N)	Potential (Y) N
Landsliding	Present Y / (N)	Potential Y / (N)	Landsliding	Present Y / (N)	Potential Y (N)
Other:	Present Y / N	Potential Y / N	Other:	Present Y / N	Potential Y / N
Notes: Stable banks			Notes: Stable banks		

LEFT FLOODPLAIN PARAMETERS		RIGHT FLOODPLAIN PARAMETERS	
Soil Maturity little		Soil Maturity little	
Natural Levees (Y/N)		Natural Levees (Y/N)	
Description:		Description	
Artificial Levees (Y/N)		Artificial Levees (Y/N)	
Description:		Description:	
Side Channels		Side Channels	
Perennial (Y/N)	Ephemeral (Y/N)	Perennial (Y/N)	Ephemeral (Y/N)
Intermittent (Y/N)	Relic/Abandoned (Y/N)	Intermittent (Y/N)	Relic/Abandoned (Y/N)
Discontinuous 1-2' deep depressions w/ cottonwoods			
Woody Riparian Buffer Width (ft) 10-15		Woody Riparian Buffer Width (ft) 10-15	
Woody Riparian Plant Density (L,M,H)		Woody Riparian Plant Density (L,M,H)	
Dominant Woody Species unknown - see photos		Dominant Woody Species unknown - see photos	
Crevasse Splays (Y/N)		Crevasse Splays (Y/N)	
Crevasse Channels (Y/N)		Crevasse Channels (Y/N)	
Notes:		Notes:	

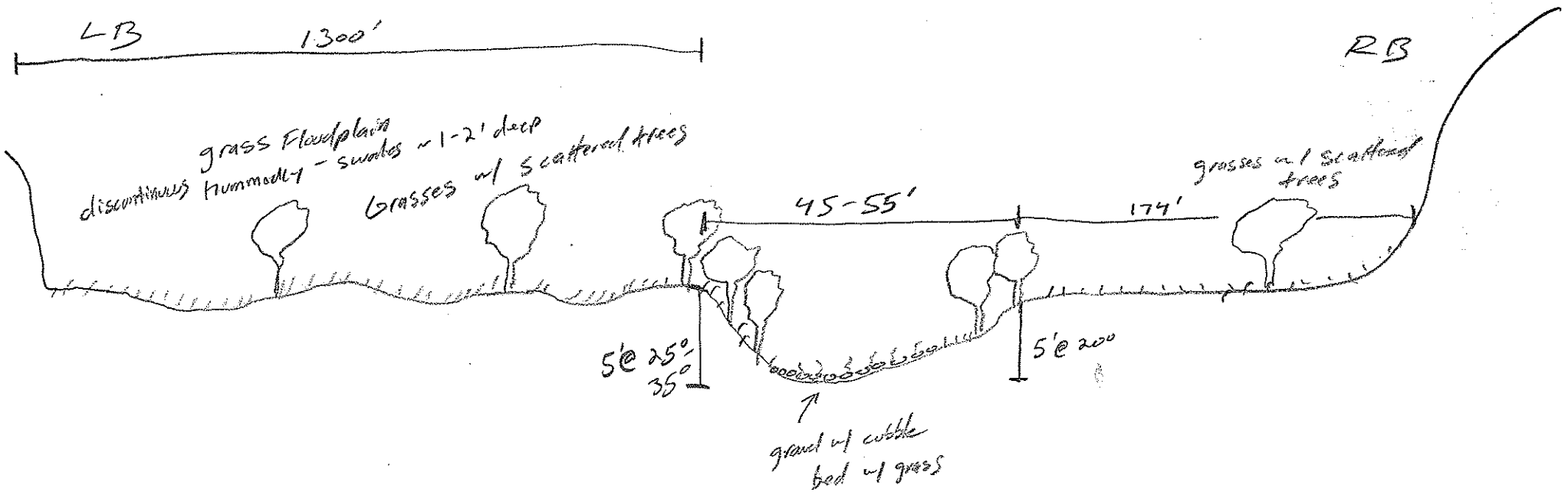
CHANNEL MORPHOLOGY	INFRASTRUCTURE
Bankfull Width (ft) 45-55'	Bridges (Y/N)
Bankfull Depth (ft) ~4' on average	Distance from Crossing (ft) U.S. / D.S.
Bankfull Indicator(s) topography - Top of banks	Associated Instability (Y/N)
	Pier Scour Present (Y/N) If yes, depth:
Unvegetated Channel Width (ft) varies 5-15'	
	Roads (Y/N)
Incision Evidence NO	(RR, LB, US, DS)
	Other Infrastructure
Aggradation Evidence NO	
Bars (Y/N)	
Vegetated Islands (Y/N)	
Pool Depths (ft) 3-5'	
Channel In Low Elevation of Valley Floor (Y/N)	
Notes: Rick - 5' excavation depth below channel is based on max pool depth w/in ~ 50' US & DS of X-ing	Notes:

CHANNEL DISTURBANCE/PERTERBATIONS None	
Natural	Artificial
Beaver dams	In-stream structures
Debris flow	
	Flow Diversion
Landslides	
	Debris
Woody debris	
Other:	Other:

PHOTO CHECKLIST		
Site Overview	☒	D/S → U/S 405, 406, 407, 408, 409 (410 right slope)
Channel US Showing Both Banks	☒	411, 412, 413
Channel DS Showing Both Banks	☒	414, 415, 416
Channel Bed Surface Alluvium	☒	417
Channel Bed Sub-Surface Alluvium	☒	418
Bar Alluvium	☒	N/A
Bars Overview	☒	N/A
Islands Overview	☒	N/A
Left Bank Alluvium	☒	419
Left Bank Toe Detail	☒	420
Left Bank Top of Bank Detail	☒	421
Left Bank Overview	☒	422
Left Floodplain Alluvium	☒	423
Left Floodplain Overview	☒	424, 425, 426, 427 W/S to D/S
Left Floodplain Landforms	☒	428, 429
Right Bank Alluvium	☒	430
Right Bank Toe Detail	☒	431
Right Bank Top of Bank Detail	☒	432
Right Bank Overview	☒	433
Right Floodplain Alluvium	☒	434
Right Floodplain Overview	☒	435, 436, 437, 438 U/S to D/S
Right Floodplain Landforms	☒	N/A
Infrastructure	☒	N/A
Disturbance/Instability	☒	N/A

PHOTO LOG		
Photo ID	View Direction	Description
440		Tree species unknown
441		" "

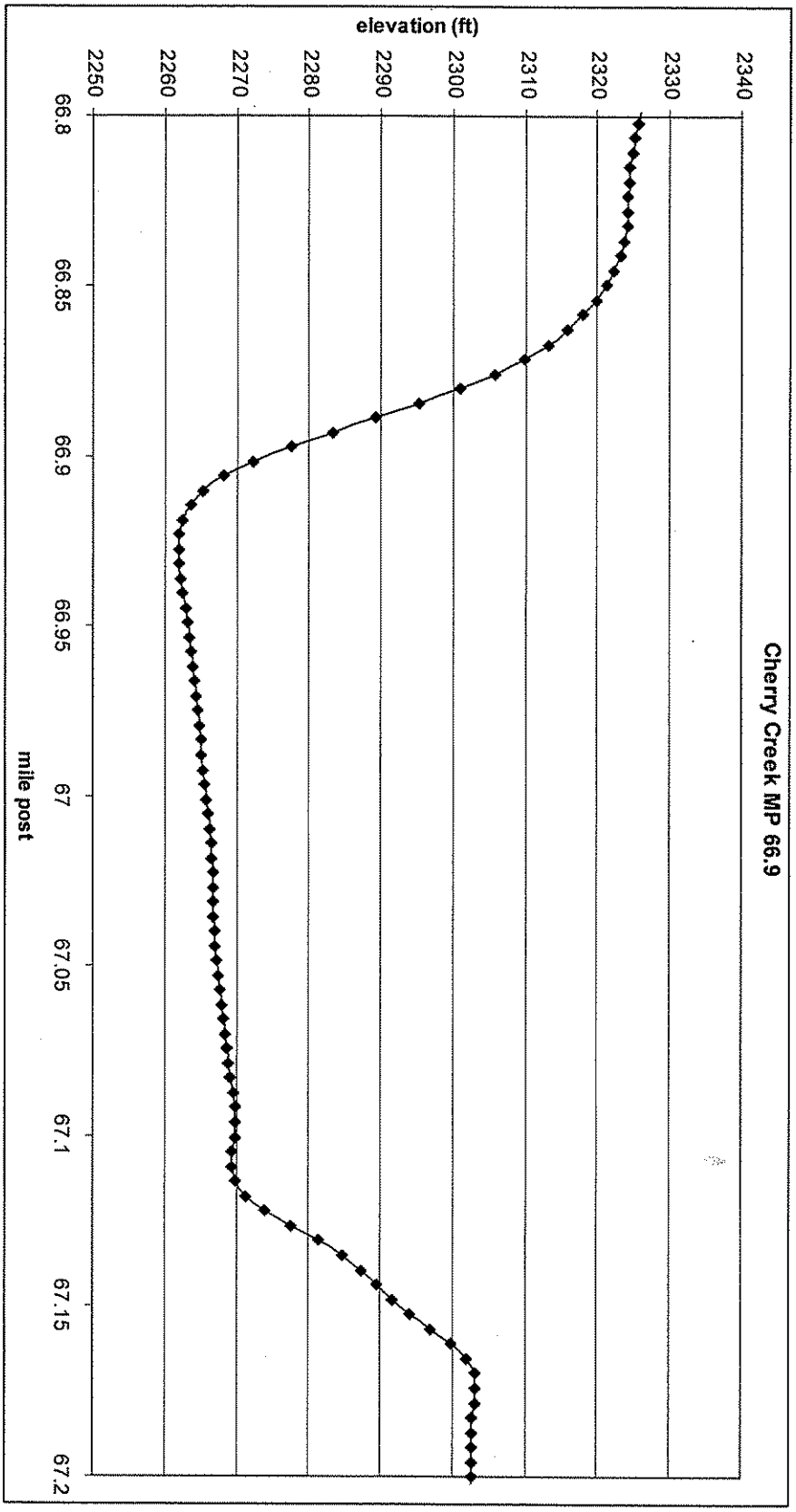
439 - Video



pipeline depth only needs to be designed @ main channel, 5' deeper than local point depths

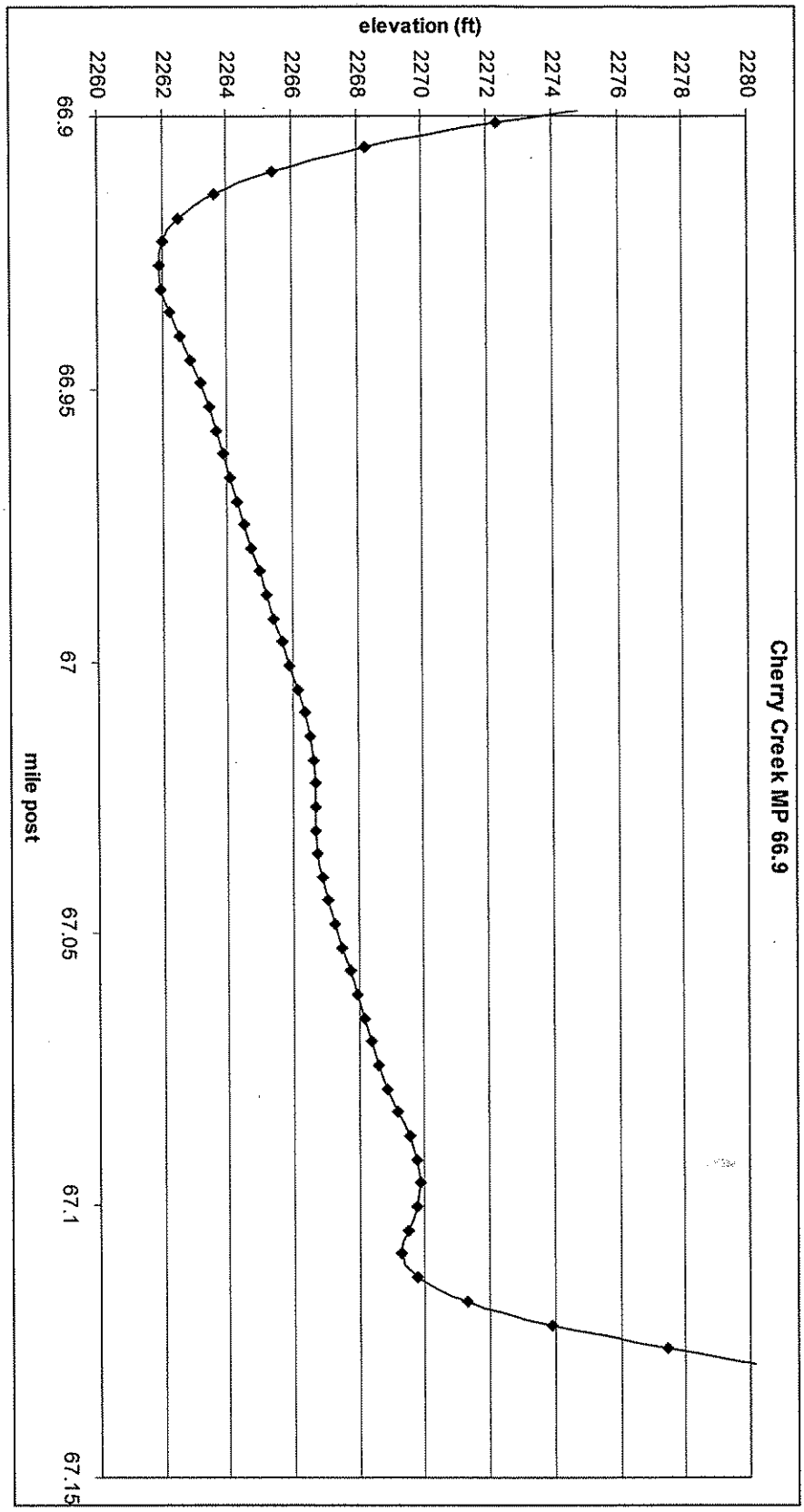
VALLEY CROSS-SECTION SKETCH

*notes – valley cross-section derived from 30 / 10 meter USGS DEM



CHANNEL CROSS-SECTION SKETCH

*notes – channel cross-section derived from 30 / 10 meter USGS DEM



PLANVIEW MAP

*notes – image background date:

Cherry Creek

Questions:

What is the likelihood the project will impact turbidity at the site?

low - Dry channel

What is the potential impact on incision and erosion?

low -

Will the project activate historical instability?

NO

What actions or alternatives can mitigate project effects?

Set 5' deep pipe @ X-ing based on max pool depths @ site

Are there any cumulative effects of pipeline?

NO

General Notes:

KEYSTONE PIPELINE XL GEOMORPHOLOGY OFFICE DATA SHEET

Site	Cherry Creek	Date	08/03/09
Done by: GF	1st Review:	Final Review:	

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
Regional Regression	54.2	--	--	--	262	1,198	2,377	4,836	7,498	11,084
No Gage Station Data Available										

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: 0.3

Width (ft)	min	max	mean	stnd dev
	10	16	12	2

meander wavelength (ft) 627

meander amplitude (ft) 264

Sinuosity 1.49

radius of curvature (ft)	Upstream (ft)		Downstream (ft)	
	distance from crossing	radius of curvature	distance from crossing	radius of curvature
	196	5307	1617	270
	238	5779	2116	299
	237	6344	2436	175
			3611	502
			4595	229

Channel form (braided, anabranching, single thread):

Single Thread

Channel confinement at crossing (W_v / W_c): 47.1

Valley

Gradient: 0.3

width	min	max	mean	stnd dev
	695	1312	1059	258

describe geology (lithology, erodibility):

Alluvium of modern channels and flood plains

Shale with several zones of calcareous concretions Thickness (984ft)

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:

US 1. Avulsion (0.25 mi River Left,) 2. Multithreaded channel (0.10 mi upstream of culvert crossing)

What is elevation of the channel relative to the floodplain (perched, incised)? What is evidence?
The floodplain elevation is greater than the elevation of the channel's water surface.
Unique features, exceptions, etc: There are several road crossing (possibly with culverts) near this crossing.
There could have been more avulsions in the past but due to land use activity, it is difficult to determine where these occurred.

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 (0.30 mi river left, par.) 2. Buildings (0.40 mi river right) DS 1. Buildings (0.40 mi, river left)
If visible, describe any direct or indirect evidence of general scour/channel incision (straightened channel, etc):
It appears that the channel near the crossing has been straightened due to the longer wavelength and smaller amplitudes at this location as compared to US & DS.

17552000

17556000

1248000

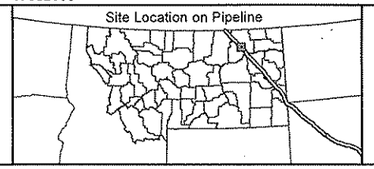
17552000

17556000

- Perennial Stream Crossings
- Intermittent Stream Crossings
- Proposed Pipeline Route
- 1/10 Mile Post

Aerial: 2005 NAIP

Site Location on Pipeline



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Cherry Creek - MILE POST 66.9
2005 NAIP Aerial

ENTRIX
200 1st Ave W Ste 500
Seattle, WA 98119
ph (206) 269-0104
fx (206) 269-0098
www.entrix.com

Coordinate System: NAD 1983 UTM Zone 13 feet

0 225 450 900 Feet

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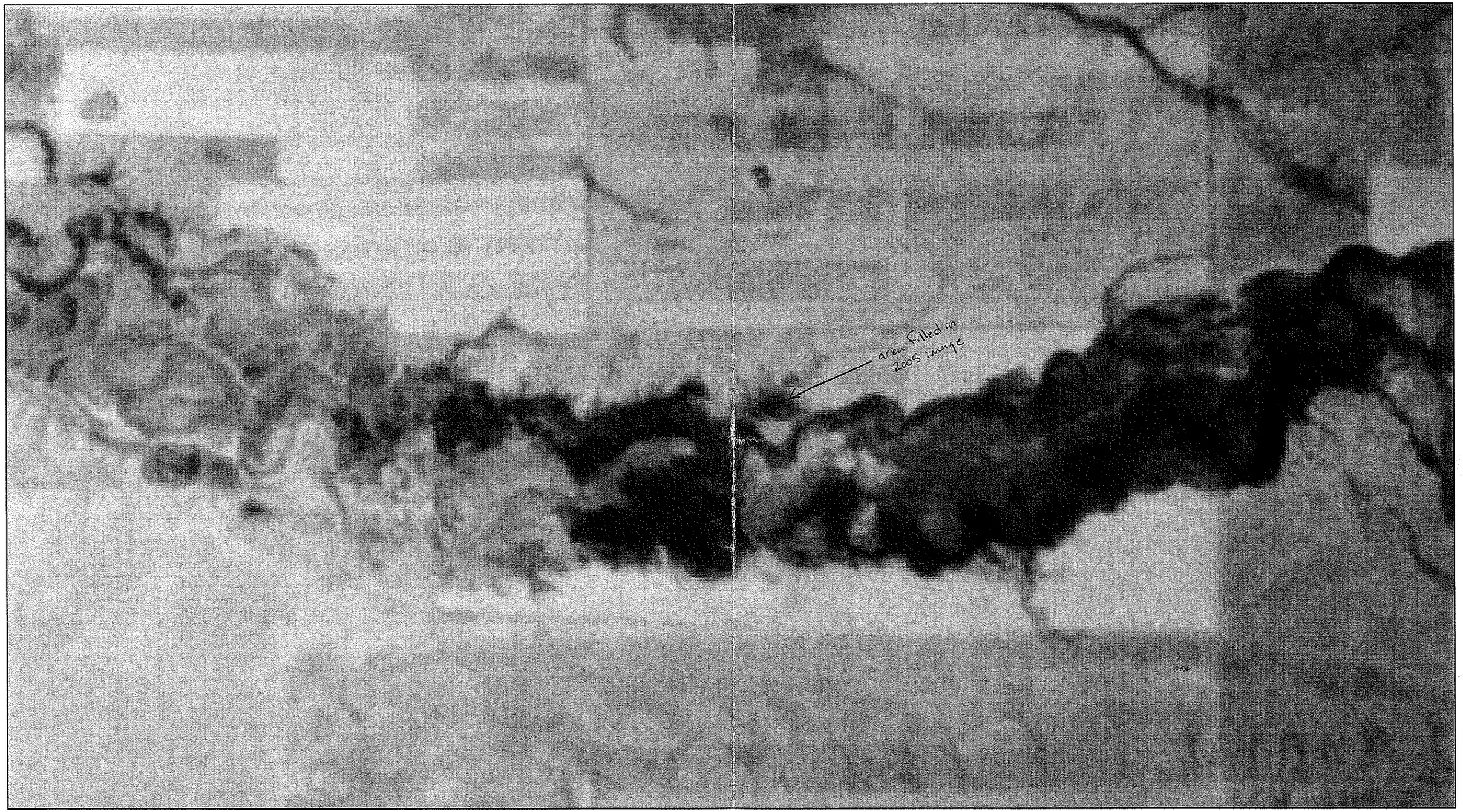
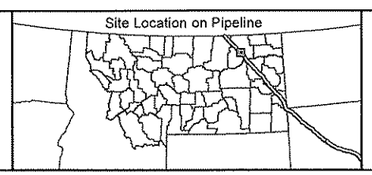
File: \\GeomorphGIS\Keystone-MT Stream Crossing\mxd



- Intermittent Stream Crossings
- Perennial Stream Crossings
- SteeleCitySegmentMP
- Proposed Pipeline Route

Aerials: USGS EarthExplorer
http://edcsns17.cr.usgs.gov/EarthExplorer/



KEYSTONE XL PIPELINE EIS
GEOMORPHOLOGY ASSESSMENT

Cherry Creek - MILE POST 66.9
1976 Historic Aerial

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