Partridge River Level 2 Rosgen Geomorphic Survey

Rosgen Classification
Partridge River above Dunka Road

Prepared for
Poly Met Mining Inc.

September 2013

BARR

Partridge River Level 2 Rosgen Geomorphic Survey

Rosgen Classification
Partridge River above Dunka Road

Prepared for
Poly Met Mining Inc.

September 2013

BARR

4700 West 77th Street
Minneapolis, MN 55435-4803
Phone: (952) 832-2600
Fax: (952) 832-2601

Partridge River Level 2 Rosgen Geomorphic Survey
Rosgen Classification
Partridge River above Dunka Road

September 2013

Table of Contents

List of Figures

List of Appendices

1.0 Introduction

The United States Forest Service Region 9 (USFS R9) and Poly Met Mining, Inc. (PolyMet) are in the process of evaluating the feasibility of a land exchange which includes lands within and around the NorthMet Mining Project mine site in northeastern Minnesota. The USFS owns the surface rights in the land exchange area. As part of the land exchange, an evaluation of the geomorphology the Partridge River within the Land Exchange parcel is required in order to identify any stream reaches that are sensitive to fluvial geomorphic impacts and to characterize the locations used for sampling aquatic biology. The purpose of this report is to summarize the stream geomorphology within the water courses residing within the Land Exchange area that have not been previously field surveyed.

1.1 Description of Partridge River

The Partridge River once originated from Iron Lake near Babbitt, Minnesota, in the upper portion of the St. Louis River Watershed. The North Shore Mine has separated the Partridge River from Iron Lake, however, and the headwaters are now located immediately south of the mine. The Partridge River flows southwest to Colby Lake, and continues a short distance from there before joining the St. Louis River south of Aurora, Minnesota. The total length of the Partridge River is approximately 32 miles. The Partridge River watershed above Colby Lake is a mix of upland and marshland, with very little development in its watershed. The Partridge River varies from sluggish, marshy reaches to large open ponds to steep boulder rapids.

1.2 Physical Classification of Channels

Physical classification of a stream or river determines its physical nature based on the relationship of its physical geometry and hydraulic characteristics. The purpose of a physical classification is to evaluate the stability of a stream under existing conditions, determine its sensitivity to change, and to indicate how restoration may be approached if a portion of the stream becomes unstable. The most popularly accepted system of physical classification is that developed by D.L. Rosgen (References (1) and (2)). The Rosgen system has eight basic stream types, which are further subdivided according to channel slope and materials. Furthermore, the classification is separated into levels, ranging from Level I (broad level characterization) to Level IV (verification of field measurements). A general description of the Rosgen classification system is presented in Appendix A.

1.3 Previous Studies

Previous studies of the Partridge River include a Level I Rosgen classification for the Partridge River from its headwaters to Colby Lake and a Level II Rosgen classification for two reaches of the Partridge River downstream of Dunka Road for the NorthMet Project (Reference (3)). A Level I classification is performed using available topography, aerial photography, and other readily available information such as ground photographs. A Level II classification includes basic field measurements of the selected reaches so that the channel can be characterized in greater detail.

The Level I Rosgen classification for the portions of the Partridge River upstream of Dunka Road (presented in RS26) was performed based primarily on 2003 aerial photography and USGS 7.5 minute quadrangles with 10-foot topography. Figure 7 of (3) shows the classification for this stretch of the Partridge River and is attached in Appendix B. Moving upstream from Dunka Road, the Level I Rosgen classification identified a 1,300 foot reach of Type B channel (relatively steep rapids), followed by longer Type E and C segments, where the river has a lower slope and greater sinuosity (meandering). In the center of this portion of the Partridge River a 1,900 foot reach has been ditched and straightened along the North Shore Mine railroad embankment.

In RS26, the Type C reaches of the Partridge River upstream of Dunka Road are noted as "Degraded, former Type E?". Designation of these reaches as "degraded" was determined based on stream sinuosity (as determined from aerial photos) that is less than expected for Type E streams. It was assumed that this decreased sinuosity is due to hydrologic alterations in the Partridge River headwaters (by North Shore Mine) and intermittent dewatering discharges to the Partridge River. No ground data was collected for the Partridge River above Dunka Road for RS26, so the present study represents an opportunity to verify the previous stream classifications and to determine whether any degradation exists.

2.0 Level II Rosgen Classification

A level II Rosgen Classification was performed for two stream reaches on the upper Partridge River in July and August 2009. The surveyed reaches are shown in Figure 1. A Level II classification consists of a survey of the channel profile and cross-sections of the channel and floodplain. Bed material is also sampled in order to provide a sub-classification of the stream reach, providing greater insight into the sensitivity of the stream reach.

2.1 Data Collection

Two reaches of the Partridge River were physically classified on July 17, 2009 (East Reach) and August 27, 2009 (West Reach). At each reach, the stream bottom profile was surveyed for a length of one to two meander wavelengths. Two permanent monumented cross-sections were established at each reach with 2 to 4 foot rebar stakes, lath and ribbon. Water surface elevations and bankfull elevation indicators were also surveyed, and the dominant bed material was characterized for each reach.

During the field survey, data was collected using survey-grade GPS. Ground photographs were also taken of each site. During a later site visit (macroinvertebrate survey on September 23, 2009), a Marsh-McBirney flowmeter was used to measure stream flow during flow conditions lower than at the time of the July and August surveys (water surface approximately 0.6 feet lower on the East Reach).

2.2 Partridge River East Reach

The East Reach is located north of Dunka Road, approximately 1.25 miles upstream of the road crossing and culvert. The measured parameters, cross-sections and photographs of this reach are shown in Appendix C, Data Sheet 1. In this area, the Partridge River meanders through wetlands with occasional low beaver dams that retard flow and increase water levels without creating large drops. The river is best characterized as a Rosgen Type E stream through this reach. The channel is slightly entrenched and has a low width/depth ratio and a high degree of sinuosity. These characteristics indicate that the stream has an adequate floodplain to dissipate energy during higher-than-bankfull flows. Flows in this portion of the Partridge River are often low (<3 cfs at the time of survey), but bankfull flows are likely near 100 cfs (Table 2a and 3a in Appendix A of Reference (2)).

Bank and floodplain vegetation at the East Reach consists of emergent and wetland grasses and wetland shrubs. In places the shrubs overhang the stream, but there is no evidence of significant bank undercutting or other erosion on this reach. The shrub wetland along the stream is bordered by a black spruce swamp on both banks, with a strip of dead spruce at the edge of the shrub wetland. Stream bed and bank material is primarily muck and peat, with occasional areas of firmer sand and isolated boulders on the stream bed.

Downstream of the surveyed reach, in the last 1,300 feet before Dunka Road, the Partridge River becomes nearly straight and passes over a series of boulder riffles, dropping 10 feet relatively quickly. This area was not surveyed and appears consistent with the Type B classification assigned in the previous Level I Rosgen study.

As a Type E6 stream, the East Reach can be sensitive to disturbances of the streambanks or significant changes in stream flow or sediment supply. As indicated in Table A-2 for type E6, the influence of riparian vegetation on channel stability is very high. Because of the well-developed bank vegetation (100% coverage on the banks), this reach is expected to be stable under moderate changes in stream flow and sediment supply. The recovery potential of this channel (should the banks be disturbed) is good.

2.3 Partridge River West Reach

The West Reach is located approximately 0.5 miles downstream of the headwaters of the Partridge River and the edge of the North Shore Mine. At approximately the center of the study reach, a small tributary (Yelp Creek) joins the Partridge River from the southwest. The measured parameters, cross-sections and photographs of this reach are shown in Appendix C, Data Sheet 2. Conditions in this area are similar to the downstream East Reach, although the observed water levels were closer to the top of the stream banks during the field visits. Upstream of Yelp Creek, the Partridge steepens slightly and the water depth decreases. At the downstream end of the reach a submerged beaver dam was observed (water depth 1.5 feet over dam), possibly acting as a water level control for the survey reach.

Throughout this reach, and especially downstream of Yelp Creek, the river is best characterized as a Rosgen Type E stream. The channel is slightly entrenched and has a low width/depth ratio and moderately high sinuosity. The sinuosity of this reach is slightly lower than expected for a Type E stream (1.3 rather than >1.5), but the remainder of the channel parameters support the classification as Type E. The stream characteristics indicate that the stream has an adequate floodplain to dissipate energy during higher-than-bankfull flows. Flows in this portion of the Partridge River are often low

(~3 cfs at the time of survey), but bankfull flows during snowmelt or large storms are likely near 70 cfs downstream of Yelp Creek (Table 1 and 2a in Appendix A of Reference (2)).

Like the East Reach, bank and floodplain vegetation at the West Reach consists of emergent and wetland grasses and wetland shrubs. Unlike the East Reach, there are no significant areas of overhanging shrubs or non-submerged banks. The shrub wetland along the stream is bordered by a black spruce swamp on both banks, with a strip of dead spruce at the edge of the shrub wetland. Stream bed and bank material is primarily muck and peat.

Like the East Reach, the West Reach is a Type E6 stream and is sensitive to disturbances of the streambanks or significant changes in stream flow or sediment supply. As indicated in Table A-2 for type E6, the influence of riparian vegetation on channel stability is very high. Because of the well-developed bank vegetation (100% coverage on the banks), this reach is expected to be stable under moderate changes in stream flow and sediment supply. The recovery potential of this channel (should the banks be disturbed) is good.

3.0 Conclusions

The Rosgen Level I physical classification the upper Partridge River, as reported in RS26 (Reference (3)), indicated that the upper five miles of the Partridge River are primarily Rosgen Type C and E streams. This classification also indicated that a portion of the river was potentially degraded due to prior disturbances in the watershed and flow regime, based on lower than expected stream sinuosity.

This survey investigated two reaches on the upper Partridge River and found both to be consistent with Rosgen Type E streams, despite the lower than expected sinuosity at the West Reach. This decrease in sinuosity is possibly due to prior disturbances, but the stream appears to be stable in its current form. There is no evidence of erosion, downcutting, or channel widening at either of the surveyed reaches; both reaches have well-developed floodplains and vigorous bank vegetation. In both locations, water levels during average- and low-flow conditions are likely controlled by low beaver dams scattered throughout the wetlands.

Because of the well-developed floodplains and complete coverage of the stream banks with wetland vegetation, these reaches of the Partridge River are likely able to withstand moderate changes to the base flow with no significant degradation.

The need for more detailed classification or monitoring of the Partridge River in the future should be based on the level of impact to base flow estimated from any proposed dewatering discharges.

References

1. **Rosgen, D.L.** A Classification of Natural Rivers. 1994, 22, pp. 169-199.

2. —. Applied River Morphology. Wildland Hydrology. Pogosa Springs, Colorado : s.n., 1996.

3. **Barr Engineering Company.** Partridge River Level 1 Rosgen Geomorphic Survey. Rosgen Classification Partridge River from Headwaters to Colby Lake. (RS26). 2005.

4. —. Streamflow and Lake Level Changes, Hydrologic/Hydraulic Modeling Results for the PolyMet NorthMet Mine Site, RS73B Draft-03. September 2008.

Figures

Partridge River
Survey Thalweg
Survey Cross-Section

1,000 500 0 1,000 2,000 Feet

FIGURE 1
ROSGEN LEVEL II CLASSIFICATION SITES
Partridge River
St. Louis County, Minnesota

Appendices

Appendix A

Rosgen Classification System

Rosgen Classification System

The classification system used to classify the stream channels was developed by D.L. Rosgen ("A Classification of Natural Rivers", Catena, 1994) Rosgen's classification system describes a stream on a reach-by-reach basis. A single stream can have several different stream types over its length. The system defines a stream type according to the shape, pattern, and profile of the reach. In particular, the following parameters are used to classify a stream type: the degree of entrenchment of the channel, the ratio of width to depth, degree of channel meandering or sinuosity, channel material, and the channel surface slope. Some of these parameters are illustrated on Figure A-1.

The Rosgen classification system specifies seven basic stream types, ranging from A to G as shown on Figure A-2. Each type has six subclasses corresponding to the predominant bed material present in the reach. These subclasses are numbered from 1 to 6: 1 is bedrock, 2 is boulder, 3 is cobble, 4 is gravel, 5 is sand, and 6 is silt. This allows for 42 combinations of stream type. A description of the stream types is given in Table A-1. This table gives a range of values of the criteria used for stream classification. These ranges are those most commonly observed; the actual observed values can lie outside of these ranges to a certain extent, recognizing that as the stream type changes, the criteria will adjust accordingly.

Entrenchment Ratio is defined as the ratio of the width of the flood-prone area to the bankfull surface width of the channel. Flood-prone area is defined by Rosgen as the width measured at an elevation which is determined at twice the maximum bankfull depth. Field observation shows this elevation to be a frequent flood (50 year) or less, rather than a rare flood elevation. The entrenchment ratio describes the interrelationship of the river to its valley and landform features. It is a measure of channel down-cutting compared to its floodplain. This interrelationship determines whether the river (stream) is deeply incised or entrenched in the valley floor or deposit feature. The entrenchment ratio indicates whether the flat area adjacent to the channel is a frequent floodplain, a terrace (abandoned floodplain), or is outside the flood-prone area.

Width/Depth Ratio is the ratio of bankfull channel width to bankfull mean depth; it is used to describe the dimension and shape of the channel.

Sinuosity is the ratio of stream length to valley length. It can also be described as the ratio of valley slope to channel slope. This value typically varies from 1.0 to 2.5, where a value of 1.0 corresponds to a straight channel. Sinuosity can often be determined from aerial photographs, and interpretations can then be made of slope, channel materials, and entrenchment. Values of sinuosity appear to be modified by bedrock control, roads, channel confinement, and vegetation types, among other factors. Generally, as gradient and particle size decrease, there is a corresponding increase in sinuosity. Meander geometry characteristics are directly related to sinuosity following minimum expenditure of energy concepts. Based on these relations and ease of determination, sinuosity is one of the delineative criteria for stream classification.

Water Surface Slope is of major importance to the morphological character of the channel and its sediment, hydraulic, and biological function. It is determined by measuring the difference in water surface elevation per unit stream length. It is typically measured through at least 20 channel widths or two meander wavelengths (Rosgen). In broad level delineations, slope can be estimated by measuring sinuosity from aerial photos and measuring valley slope from topographic maps.

Channel Materials refer to the bed and bank materials of the stream. Channel material is critical for sediment transport and hydraulic influences, and also modifies the form, plan, and profile of the stream. Interpretations of biological function and stability also require this information. The channel materials can often be estimated from soils maps and geologic information. They can also be determined in the field, and at the detailed level the materials are measured and the size plotted on percent distribution paper.

Bankfull Discharge occurs at approximately the 1.5 year recurrence interval and is referenced to as the dominant discharge for the stream. Hydraulic geometry and sediment transport relations rely heavily on the frequency and magnitude of bankfull discharge.

Different types of streams have differing sensitivities to disturbance and varying recovery potential. Sensitivity and recovery potential are interrelated to sediment supply in the stream, bank erosion potential, and the influence of vegetation on controlling bank erosion. These differences are itemized by stream type in Table A-2. The information in this table is best applied when a stream's behavior can be assessed by appearance and by extrapolating information from similar stream types. Knowing the sensitivity of each stream type allows for better management of the stream systems, potential impact assessment, and risk analysis.

Table A-1 Summary of Criteria for General Classification (from Rosgen)

Stream Type	General Description	Entrenchment Ratio	W/D Ratio	Sinuosity	Slope	Landform/Soils/Features
A	Steep, entrenched, debris transport streams.	< 1.4	<12	1.0 to 1.2	0.04 to 0.10	High relief, mountainous environments; entrenched and confined streams with cascading reaches; frequent deep pools
B	Moderately entrenched, moderate gradient, riffle dominated channel with infrequent pools. Very stable.	1.4 to 2.2	>12	>12	0.02 to 0.039	Moderate relief, colluvial deposition and/or residual soils. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids with occasional pools.
C	Low gradient, meandering alluvial channels with broad, well defined floodplain.	>2.2	>12	>1.4	<0.02	Broad valleys with terraces, associated with floodplain, alluvial soils. Slightly entrenched with well-defined meandering channel. Riffle-pool bed morphology.
D	Braided channel; very wide channel with eroding banks.	n/a	>40	n/a	<0.04	Broad valleys with alluvial and colluvial fans. Abundant sediment supply.
E	Low gradient, meandering stream with low width/depth ratio and little deposition. Very efficient and stable.	>2.2	<12	>1.5	<0.02	Broad valley/meadows. Alluvial materials with floodplain. Highly sinuous with stable, well vegetated banks. Riffle-pool morphology with very low width/depth ratio.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio	<1.4	>12	>1.4	<0.02	Entrenched in highly weathered material. Gentle gradients with high W/D ratio. Meandering, laterally unstable with high bank-erosion rates. Riffle-pool morphology.
G	Entrenched Gully step/pool with low width/depth ration on moderate gradients	<1.4	<12	>1.2	0.02 to 0.039	Gully, step-pool morphology with moderate slopes and low W/D ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials. Unstable, with grade control problems and high bank erosion rates.

Table A-2. Management Interpretations of various stream types (from Rosgen, 1996)

Stream Type	Sensitivity to Disturbance[a]	Recovery Potential[b]	Sediment Supply[c]	Streambank Erosion Potential	Vegetation Controlling Influence[d]
A1	Very low	Excellent	Very low	Very low	Negligible
A2	Very low	Excellent	Very low	Very low	Negligible
A3	Very high	Very poor	Very high	Very high	Negligible
A4	Extreme	Very poor	Very high	Very high	Negligible
A5	Extreme	Very poor	Very high	Very high	Negligible
A6	High	Poor	High	High	Negligible
B1	Very low	Excellent	Very low	Very low	Negligible
B2	Very low	Excellent	Very low	Very low	Negligible
B3	Low	Excellent	Low	Low	Moderate
B4	Moderate	Excellent	Moderate	Low	Moderate
B5	Moderate	Excellent	Moderate	Moderate	Moderate
B6	Moderate	Excellent	Moderate	Low	Moderate
C1	Low	Very good	Very low	Low	Moderate
C2	Low	Very good	Low	Low	Moderate
C3	Moderate	Good	Moderate	Moderate	Very high
C4	Very high	Good	High	Very high	Very high
C5	Very high	Fair	Very high	Very high	Very high
C6	Very high	Good	High	High	Very high
D3	Very high	Poor	Very high	Very high	Moderate
D4	Very high	Poor	Very high	Very high	Moderate
D5	Very high	Poor	Very high	Very high	Moderate
D6	High	Poor	High	High	moderate
Da4	Moderate	Good	Very low	Low	Very high
DA5	Moderate	Good	Low	Low	Very high
DA6	Moderate	Good	Very low	Very low	Very high
E3	High	Good	Low	Moderate	Very high
E4	Very high	Good	Moderate	High	Very high
E5	Very high	Good	Moderate	High	Very high
E6	Very high	Good	Low	Moderate	Very high
F1	Low	Fair	Low	Moderate	Low
F2	Low	Fair	Moderate	Moderate	Low
F3	Moderate	Poor	Very high	Very high	Moderate
F4	Extreme	Poor	Very high	Very high	Moderate
F5	Very high	Poor	Very high	Very high	Moderate
F6	Very high	Fair	High	Very high	Moderate
G1	Low	Good	Low	Low	Low
G2	Moderate	Fair	Moderate	Moderate	Low
G3	Very high	Poor	Very high	Very high	High
G4	Extreme	Very poor	Very high	Very high	High
G5	Extreme	Very poor	Very high	Very high	High
G6	Very high	Poor	High	High	High

[a] Includes increases in streamflow magnitude and timing and/or sediment increases.
[b] Assumes natural recovery once cause of instability is corrected.
[c] Includes suspended and bedload from channel derived sources and/or from stream adjacent slopes.
[d] Vegetation that influences width/depth ratio-stability.

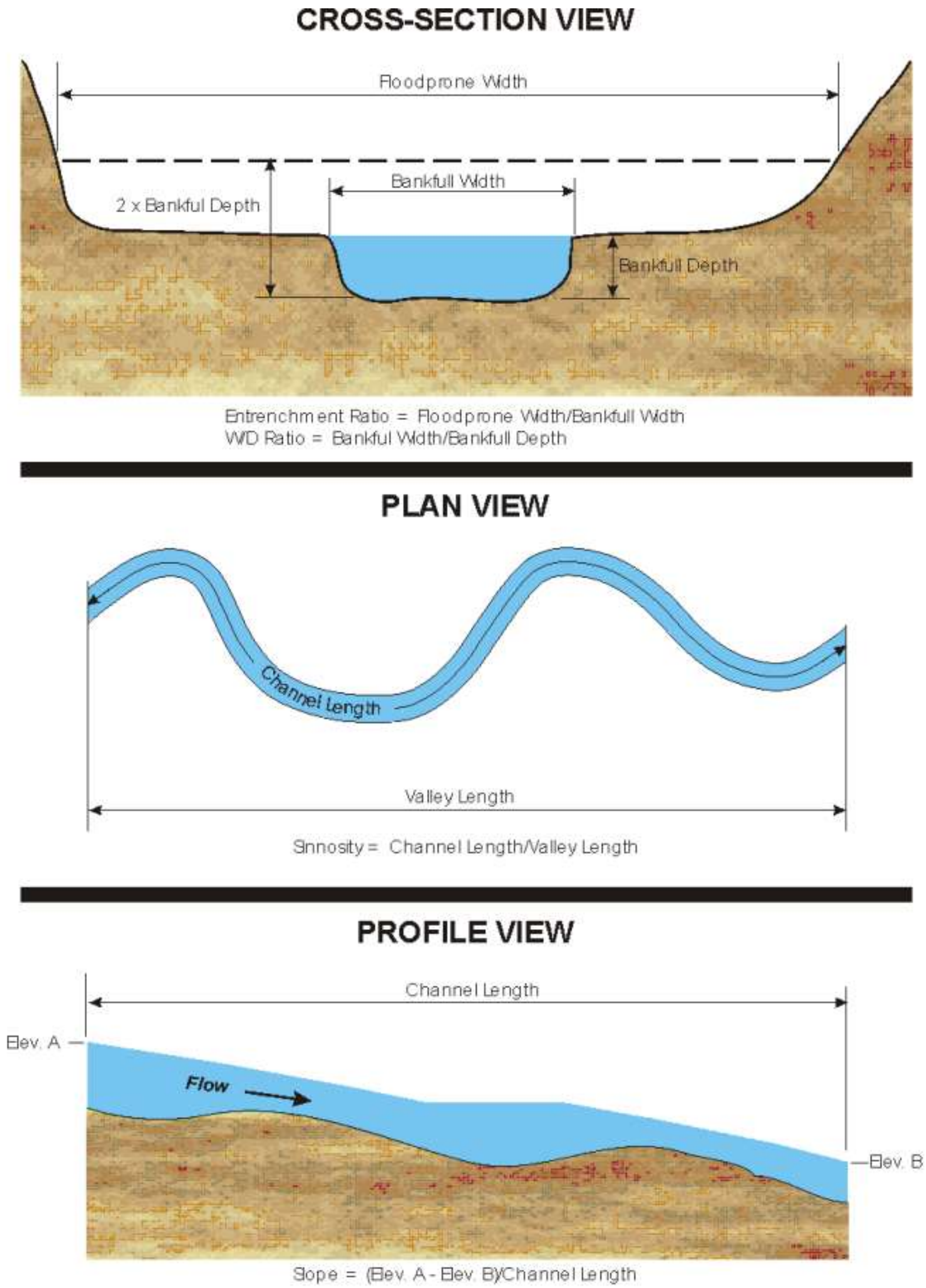


Figure A-1. Channel Parameters Defined (from Rosgen 1996)

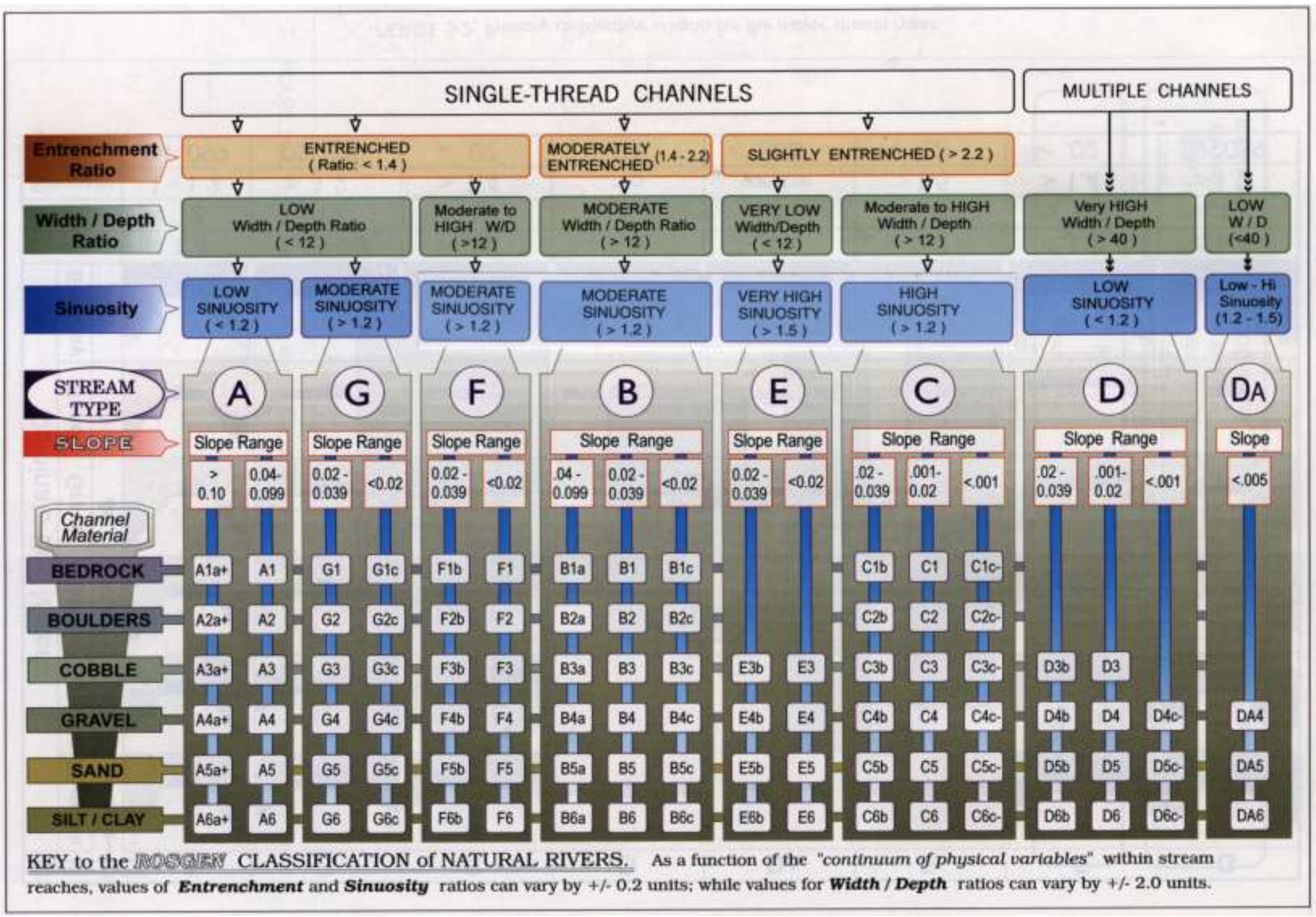


Figure A-2. Rosgen Classification System (from Rosgen 1996)

Appendix B

Selected Figures from RS26, Barr 2005

Barr Footer: Date: 12/8/2005 2:47:42 PM File: I:\Client\Polymet\Maps\Partridge River\Figures\Figure 7.mxd User: TJA

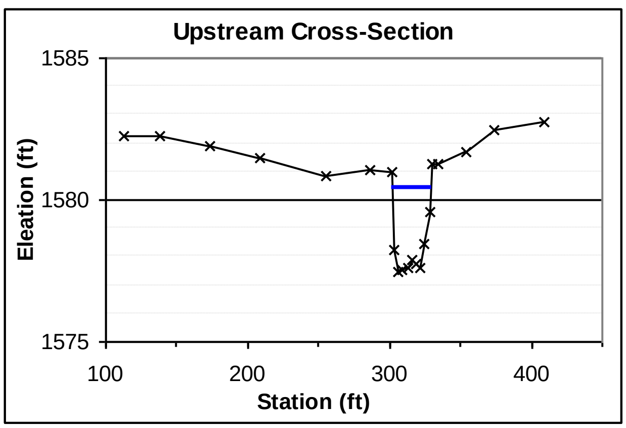
Appendix C

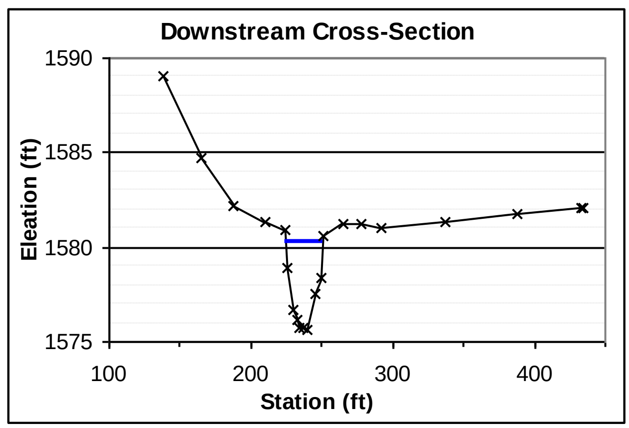
Rosgen Level II Classification Data Sheets

Data Sheet 1. Partridge River East Reach

Channel Dimensions:

Parameter	Upstream Cross-Section	Downstream Cross-Section
Bankfull Width	27 ft	27 ft
Bankfull Area	80 ft^2	94 ft^2
Bankfull Mean Depth	2.9 ft	3.5 ft
Bankfull Max. Depth	3.6 ft	4.9 ft
Entrenchment Ratio	19	19
Width/Depth Ratio	9.2	7.7
Floodprone Width	500 ft (est.)	500 ft (est.)
Dominant Bed Material	Peat/Muck	Peat/Muck
Avg. Channel Slope	0.0002	
Sinuosity	1.6	
Channel Type	**E6**	





Data Sheet 2. Partridge River West Reach

Channel Dimensions:

Parameter	Cross-Section 1 (upstream of Yelp Creek)	Cross-Section 2 (downstream of Yelp Creek)
Bankfull Width	24 ft	23 ft
Bankfull Area	62 ft^2	88 ft^2
Bankfull Mean Depth	2.5 ft	3.9 ft
Bankfull Max. Depth	3.7 ft	4.9 ft
Entrenchment Ratio	17	18
Width/Depth Ratio	9.6	5.8
Floodprone Width	400 ft (est.)	400 ft (est.)
Dominant Bed Material	Peat/Muck	Peat/Muck
Avg. Channel Slope	0.0001	
Sinuosity	1.3	
Channel Type	**E6**