

Appendix E
Troy Mine Mill Site Conceptual
Channel Design



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Draft Memorandum

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Date: December 3, 2010

Subject: Troy Mine Mill Site Conceptual Channel Design

CDM has prepared a design and cost estimate for a conceptual drainage channel design at the Troy Mine mill site to support the *Draft Environmental Assessment* currently being prepared for final reclamation of the mine. The mill pad and waste rock dump located just below the mine portal are built across a drainage that enters the site from the west. Currently water from this drainage is collected in a detention basin on the upslope side of the millsite and routed beneath the mill site through two culverts to the downslope side of the site where it enters Stanley Creek. The culverts are over 600 feet long and could not be maintained with any assurance in the long term. Under the Agency-Mitigated Alternative for the reclamation plan, these culverts will be plugged and the drainage channel reconstructed over or around the mill pad/waste rock dump.

The purpose of this memorandum is to present a conceptual design for the new channel and provide approximate reclamation costs for construction of the new channel. Maintenance of the new channel is designed to be minimal and should not extend beyond the first few years after construction.

Alternative Considered but not Selected

The most desirable solution for channel design is removal of the fill at the mill site patio and construction of a channel along the original natural alignment at the original grade. This solution would eliminate the difficulty of maintaining a stable channel on the face of the fill and allow for a construction of a naturally functioning channel, which could minimize long-term maintenance costs. However, rebuilding the original channel for the larger drainage will require removing a large portion of the mill site fill. It will also require relocating the access road and buried pipeline that are currently at the mill site.

Two scenarios were investigated to determine the feasibility of establishing a more natural channel gradient across the site. In the first scenario, the existing twin culverts would be

plugged and the surrounding depression filled. The channel would cross the filled depression and follow an approximate 4H:1V grade to the toe of the mill site fill slope at the location of the original channel. For estimation purposes, it is assumed that the bottom width of the cut would be 24 feet to accommodate the new channel, and the side slopes of the cut would rise at 2H:1V. An AutoCAD drawing of the required cut is attached as Figure 1. The volume of cut would be 71,000 cy. The excavated material would be transported to the relatively flat portion of the mill site, where it would be placed in lifts and compacted to form a fill at a slope no greater than 2H:1V.

A second scenario would plug the twin culverts but begin excavation approximately at the top of the culverts. The channel would be excavated at a slightly lesser gradient because it is starting at a lower elevation, and would terminate at the some point in the original channel. This layout results in about 110,000 cy of excavation. Although this channel is presumably near the original channel grade, it may not replicate the original channel because we do not know the alignment of the original channel.

If we assume the excavation can be accomplished for about \$4 per cubic yard, the cost of excavation would be in the range of \$280,000 to \$440,000. This cost would be in addition to costs for building the new channel and revegetating the fresh cut slopes. Because of the greatly increased cost of this alternative compared to the costs of the options discussed below, this alternative was not pursued further.

Selected Alternative

Two options for the selected alternative were considered for evaluation as shown in the attached Figure 2. Both options originate from the end of the natural channel above the current detention basin, which will be backfilled during reclamation. Option 1 routes the drainage in an easterly direction across the top of the reclaimed mill pad/waste rock dump, down the face of the dump and into an energy dissipation basin before discharging to the original channel and Stanley Creek. These options are shown on the attached layout for the mill site.

Option 2 routes the water to the northeast on reclaimed ground until it reaches the north end of the mill pad/waste rock dump where it descends a steep slope. At the base of the steepest portion of the slope, an energy dissipation basin will reduce the velocity of the stream before it is routed through a constructed channel the remaining distance to Stanley Creek.

There is a minor drainage that enters the southern portion of the mill site that would also be routed across the mill patio to the road. Then it would be routed on the uphill (west) side of the road to the larger channel.. This would require shaping a small channel through the reclaimed area and lining it with appropriately sized rock. This design applies to Option 1 or Option 2. These costs are incidental compared to the costs for the main drainage and are not considered further in this memorandum.

Hydrology and Hydraulics

The design storm for permanent drainage channels at mine sites in Montana is the 100-year 24-hour storm. The Forest Service sizes culverts for the 100-year peak flow, which is the event that occurs with a probability of 1% in any given year. The 100-year flow was calculated using the USGS *Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998* (Parrett and Johnson, 2004). It was assumed that a burn could occur in the even-aged forest in this tributary drainage so a forest cover factor of 50% was used to represent 50% crown kill. The calculated 100-year flow under this condition is 33 cfs. An attachment provides documentation of the calculation.

Hydraulic calculations were performed using the Bathurst resistance calculation method as described in the *Stormwater Collection Systems Design Handbook* (Mays, 2001, Section 16.5). This iterative method determines the rock size necessary to prevent movement of the rock with a selected factor of safety. A typical industry standard factor of safety of 1.3 was selected for this calculation. This method is specifically meant for steep (greater than 10%) channel slopes where Manning's equation is not valid. Calculations show that a channel with a bottom width of 3 feet and side slopes of 2H:1V will be more than adequate to accommodate the calculated peak flow. The attached sketch shows the typical cross-sections for gentler and steeper portions of the channel.

For the portions of the channel with a slope of less than 10%, a rock size of $d_{50} = 16$ inches was calculated. For the steeper portions of the channels (77% for Option 1 and 50% for Option 2) a $d_{50} = 5.6$ feet is required. The latter gradation will range from a d_{10} of 2.8 feet to a d_{90} of 7 feet. Excel spreadsheet calculations are attached.

Conceptual Design

The channel options were designed as rock-lined channels using guidance from the USACE manual *Hydraulic Design of Flood Control Channels* (ASCE, 1995). The design includes a 9-inch thick filter bed of $d_{50} = 6$ inches beneath the riprap. Below this will be 1-inch minus bedding to protect the liner to be constructed where the channel crosses the mill patio. The liner will prevent infiltration of water into the mill fill. This liner could be constructed of HDPE, geosynthetic clay liner (GCL), or clay. Bedding material may need to be placed below the liner as well to provide a suitable surface for installation.

On the steep portion of the channel, installation of a liner will not be feasible. Riprap should be underlain by rock filter layers that prevent scour of the underlying material. It may be that appropriate sized material is already in place in this portion of the mill site, and it will not be necessary to place filter layers in that case.

The design includes a four foot culvert for passage of the drainage beneath the realigned and reconstructed road. A four foot culvert is oversized for the design flow and slope but is preferred to smaller sizes because of its ability to pass debris more readily.

The energy dissipation basin at the base of the steep slopes is intended to reduce velocities before a milder channel routes the discharge to Stanley Creek. The final design of this basin is recommended to be in accordance with US Department of Transportation (USDOT) guidelines (USDOT, 1975) for energy dissipaters. For purposes of this conceptual design, it is assumed that a basin 30 feet wide and 50 feet long will be more than adequate to dissipate energy from the design storm. The rock size for the basin is assumed to have a d_{50} of 16 inches but this may need to be adjusted during final design.

Although this channel has been designed for cost estimating purposes as a riprap channel, modifications can be made to provide a more natural appearance and function, especially in the gentler reaches. Woody debris can be incorporated between the rocks, rocks can be arranged to create step pools, and shrubs and trees can be planted between rocks on the banks. However, the framework of large rock sizes is still needed throughout the channel to provide stability under high flows. Addition of these items will increase installation time but should not significantly affect material costs relative to the high cost of the rock.

Both options present construction problems with using large rock on steep slopes. The 2H:1V slope of Option 2 is tractable with conventional equipment. Placement of large rock on the angle of repose slope of Option 1 will be more difficult. Equipment tethered from above may be able to shape the channel and place the required large rock. If sufficiently large rock is already present in the face of the dump, it may not be necessary to place rock here, making this option more attractive. However, without incising a channel in the face with equipment there will be no certainty that the discharge will be funneled to the energy dissipation basin.

Cost Estimate

A cost estimate for each option was prepared and these are attached to this memorandum. The largest and most uncertain cost is the cost of providing and placing rock. It is assumed that the $d_{50} = 16$ -inch and $d_{50} = 6$ -inch gradations can be found in the waste rock dump or other nearby areas and a cost of \$30/cy will be sufficient for collection and placement of these materials. However, the $d_{50} = 5$ -foot plus rock may need to be imported from a greater distance. A cost of \$60/cy has been used for this rock assuming it can be found within 30 miles.

Other elements accounted for in the cost estimates are mobilization, erosion control, clearing and grubbing of timbered areas, installation of a culvert, and construction of an access road from the existing access road to construct the energy dissipater. Construction costs include a 15% contingency. Engineering design and oversight costs are estimated at 20% of construction costs. The total cost estimate for Option 1 is about \$238,000 and the estimated total cost of Option 2 is \$290,000. The attached cost sheets present breakdowns of the estimated costs of the two options.

References

- American Society of Civil Engineers, 1995. Hydraulic Design of Flood Control Channels. Technical Engineering and Design Guides as Adapted from the US Army Corps of Engineers, No. 10. New York, N. Y.
- Mays, L., 2001. Stormwater Collection Systems Design Handbook.
- Parrett, C. and D.L.R. Johnson, 2004. Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998. US Geological Survey Water-Resources Investigations Report 03-4308, Helena MT. February 2004.
- US Department of Transportation, 1975. Hydraulic Design of Energy Dissipators for Culverts and Cahnnels. Hydraulic Engineering Circular No. 14. June 1975.

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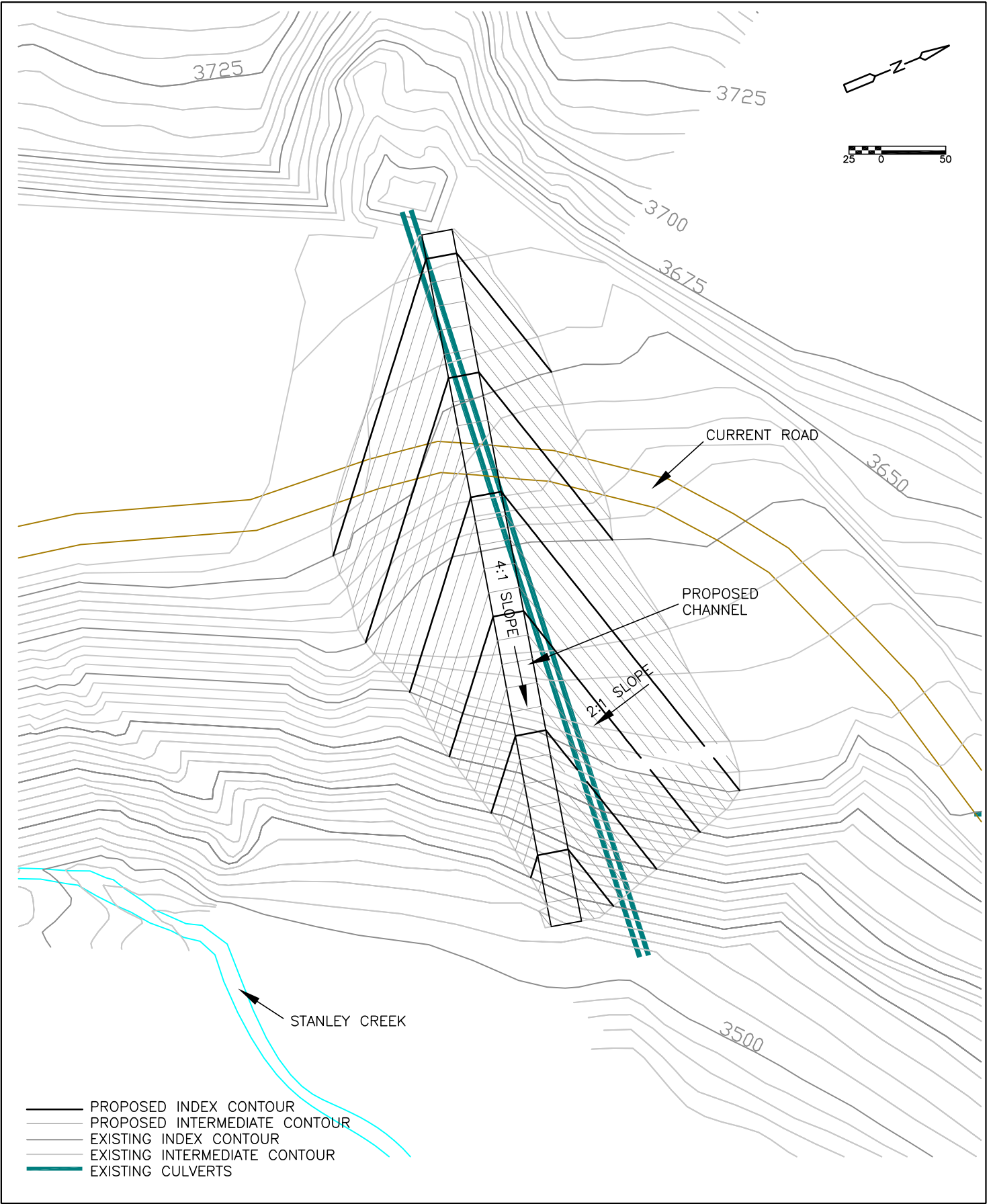
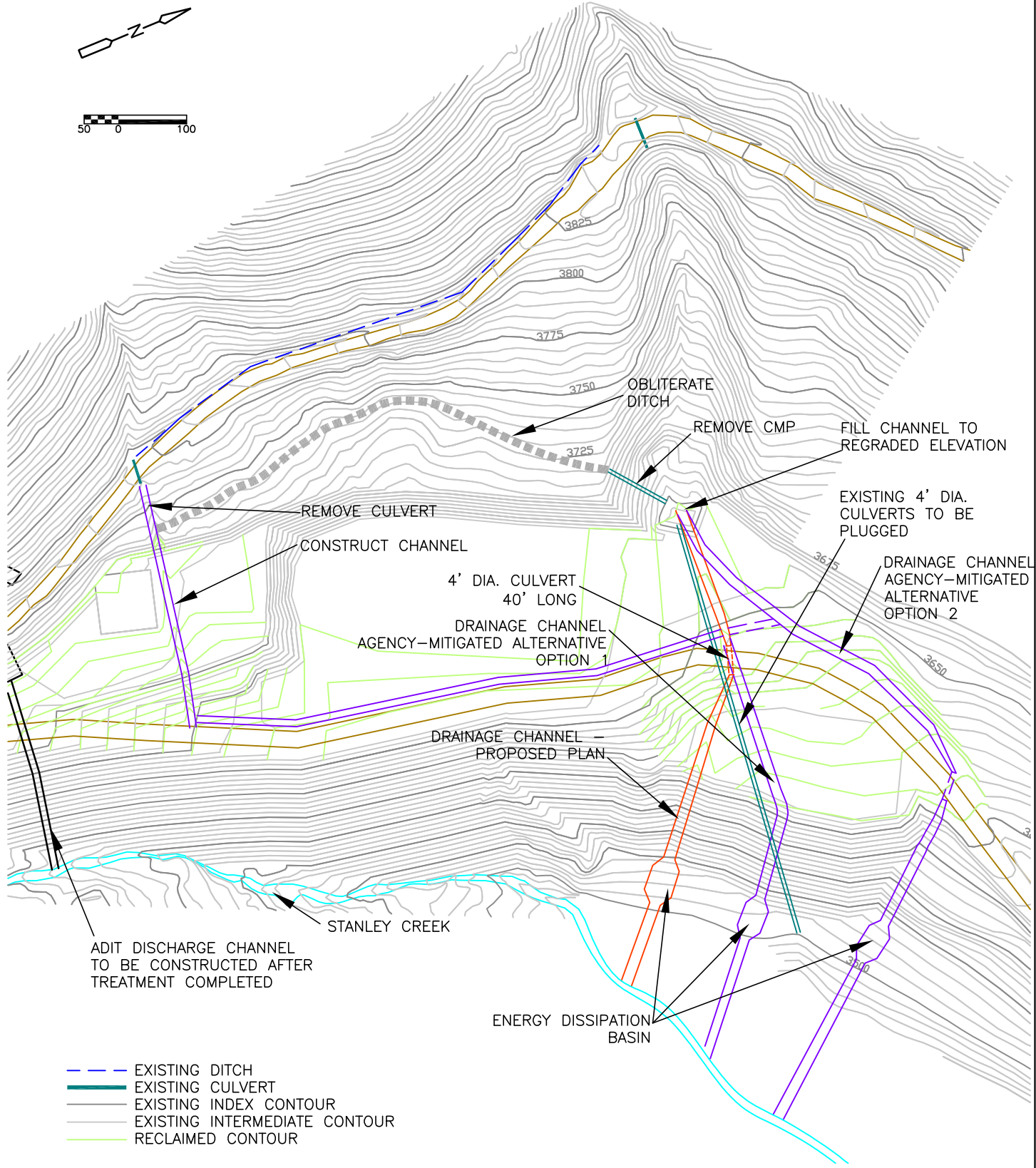
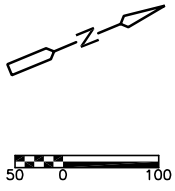


FIGURE 1
Excavation for 4:1 Channel Slope
Troy Mine Waterline Conceptual
Channel Design



- EXISTING DITCH
- EXISTING CULVERT
- EXISTING INDEX CONTOUR
- EXISTING INTERMEDIATE CONTOUR
- RECLAIMED CONTOUR

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FIGURE 2
Channel Options
Troy Mine Conceptual
Channel Design

Determine peak flow of 100 year event at mill site drainage. Use WRIR 03-4308 (Parrelle Johnson, 2004) to calculate 100-yr flow.

Drainage Area = 0.179 sq. mi. (USGS topo)
 Ave Annual precip = 24" (Troy average precip)
 Forest cover = 50% Burned condition with 50% crown kill.

Use West Region Equation:

$$Q_{100} = 18.7 A^{0.812} P^{1.06} (F+1)^{-0.664}$$

$$Q_{100} = 18.7 \times (0.179)^{0.812} (24)^{1.06} (51)^{-0.664}$$

$$Q_{100} = 33 \text{ cfs.}$$

Steep Slope Riprap Design
 Ref: Stormwater Collection Systems Design Handbook, Larry Mays, 2001, Section 16.5
 Troy - Mine, Millpad Channel, 10% slope
 Target Flow = 33 cfs

Channel Dimensions		Hydraulic Calculations									
		Depth		Area		Wetted Perimeter		Top Width		Hydraulic Radius	
		(ft)	(m)	(sf)	(sm)	(ft)	(m)	(ft)	(m)	(ft)	(m)
Bottom Width(ft) =	3.28	0.328	0.100	1.292	0.120	4.748	1.447	4.593	1.4	0.272	0.083
Bottom Width(m) =	1	0.394	0.120	1.602	0.149	5.042	1.537	4.856	1.48	0.318	0.097
Sideslopes =	2 :1(H:V)	0.459	0.140	1.929	0.179	5.335	1.626	5.118	1.56	0.362	0.110
Slope (m/m) =	0.1	0.525	0.160	2.273	0.211	5.628	1.716	5.381	1.64	0.404	0.123
Length (ft) =	581	0.591	0.180	2.635	0.245	5.922	1.805	5.643	1.72	0.445	0.136
Length (m) =	177	0.656	0.200	3.014	0.280	6.215	1.894	5.906	1.8	0.485	0.148
Trial Lining		0.722	0.220	3.410	0.317	6.509	1.984	6.168	1.88	0.524	0.160
D90 (ft) =	1.64	0.787	0.240	3.823	0.355	6.802	2.073	6.430	1.96	0.562	0.171
D90 (m) =	0.5	0.853	0.260	4.254	0.395	7.096	2.163	6.693	2.04	0.600	0.183
D50 (ft) =	1.31	0.919	0.280	4.702	0.437	7.389	2.252	6.955	2.12	0.636	0.194
D50 (m) =	0.4	0.984	0.300	5.167	0.480	7.683	2.342	7.218	2.2	0.673	0.205
D10 (ft) =	0.66	1.050	0.320	5.649	0.525	7.976	2.431	7.480	2.28	0.708	0.216
D10 (m) =	0.2	1.115	0.340	6.148	0.571	8.269	2.521	7.743	2.36	0.744	0.227
		1.181	0.360	6.665	0.619	8.563	2.610	8.005	2.44	0.778	0.237
		1.247	0.380	7.199	0.669	8.856	2.699	8.268	2.52	0.813	0.248
Range of Depth to be Evaluated		1.312	0.400	7.750	0.720	9.150	2.789	8.530	2.6	0.847	0.258
Least Depth (m) =	0.1	1.378	0.420	8.318	0.773	9.443	2.878	8.793	2.68	0.881	0.268
Maximum Depth (m)=	2	1.444	0.440	8.904	0.827	9.737	2.968	9.055	2.76	0.914	0.279
Increment (m) =	0.02	1.509	0.460	9.507	0.883	10.030	3.057	9.318	2.84	0.948	0.289
		1.575	0.480	10.127	0.941	10.324	3.147	9.580	2.92	0.981	0.299
		1.640	0.500	10.764	1.000	10.617	3.236	9.843	3	1.014	0.309
Angles		1.706	0.520	11.418	1.061	10.910	3.326	10.105	3.08	1.047	0.319
Side Slope, degrees	26.57	1.772	0.540	12.090	1.123	11.204	3.415	10.367	3.16	1.079	0.329
Bed Slope, degrees	5.74	1.837	0.560	12.779	1.187	11.497	3.504	10.630	3.24	1.111	0.339
Riprap Angle of		1.903	0.580	13.485	1.253	11.791	3.594	10.892	3.32	1.144	0.349
Repose, degrees	43	1.969	0.600	14.208	1.320	12.084	3.683	11.155	3.4	1.176	0.358
(Get from Charts)		2.034	0.620	14.949	1.389	12.378	3.773	11.417	3.48	1.208	0.368
		2.100	0.640	15.707	1.459	12.671	3.862	11.680	3.56	1.240	0.378
Factor of Safety	1.3	2.165	0.660	16.482	1.531	12.965	3.952	11.942	3.64	1.271	0.387

Note: Gradation calculation (D90 and D10) based on USFS Specs. for Roads and Bridges

Bathurst Resistance Calculations

Depth (ft)	Depth (m)	b	c1	f(FR)	c2	f(REG)	f(CG)	V*	Sum of f (functions) n	V/V*	Velocity (V) m/sec	Froude Number	Correction for slope 0.98			
													Flow, Q m³/sec	Flow, Q ft³/sec	To N/m²	To N/m²
0.33	0.1	0.180	0.624	1.319 ^{1/2} v/c1	1.745	3.233	0.602	0.313	2.568	0.082	2.650	0.830	0.838	0.100	3.5	80.9
0.39	0.12	0.199	0.580	1.220 ^{1/2} v/c1	1.944	3.700	0.582	0.343	2.627	0.082	2.722	0.934	0.861	0.139	4.9	94.5
0.46	0.14	0.215	0.545	1.153 ^{1/2} v/c1	2.118	4.137	0.565	0.371	2.696	0.082	2.805	1.040	0.887	0.186	6.6	107.6
0.52	0.16	0.231	0.515	1.105 ^{1/2} v/c1	2.273	4.552	0.550	0.396	2.770	0.081	2.893	1.146	0.915	0.242	8.5	120.2
0.59	0.18	0.244	0.490	1.070 ^{1/2} v/c1	2.413	4.946	0.538	0.420	2.846	0.080	2.983	1.253	0.943	0.307	10.8	132.4
0.66	0.2	0.256	0.469	1.042 ^{1/2} v/c1	2.540	5.324	0.527	0.443	2.922	0.079	3.073	1.361	0.972	0.381	13.4	144.3
0.72	0.22	0.268	0.450	1.020 ^{1/2} v/c1	2.656	5.687	0.517	0.465	2.998	0.078	3.162	1.469	1.000	0.465	16.4	155.9
0.79	0.24	0.278	0.433	1.003 ^{1/2} v/c1	2.763	6.039	0.508	0.485	3.073	0.077	3.250	1.577	1.028	0.560	19.8	167.2
0.85	0.26	0.288	0.419	0.988 ^{1/2} v/c1	2.862	6.379	0.499	0.505	3.147	0.076	3.337	1.685	1.055	0.666	23.5	178.4
0.92	0.28	0.297	0.405	0.976 ^{1/2} v/c1	2.954	6.711	0.491	0.524	3.219	0.075	3.422	1.794	1.082	0.783	27.6	189.3
0.98	0.3	0.306	0.393	0.966 ^{1/2}v/c1	3.040	7.034	0.484	0.542	3.290	0.075	3.506	1.902	1.109	0.913	32.2	200.1
1.05	0.32	0.314	0.381	0.958 ^{1/2} v/c1	3.122	7.350	0.477	0.560	3.360	0.074	3.588	2.010	1.135	1.055	37.2	210.7
1.12	0.34	0.321	0.371	0.950 ^{1/2} v/c1	3.198	7.660	0.471	0.578	3.429	0.073	3.669	2.119	1.160	1.210	42.7	221.2
1.18	0.36	0.328	0.361	0.944 ^{1/2} v/c1	3.271	7.963	0.465	0.594	3.496	0.072	3.748	2.227	1.185	1.379	48.7	231.6
1.25	0.38	0.335	0.352	0.938 ^{1/2} v/c1	3.341	8.262	0.459	0.611	3.562	0.071	3.825	2.335	1.210	1.562	55.1	241.8
1.31	0.4	0.342	0.344	0.934 ^{1/2} v/c1	3.407	8.556	0.454	0.626	3.627	0.070	3.901	2.444	1.234	1.760	62.1	252.0
1.38	0.42	0.348	0.336	0.929 ^{1/2} v/c1	3.470	8.846	0.449	0.642	3.690	0.069	3.976	2.552	1.257	1.972	69.6	262.1
1.44	0.44	0.354	0.329	0.926 ^{1/2} v/c1	3.531	9.132	0.444	0.657	3.753	0.069	4.050	2.661	1.281	2.201	77.7	272.1
1.51	0.46	0.360	0.322	0.922 ^{1/2} v/c1	3.589	9.415	0.439	0.672	3.815	0.068	4.122	2.769	1.303	2.446	86.3	282.0
1.57	0.48	0.366	0.315	0.919 ^{1/2} v/c1	3.646	9.694	0.435	0.686	3.875	0.067	4.193	2.877	1.326	2.707	95.5	291.8
1.64	0.5	0.371	0.309	0.917 ^{1/2} v/c1	3.700	9.971	0.430	0.700	3.935	0.067	4.263	2.986	1.348	2.986	105.4	301.6
1.71	0.52	0.376	0.303	0.915 ^{1/2} v/c1	3.753	10.245	0.426	0.714	3.993	0.066	4.332	3.094	1.370	3.282	115.8	311.4
1.77	0.54	0.381	0.297	0.913 ^{1/2} v/c1	3.804	10.516	0.422	0.728	4.051	0.065	4.400	3.203	1.391	3.597	126.9	321.0

Maximum Boundary Shear Stresses

Depth (ft)	d (m)	B/R	Kbs	Kss	Fsf	T bed N/m²	T bank N/m²	Stresses Allowable?	
								Bed	Bank
0.33	0.1	12.060	1.176	0.923	0.892	95.2	84.9	OK	OK
0.39	0.12	10.327	1.201	0.942	0.895	113.5	101.6	OK	OK
0.46	0.14	9.074	1.223	0.960	0.898	131.6	118.2	OK	OK
0.52	0.16	8.123	1.244	0.977	0.901	149.5	134.7	OK	OK
0.59	0.18	7.373	1.264	0.992	0.904	167.3	151.3	OK	OK
0.66	0.2	6.766	1.282	1.006	0.907	185.0	167.8	OK	OK
0.72	0.22	6.262	1.299	1.020	0.910	202.5	184.3	OK	OK
0.79	0.24	5.837	1.315	1.033	0.913	220.0	200.8	OK	OK
0.85	0.26	5.473	1.331	1.045	0.915	237.4	217.3	OK	OK
0.92	0.28	5.156	1.345	1.056	0.918	254.7	233.8	OK	OK
0.98	0.3	4.878	1.359	1.067	0.920	272.0	250.3	OK	OK
1.05	0.32	4.632	1.373	1.078	0.923	289.2	266.9	OK	OK
1.12	0.34	4.413	1.386	1.088	0.925	306.5	283.4	OK	OK
1.18	0.36	4.215	1.398	1.097	0.927	323.7	300.0	OK	OK
1.25	0.38	4.036	1.410	1.106	0.929	340.9	316.7	OK	OK
1.31	0.4	3.873	1.421	1.115	0.931	358.1	333.3	OK	OK
1.38	0.42	3.725	1.432	1.124	0.933	375.2	350.1	OK	OK
1.44	0.44	3.588	1.442	1.132	0.935	392.4	366.8	OK	OK
1.51	0.46	3.461	1.453	1.140	0.936	409.6	383.6	OK	OK
1.57	0.48	3.345	1.463	1.148	0.938	426.8	400.4	OK	OK
1.64	0.5	3.236	1.472	1.156	0.940	444.0	417.3	OK	OK
1.71	0.52	3.135	1.481	1.163	0.941	461.3	434.2	OK	OK
1.77	0.54	3.040	1.490	1.170	0.943	478.5	451.2	OK	OK

Where C is = 0.785
z C
1.5 0.76
2 0.785
3 0.85
4 0.935
6 0.97

Permissible Shear Stresses

Depth (ft)	d (m)	E	Ab	Cl	Cb	Ca	Al (estimated)	Tp_bank N/m²
0.33	0.1	6.78	0.15	2.01	1.00	0.42	0	250.8
0.39	0.12	5.67	0.18	2.01	1.00	0.42	0	250.9
0.46	0.14	4.87	0.21	2.01	1.00	0.42	0	251.0
0.52	0.16	4.27	0.23	2.01	1.00	0.42	0	251.2
0.59	0.18	3.80	0.26	2.01	1.00	0.42	0	251.3
0.66	0.2	3.43	0.29	2.01	1.00	0.42	0	251.4
0.72	0.22	3.12	0.32	2.01	1.00	0.42	0	251.5
0.79	0.24	2.87	0.35	2.01	1.00	0.42	0	251.7
0.85	0.26	2.65	0.38	2.01	1.00	0.42	0	251.8
0.92	0.28	2.46	0.41	2.01	1.00	0.42	0	251.9
0.98	0.3	2.30	0.43	2.02	1.00	0.42	0	252.0
1.05	0.32	2.16	0.46	2.02	1.00	0.42	0	252.2
1.12	0.34	2.03	0.49	2.02	1.00	0.42	0	252.3
1.18	0.36	1.92	0.52	2.02	1.00	0.42	0	252.4
1.25	0.38	1.82	0.55	2.02	1.00	0.42	0	252.6
1.31	0.4	1.73	0.58	2.02	1.00	0.42	0	252.7
1.38	0.42	1.64	0.61	2.02	1.00	0.42	0	252.8
1.44	0.44	1.57	0.64	2.02	1.00	0.42	0	253.0
1.51	0.46	1.50	0.67	2.02	1.00	0.42	0	253.1
1.57	0.48	1.44	0.70	2.02	1.00	0.42	0	253.2
1.64	0.5	1.38	0.73	2.03	1.00	0.42	0	253.3
1.71	0.52	1.33	0.75	2.03	1.00	0.42	0	253.5
1.77	0.54	1.28	0.78	2.03	1.00	0.42	0	253.6

Steep Slope Riprap Design
 Ref: Stormwater Collection Systems Design Handbook, Larry Mays, 2001, Section 16.5
 Troy - Mine, Millpad Channel, 77% slope
 Target Flow = 33 cfs

Channel Dimensions		Hydraulic Calculations									
		Depth		Area		Wetted Perimeter		Top Width		Hydraulic Radius	
		(ft)	(m)	(sf)	(sm)	(ft)	(m)	(ft)	(m)	(ft)	(m)
Bottom Width(ft) =	2.99	0.328	0.100	1.195	0.111	4.453	1.357	4.298	1.31	0.268	0.082
Bottom Width(m) =	0.91	0.394	0.120	1.485	0.138	4.746	1.447	4.560	1.39	0.313	0.095
Sideslopes =	2 :1(H:V)	0.459	0.140	1.793	0.167	5.040	1.536	4.823	1.47	0.356	0.108
Slope (m/m) =	0.77	0.525	0.160	2.118	0.197	5.333	1.626	5.085	1.55	0.397	0.121
Length (ft) =	200	0.591	0.180	2.461	0.229	5.627	1.715	5.348	1.63	0.437	0.133
Length (m) =	61	0.656	0.200	2.820	0.262	5.920	1.804	5.610	1.71	0.476	0.145
Trial Lining		0.722	0.220	3.197	0.297	6.213	1.894	5.873	1.79	0.515	0.157
		0.787	0.240	3.591	0.334	6.507	1.983	6.135	1.87	0.552	0.168
D90 (ft) =	6.97	0.853	0.260	4.002	0.372	6.800	2.073	6.398	1.95	0.588	0.179
D90 (m) =	2.125	0.919	0.280	4.430	0.412	7.094	2.162	6.660	2.03	0.625	0.190
D50 (ft) =	5.58	0.984	0.300	4.876	0.453	7.387	2.252	6.923	2.11	0.660	0.201
D50 (m) =	1.7	1.050	0.320	5.339	0.496	7.681	2.341	7.185	2.19	0.695	0.212
D10 (ft) =	2.79	1.115	0.340	5.819	0.541	7.974	2.431	7.448	2.27	0.730	0.222
D10 (m) =	0.85	1.181	0.360	6.316	0.587	8.268	2.520	7.710	2.35	0.764	0.233
		1.247	0.380	6.831	0.635	8.561	2.609	7.972	2.43	0.798	0.243
Range of Depth to be Evaluated		1.312	0.400	7.363	0.684	8.855	2.699	8.235	2.51	0.831	0.253
		1.378	0.420	7.911	0.735	9.148	2.788	8.497	2.59	0.865	0.264
Least Depth (m) =	0.1	1.444	0.440	8.478	0.788	9.441	2.878	8.760	2.67	0.898	0.274
Maximum Depth (m) =	2	1.509	0.460	9.061	0.842	9.735	2.967	9.022	2.75	0.931	0.284
Increment (m) =	0.02	1.575	0.480	9.662	0.898	10.028	3.057	9.285	2.83	0.963	0.294
		1.640	0.500	10.280	0.955	10.322	3.146	9.547	2.91	0.996	0.304
Angles		1.706	0.520	10.915	1.014	10.615	3.236	9.810	2.99	1.028	0.313
Side Slope, degrees	26.57	1.772	0.540	11.567	1.075	10.909	3.325	10.072	3.07	1.060	0.323
Bed Slope, degrees	50.35	1.837	0.560	12.236	1.137	11.202	3.414	10.335	3.15	1.092	0.333
Riprap Angle of		1.903	0.580	12.923	1.201	11.496	3.504	10.597	3.23	1.124	0.343
Repose, degrees	43	1.969	0.600	13.627	1.266	11.789	3.593	10.860	3.31	1.156	0.352
(Get from Charts)		2.034	0.620	14.348	1.333	12.082	3.683	11.122	3.39	1.188	0.362
		2.100	0.640	15.087	1.402	12.376	3.772	11.385	3.47	1.219	0.372
Factor of Safety	1.3	2.165	0.660	15.842	1.472	12.669	3.862	11.647	3.55	1.250	0.381

Note: Gradation calculation (D90 and D10) based on USFS Specs. for Roads and Bridges

Bathurst Resistance Calculations

Depth (ft)	Depth (m)	b	c1	f(FR)	c2	f(REG)	f(CG)	V*	Sum of f (functions) n	VV*	Velocity (V) m/sec	Froude Number	Correction for slope 0.98			
													Flow, Q m ³ /sec	Flow, Q ft ³ /sec	To N/m ²	
0.33	0.1	0.109	0.842	2.222 ^{1/2} v ² c1	1.478	1.300	0.740	0.869	2.138	0.098	2.210	1.921	1.940	0.213	7.5	394.2
0.39	0.12	0.120	0.800	1.972 ^{1/2} v ² c1	1.605	1.454	0.726	0.952	2.081	0.104	2.162	2.058	1.897	0.284	10.0	459.8
0.46	0.14	0.130	0.765	1.803 ^{1/2} v ² c1	1.714	1.596	0.713	1.028	2.053	0.107	2.142	2.203	1.880	0.367	13.0	522.7
0.52	0.16	0.138	0.737	1.681 ^{1/2} v ² c1	1.809	1.728	0.703	1.099	2.041	0.110	2.138	2.351	1.877	0.463	16.3	583.5
0.59	0.18	0.146	0.713	1.588 ^{1/2} v ² c1	1.891	1.853	0.693	1.166	2.040	0.112	2.145	2.501	1.882	0.572	20.2	642.4
0.66	0.2	0.153	0.692	1.516 ^{1/2} v ² c1	1.965	1.970	0.685	1.229	2.046	0.113	2.158	2.652	1.894	0.695	24.5	699.8
0.72	0.22	0.160	0.674	1.458 ^{1/2} v ² c1	2.030	2.082	0.677	1.289	2.056	0.114	2.175	2.804	1.909	0.833	29.4	755.8
0.79	0.24	0.166	0.658	1.410 ^{1/2} v ² c1	2.090	2.190	0.670	1.346	2.069	0.115	2.195	2.956	1.926	0.986	34.8	810.7
0.85	0.26	0.172	0.643	1.369 ^{1/2} v ² c1	2.144	2.293	0.664	1.401	2.085	0.115	2.218	3.108	1.946	1.155	40.8	864.5
0.92	0.28	0.177	0.630	1.335 ^{1/2} v ² c1	2.193	2.393	0.658	1.454	2.101	0.115	2.241	3.259	1.966	1.341	47.3	917.5
0.98	0.3	0.182	0.618	1.305 ^{1/2} v ² c1	2.239	2.490	0.652	1.505	2.119	0.115	2.265	3.410	1.988	1.545	54.5	969.6
1.05	0.32	0.187	0.607	1.279 ^{1/2} v ² c1	2.281	2.584	0.647	1.555	2.138	0.115	2.290	3.561	2.010	1.766	62.3	1021.1
1.12	0.34	0.191	0.597	1.256 ^{1/2} v ² c1	2.321	2.676	0.642	1.603	2.157	0.115	2.316	3.711	2.032	2.006	70.8	1072.0
1.18	0.36	0.195	0.588	1.236 ^{1/2} v ² c1	2.358	2.765	0.637	1.649	2.177	0.115	2.341	3.860	2.054	2.265	79.9	1123.3
1.25	0.38	0.199	0.579	1.218 ^{1/2} v ² c1	2.393	2.853	0.632	1.694	2.197	0.115	2.367	4.010	2.077	2.545	89.8	1172.1
1.31	0.4	0.203	0.571	1.202 ^{1/2} v ² c1	2.426	2.939	0.628	1.738	2.217	0.115	2.392	4.158	2.099	2.844	100.4	1221.5
1.38	0.42	0.207	0.563	1.187 ^{1/2} v ² c1	2.457	3.023	0.624	1.781	2.237	0.114	2.418	4.306	2.122	3.165	111.7	1270.5
1.44	0.44	0.210	0.556	1.173 ^{1/2} v ² c1	2.487	3.106	0.620	1.823	2.257	0.114	2.443	4.454	2.144	3.508	123.8	1319.1
1.51	0.46	0.213	0.549	1.160 ^{1/2} v ² c1	2.515	3.187	0.616	1.864	2.278	0.114	2.469	4.601	2.166	3.874	136.7	1367.3
1.57	0.48	0.217	0.542	1.149 ^{1/2} v ² c1	2.543	3.267	0.612	1.904	2.298	0.113	2.494	4.748	2.188	4.262	150.4	1415.3
1.64	0.5	0.220	0.536	1.138 ^{1/2} v ² c1	2.569	3.346	0.608	1.943	2.318	0.113	2.519	4.895	2.210	4.674	165.0	1463.0
1.71	0.52	0.223	0.530	1.129 ^{1/2} v ² c1	2.594	3.424	0.605	1.982	2.338	0.113	2.543	5.041	2.232	5.111	180.4	1510.4
1.77	0.54	0.226	0.524	1.119 ^{1/2} v ² c1	2.618	3.501	0.601	2.020	2.357	0.112	2.568	5.186	2.253	5.573	196.7	1557.7

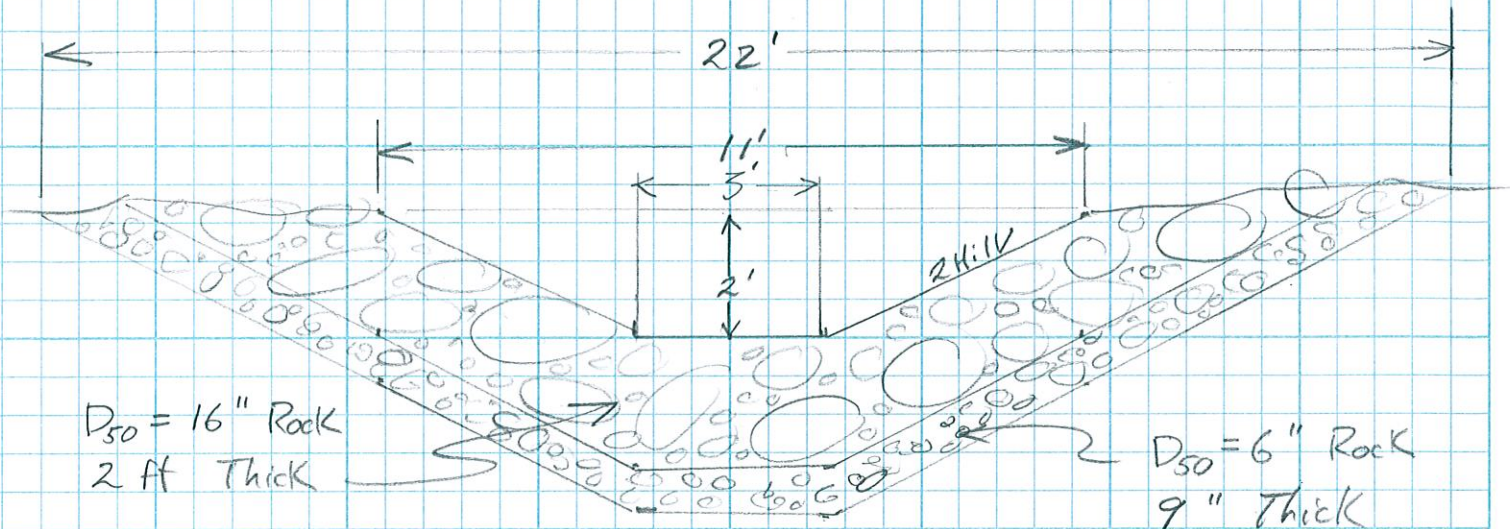
Maximum Boundary Shear Stresses

Depth (ft)	d (m)	B/R	Kbs	Kss	Fsf	T bed N/m ²	T bank N/m ²	Stresses Allowable?	
								Bed	Bank
0.33	0.1	11.127	1.188	0.933	0.976	468.4	457.2	OK	OK
0.39	0.12	9.540	1.214	0.953	0.974	558.2	543.7	OK	OK
0.46	0.14	8.390	1.238	0.972	0.973	647.1	629.6	OK	OK
0.52	0.16	7.516	1.260	0.989	0.973	735.1	715.1	OK	OK
0.59	0.18	6.827	1.280	1.005	0.973	822.4	800.3	OK	OK
0.66	0.2	6.267	1.299	1.020	0.974	909.1	885.2	OK	OK
0.72	0.22	5.803	1.317	1.034	0.975	995.3	970.0	OK	OK
0.79	0.24	5.410	1.334	1.047	0.975	1081.1	1054.6	OK	OK
0.85	0.26	5.073	1.350	1.059	0.976	1166.7	1139.2	OK	OK
0.92	0.28	4.780	1.365	1.071	0.978	1252.0	1223.9	OK	OK
0.98	0.3	4.523	1.379	1.082	0.979	1337.1	1308.5	OK	OK
1.05	0.32	4.295	1.393	1.093	0.980	1422.1	1393.3	OK	OK
1.12	0.34	4.091	1.406	1.104	0.981	1507.0	1478.1	OK	OK
1.18	0.36	3.908	1.418	1.113	0.982	1591.9	1563.1	OK	OK
1.25	0.38	3.742	1.431	1.123	0.983	1676.8	1648.2	OK	OK
1.31	0.4	3.591	1.442	1.132	0.984	1761.6	1733.6	OK	OK
1.38	0.42	3.452	1.453	1.141	0.985	1846.5	1819.1	OK	OK
1.44	0.44	3.325	1.464	1.149	0.986	1931.4	1904.7	OK	OK
1.51	0.46	3.208	1.475	1.158	0.987	2016.4	1990.6	OK	OK
1.57	0.48	3.099	1.485	1.166	0.988	2101.5	2076.8	OK	OK
1.64	0.5	2.998	1.495	1.173	0.989	2186.7	2163.1	OK	OK
1.71	0.52	2.904	1.504	1.181	0.990	2271.9	2249.6	OK	OK
1.77	0.54	2.816	1.513	1.188	0.991	2357.3	2336.4	OK	OK

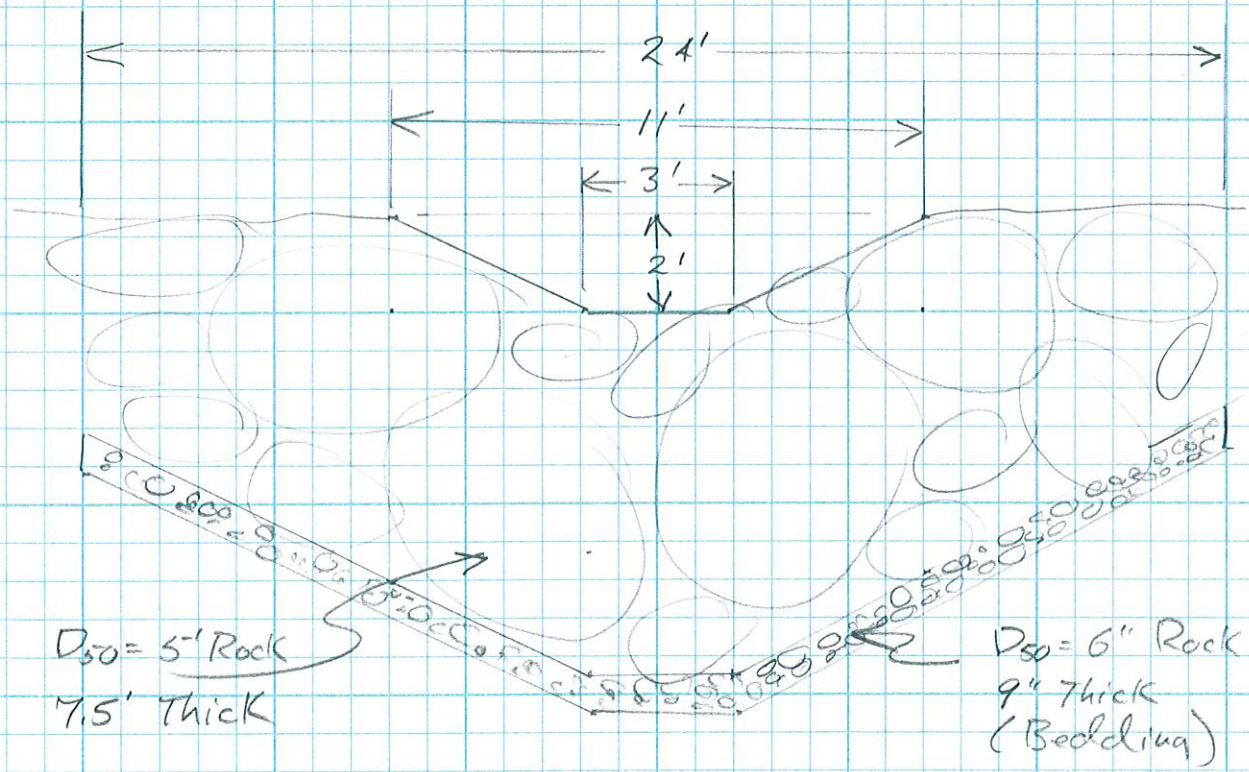
Where C is = 0.785
z C
1.5 0.76
2 0.785
3 0.85
4 0.935
6 0.97

Permissible Shear Stresses

Depth (ft)	d (m)	E	Ab	Cl	Cb	Ca	Al (estimated)	Tp_bank N/m ²
0.33	0.1	5.35	0.19	2.01	1.00	0.42	0	1066.5
0.39	0.12	4.50	0.22	2.01	1.00	0.42	0	1067.2
0.46	0.14	3.88	0.26	2.01	1.00	0.42	0	1067.9
0.52	0.16	3.42	0.29	2.01	1.00	0.42	0	1068.5
0.59	0.18	3.06	0.33	2.01	1.00	0.42	0	1069.2
0.66	0.2	2.76	0.36	2.01	1.00	0.42	0	1069.8
0.72	0.22	2.52	0.40	2.01	1.00	0.42	0	1070.5
0.79	0.24	2.32	0.43	2.02	1.00	0.42	0	1071.1
0.85	0.26	2.15	0.47	2.02	1.00	0.42	0	1071.8
0.92	0.28	2.00	0.50	2.02	1.00	0.42	0	1072.4
0.98	0.3	1.87	0.53	2.02	1.00	0.42	0	1073.1
1.05	0.32	1.76	0.57	2.02	1.00	0.42	0	1073.8
1.12	0.34	1.65	0.60	2.02	1.00	0.42	0	1074.4
1.18	0.36	1.56	0.64	2.02	1.00	0.42	0	1075.1
1.25	0.38	1.48	0.67	2.02	1.00	0.42	0	1075.7
1.31	0.4	1.41	0.71	2.02	1.00	0.42	0	1076.4
1.38	0.42	1.34	0.74	2.03	1.00	0.42	0	1077.1
1.44	0.44	1.28	0.78	2.03	1.00	0.42	0	1077.7
1.51	0.46	1.23	0.81	2.03	1.00	0.42	0	1078.4
1.57	0.48	1.18	0.85	2.03	1.00	0.42	0	1079.1
1.64	0.5	1.13	0.88	2.03	1.00	0.42	0	1079.8
1.71	0.52	1.09	0.92	2.03	1.00	0.42	0	1080.4
1.77	0.54	1.05	0.96	2.03	1.00	0.42	0	1081.1



10% Slope Channel Section
1" = 3'



1.3:1 to 2:1 Channel Section
1" = 4'

**TROY MINE RECLAMATION
MILLSITE CHANNEL COST
December 2, 2010**

OPTION 1

Item	Quantity		Unit Cost	Cost		
Mobilization @ 10%				\$15,681		
Erosion control @ 5%				\$7,467		
Clear and Grub (wooded areas)	1	AC	4000	\$4,000		
Access Road	700	LF	16	\$11,200	USDA FS Cost Estimating Guide for Road Construction	
<u>Channel</u>	<u>length (ft)</u>	<u>section (ft²)</u>				
D ₅₀ = 16" Rock	650	30	722 CY	\$30.00	\$21,667	
D ₅₀ = 5' Rock	150	180	1000 CY	\$60.00	\$60,000	
D ₅₀ = 6" Rock	800	18	533 CY	\$30.00	\$16,000	
<u>Energy Dissipation Basin</u>						
D ₅₀ = 16" Rock	30	46	51 CY	\$30.00	\$1,533	
D ₅₀ = 6" Rock	30	23	26 CY	\$30.00	\$767	
<u>Liner</u>						
HDPE			1200 SY	\$15.00	\$18,000	
Bedding			400 CY	\$20.00	\$8,000	
<u>Culvert</u>						
4' Dia. CMP			40 LF	\$143.00	\$5,720	Means 33 41 13 40 2200
Excavation, Backfill, Compaction			40 LF	\$61.30	\$2,452	Means 31 23 16 13 0500, 2020 and 31 23 23 23 7000
<u>Construction contingency @ 15%</u>					<u>\$25,873</u>	
Total Construction Cost					\$198,359	
Engineering @ 20%					<u>\$39,672</u>	
Total Project Cost					\$238,031	

**TROY MINE RECLAMATION
MILLSITE CHANNEL COST
December 2, 2010**

OPTION 2

Item	Quantity		Unit Cost	Cost		
Mobilization @ 10%				\$19,086		
Erosion control @ 5%				\$9,089		
Clear and Grub (wooded areas)	1	AC	4000	\$4,000		
Access Road	400	LF	16	\$6,400	USDA FS Cost Estimating Guide for Road Construction	
<u>Channel</u>	<u>length (ft)</u>	<u>section (ft²)</u>				
D ₅₀ = 16" Rock	870	30	967 CY	\$30.00	\$29,000	
D ₅₀ = 5' Rock	200	180	1333 CY	\$60.00	\$80,000	
D ₅₀ = 6" Rock	970	18	647 CY	\$30.00	\$19,400	
<u>Energy Dissipation Basin</u>						
D ₅₀ = 16" Rock	30	46	51 CY	\$30.00	\$1,533	
D ₅₀ = 6" Rock	30	23	26 CY	\$30.00	\$767	
<u>Liner</u>						
HDPE			1500 SY	\$15.00	\$22,500	
Bedding			500 CY	\$20.00	\$10,000	
<u>Culvert</u>						
4' Dia. CMP			40 LF	\$143.00	\$5,720	Means 33 41 13 40 2200
Excavation, Backfill, Compaction			40 LF	\$61.30	\$2,452	Means 31 23 16 13 0500, 2020 and 31 23 23 23 7000
<u>Construction contingency @ 15%</u>					<u>\$31,492</u>	
Total Construction Cost					\$241,439	
Engineering @ 20%					<u>\$48,288</u>	
Total Project Cost					\$289,726	