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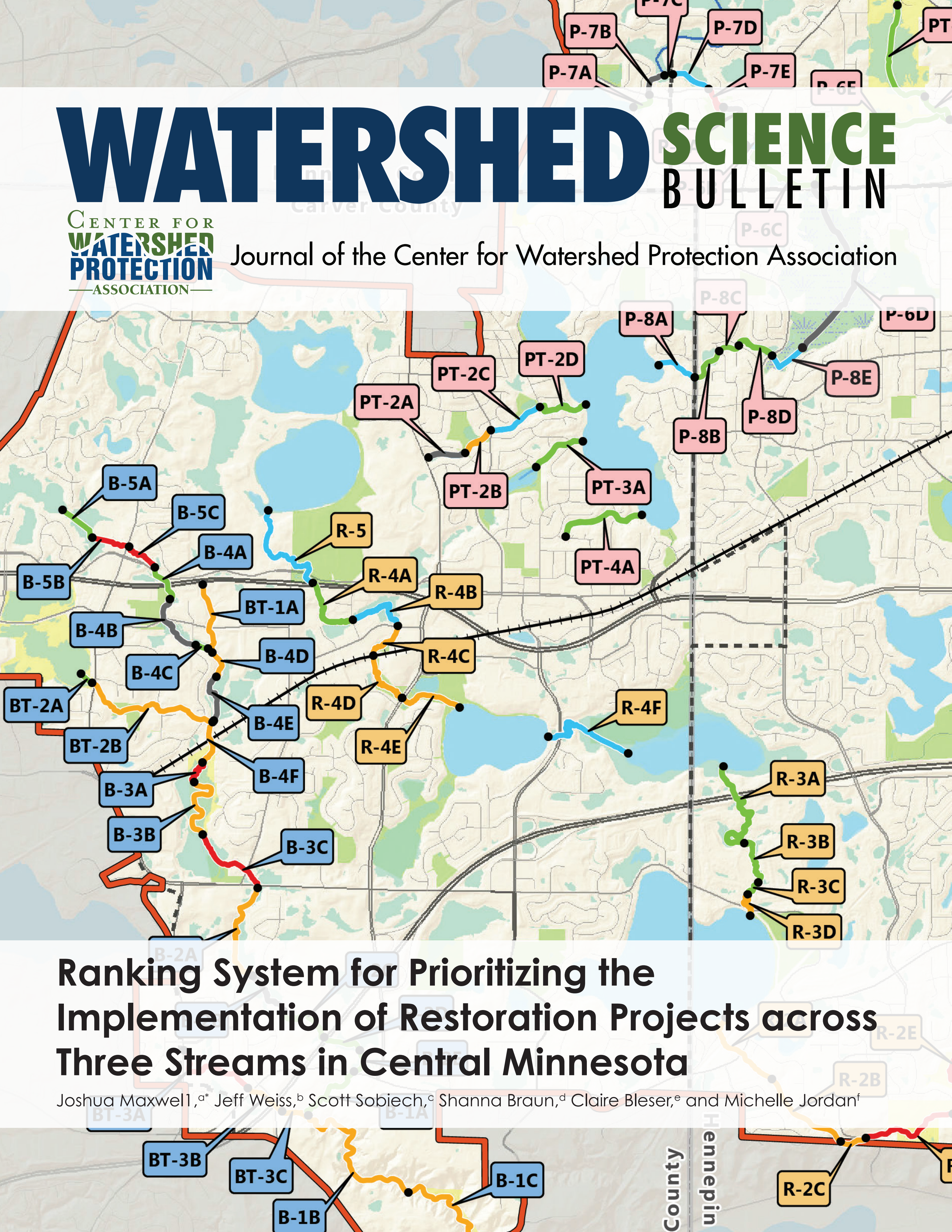


# Ranking System for Prioritizing the Implementation of Restoration Projects across Three Streams in Central Minnesota

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Front cover photo courtesy of Riley Purgatory Bluff Creek Watershed District.

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## Abstract

Prioritizing creek restoration projects can be challenging, especially when reaches span multiple and/or interacting waterbodies. The Creek Restoration Action Strategy (CRAS) is a tool for identifying stream sections in greatest need of restoration, beginning with consistent assessment of creek conditions. In developing the CRAS, eight prioritization categories were identified and grouped into two tiers: Tier I—infrastructure risk, channel stability, ecological benefits, and water quality; and Tier II—public education, project cost, partnerships, and watershed benefits. Tier I assessment utilizes primarily field data and is applied to all subreaches. Priority reaches identified by Tier I assessment then undergo Tier II ranking to inform final project selection. Overall, 87 subreaches were assessed using the tool, with 15 subreaches (17%) considered low, 38 (44%) moderate, 24 (28%) poor, and 10 (11%) in severe restoration need (immediate restoration would greatly benefit the site and the watershed downstream). This tool is being implemented across the three creeks within the Riley Purgatory Bluff Creek Watershed District, focusing the District's efforts on high-benefit projects in a cost-effective manner.

## Introduction

The Riley Purgatory Bluff Creek Watershed District (RPBCWD or District) is tasked with the protection, management, and restoration of the water resources located within its boundaries. The District's Third Generation Watershed Management Plan (RPBCWD 2011) identified stream flow (hydrology), erosion, water quality, and aquatic ecosystem biology/habitat as important concerns throughout the watershed. The plan also outlined short- and long-term goals around these themes, which include coordination with municipalities and other watershed partners regarding planned expenditures for addressing watershed issues, reducing and managing phosphorus loads, improving water quality to fully support designated uses for water bodies (The Office of the Revisor of Statutes 2015a), removing water bodies from the Minnesota Pollution Control Agency (MPCA) list of impaired waters (MPCA 2015), and preserving vegetation and habitat important to fish, waterfowl, and other wildlife, while also mitigating negative impacts of erosion.

Through various studies conducted by RPBCWD and other agencies within the District, multiple potential project sites have been identified. Many of these include projects involving streambank stabilization/restoration that may correct a wide range of issues related to stream health, including severe erosion, mass wasting, degraded infrastructure, connection to floodplain, degraded habitat, and/or degraded water quality. Within an urban setting, many of these issues can be amplified due to the altered hydrology of the watershed and the drastic stream morphological responses to disturbance (Meyer et al. 1988; Meyer et al. 2005). Increased quantities of stormwater are delivered directly to a stream via increased impervious surfaces and stormwater sewer systems (Dunne and Leopold 1978; Arnold and Gibbons 1996). Unlike streams in a undisturbed setting, this direct route increases the erosive flows within a stream (Hammer 1972; Douglas 1975; Booth 1990) and can increase the number of chemicals, metals, suspended solids (Latimer and Quinn 1998; Lenat and Crawford 1994; Porcella and Sorenson 1980; US Geological Survey 1999), and nutrients (Smart et al. 1985) reaching the

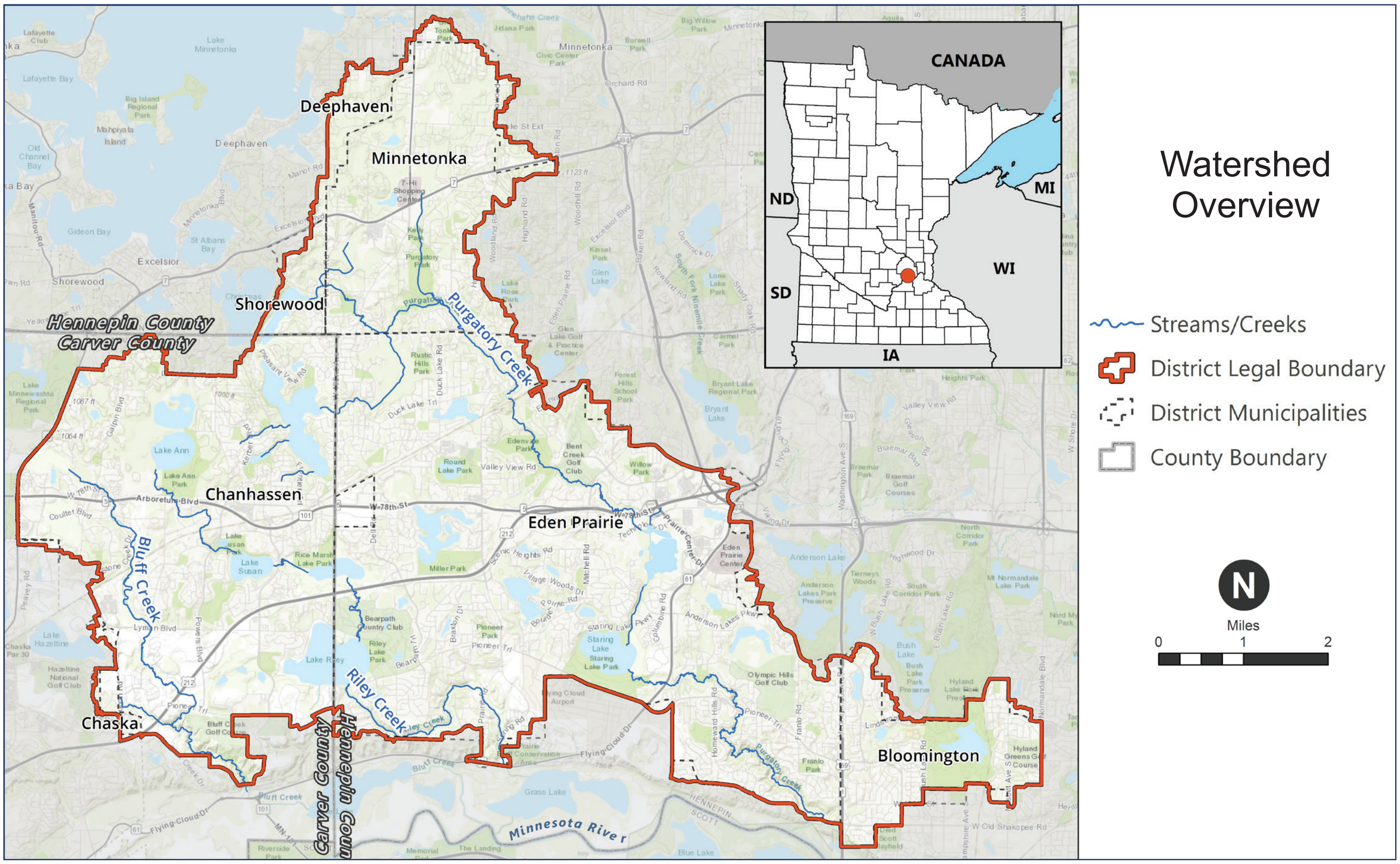


*Figure 1. Riley Purgatory Bluff Creek Watershed District.*

stream that would otherwise be filtered out in the upper watershed.

Although some potential project sites were identified, assessments had not been conducted on most stream sections in the District's three unique watersheds to evaluate and identify locations in most need of restoration across all streams. Additionally, multiple agencies and residents had inquired about how creek restoration and stabilization projects are prioritized within the District. Due to the significant cost of stream restoration projects, it may only be possible to complete a few projects in a given year. With a finite amount of resources, a prioritization method for selecting the most beneficial projects was needed.

The purpose of this study was to develop a rapid assessment method to rank and prioritize stream reaches across the watershed. The tool needed to provide information that would align with the District's goals while utilizing existing data available for the local streams. The outcome of the assessment tool will help guide future project implementation. As creeks are dynamic systems that change over time, this process had the additional objective of developing a methodology that can easily be updated as new information about each creek reach is generated. The District named the tool the Creek Restoration Action Strategy (CRAS), which incorporates existing stream assessment methods while incorporating additional information on other watershed benefits.

## Study Area

The RPBCWD is located south west of Minneapolis and St. Paul, Minnesota (MN) (Figure 1). It is approximately 50 square miles in surface area and encompasses the land area tributary to Riley Creek, Purgatory Creek, and Bluff Creek, which eventually drains to the Minnesota River. Portions of both Hennepin and Carver counties are located within the District, including the cities of Bloomington, Carver, Chanhassen, Deephaven, Eden Prairie, Minnetonka, and Shorewood. The MPCA has designated the streams as Class 2b waters, which permits the propagation and maintenance of cool or warm fish communities and associated aquatic life and indicates that they are suitable for aquatic recreation of all kinds (The Office of the Revisor of Statutes 2015a). These urban streams are each undergoing various stages of development ranging from agriculture/new development

(Bluff Creek) to redevelopment (Purgatory Creek). The MPCA has listed Bluff Creek as impaired for turbidity and fish and Riley Creek as impaired for turbidity (MPCA 2015). Each stream has multiple areas exhibiting considerable in-stream degradation, which is often more severe near the bottom 25% of each watershed when grades steepen to greater than 18%, and soil composition shifts to more highly erodible soils including mainly sand and silt.

## Methods

A combination of the Rosgen Stream Classification System (Rosgen, 1994; Rosgen 1996), components from Watershed Assessment of River Stability and Sediment Supply (WARSS) (Pfankuch 1975; Rosgen 2006), and the Minnesota Stream Habitat Assessment (MSHA) (MPCA 2014a) were selected as key components to be included in the assessment tool, as these methods addressed key variables important to assess the overall state of each subreach while allowing for extensive use of existing information to help the District prioritize stream restoration projects. In addition to the published methods, other key categories were identified as important to help prioritize restoration efforts. The following is a list of selected categories included in the CRAS:

- Infrastructure risk
- Erosion and channel stability
- Ecological benefit
- Water quality
- Watershed benefits
- Public education
- Partnership opportunities
- Project cost per pound of phosphorus per foot of stream

Using these variables, the District completed assessments of nearly all major stream reaches between the fall of 2013 and the fall of 2017, which were previously delineated in 1996 and 2003 based on the dominant stream type as identified by Rosgen stream classification system (Rosgen 1994; Rosgen 1996; RPBCWD 2011). In the process of walking and evaluating the creeks, the major reaches were divided into 93 subreaches to provide more accurate summaries of the relative condition of the different segments of each creek. Scores were developed for the 87 subreaches that were fully assessed. The subreaches not assessed entered wetland complexes and could not be scored, as no main channel could be found. The boundaries of a subreach were defined in multiple ways, including but not limited to stream crossings, obvious changes to the characteristics of the stream and surrounding area (channel shape, valley shape, or surrounding vegetation), or observed locations where erosion issues begin or end.

Scores for each prioritization variable were necessary to compare subreaches in an objective way across the watershed. Each variable was assigned points based on the severity of the condition. A score of 1, 3, 5, or 7 was given to each category such that a score of 1 was best (i.e., no degradation) and a score of 7 was worst (i.e., significant degradation). Additionally, it was determined that splitting the variables into two tiers would best allow for prioritization based on the typical key drivers of stream restoration projects. Specific scoring criteria for the two-tiered system and for each variable are described in the following sections.

### Tier I Categories and Scoring

Tier I categories consisted of those factors that affect public health and safety, align with goals in the District's Plan, and represent the key reasons why stream restoration projects are commonly undertaken by the District. Tier I categories were considered for all stream reaches evaluated and assessed based on a combination of desktop review of existing data and field evaluations. Each category in Tier I was assigned points based on the severity of degradation or the importance of the individual category to either the public or the District. These categories included infrastructure risk, erosion and channel stability, ecological benefit, and water quality.

#### I. Infrastructure Risk

The risk to infrastructure is a critical category in prioritizing stabilization/restoration projects because public safety is the top priority in communities. Inadequate or aging public infrastructure can also contribute to degraded water quality. In the case of this tool, infrastructure included public infrastructure such as roads, bridge, sanitary sewers, or storm sewers. It also included utilities (gas, electric, etc.) or private infrastructure, such as houses and outbuildings. Addressing an acute risk to public infrastructure related to creek erosion also presents an opportunity to take advantage of economies of scale and complete additional restoration in the vicinity or along the access path needed to repair the infrastructure risk. Table 1 summarizes scoring criteria for infrastructure risk. A higher score indicates a greater infrastructure risk. It should be noted that the scores and threat levels assigned to infrastructure are based on a qualitative assessment and do not reflect the results of in-depth engineering analyses to determine the stability at each individual location.

Table 1. Infrastructure risk scoring criteria.

| Score | Description |
|---|---|
| 1 | No threat |
| 3 | Long-term threat |
| 5 | Moderate-term threat |
| 7 | Short-term threat |

## II. Erosion and Channel Stability

The severity of channel erosion and stability was assessed using the Modified Pfankuch Channel Stability Rating Procedure (Pfankuch 1975). The Pfankuch assessment is based on evaluating the upper banks, lower banks, and bed of the stream while considering the stream type as identified by the Rosgen Classification System (Rosgen 1994). A higher Pfankuch score represents a more degraded, less stable stream. Ranges of Pfankuch scores for each stream type were associated with CRAS scoring categories, as shown in Table 2.

## III. Ecological Benefit

Streams are utilized by a variety of organisms that are both important to the ecosystem and provide viewing and educational opportunities for community members. For the purposes of this study and time constraints, the MPCA's MSHA (MPCA 2014a) was applied to each subreach to develop a general habitat score based on a variety of stream habitat characteristics, including surrounding land use and both in-stream and riparian features. The MSHA also had internal scores for bank erosion, siltation, and embeddedness, highlighting the importance of the variable to the state of each subreach. The erosion related scores within the MSHA were still included to limit modifications to the established stream methodology and because of the direct correlation between habitat and stream stability. However, this may result in affecting the overall influence of erosion and stability given the duplicity in assessment information. The lower the habitat rating, the more degraded the habitat was in a subreach, resulting in greater potential benefit that could be gained from a restoration project. Ecological benefit scoring criteria are included in Table 3.

Table 2. Erosion and channel stability scoring criteria.

| Score | Description | Rosgen Stream Classification Type | | | | | |
|---|---|---|---|---|---|---|---|
| | | B-5 | C-4/C-5 | E-5 | E-6 | F-4 | F-6 |
| 1 | Very stable | 48–57 | 70–79 | 50–62 | 40–51 | 85–97 | 80–87 |
| 3 | Moderately stable | 58–68 | 80–90 | 63–75 | 52–63 | 98–110 | 88–95 |
| 5 | Moderately unstable | 69–88 | 91–110 | 76–96 | 64–86 | 111–125 | 96–110 |
| 7 | Unstable | 89+ | 111+ | 97+ | 87+ | 126+ | 111+ |

Sources: Pfankuch 1975; Rosgen 1994.

Table 3. Ecological benefit scoring criteria.

| Score | MSHA Score | Habitat Quality |
|---|---|---|
| 1 | 76–100 | Excellent |
| 3 | 51–75 | Good |
| 5 | 26–50 | Fair |
| 7 | 1–25 | Poor |
| Source: MPCA 2014a. | | |

### IV. Water Quality

This category uses water quality data from the past 5 years to assess the status of the water quality within each of the major reaches. Bi-monthly grab samples were collected during the growing season (April to October) at 18 monitoring sites across the three subwatersheds to assess water quality and was extrapolated upstream from the monitoring sites to generate water quality scores. The goal was to collect at least 8 samples per site; however, across years, quantities ranged between 6 to 13 samples with most sites ranging between 9 to 11 samples. Unsafe sampling conditions, interstitial or intermittent flows, and exceeded sample holding times can explain this variation. Data include: total phosphorus, total suspended solids, chlorophyll, water temperature, dissolved oxygen, pH, chloride, and the MPCA impairment status (MPCA 2015). Recent water quality data were compared to the river eutrophication standards set by the MPCA in 2014 (The Office of the Revisoer of Statutes 2015b) and scored accordingly. As shown in Table 4, the higher the score in this category, the more degraded the water quality.

Table 4. Water quality scoring criteria.

| Score | Description |
|---|---|
| 1 | No impairments; water quality parameters well below MPCA standards |
| 3 | No impairments; water quality parameters consistently near or infrequently exceed maximum |
| 5 | Verge of being impaired; chronic water quality violations |
| 7 | Impaired; water quality parameters consistently above MPCA standards |
| Source: MPCA 2015. | |

The goal of Tier I scoring was to determine which subreaches were most degraded and in need of stabilization/restoration using scientific assessment and identifying infrastructure vulnerabilities. The results of the scoring generated a list of subreaches that can be divided into low, moderate, high, and severe levels of need to complete a stabilization and/or restoration project. Higher scores corresponded to either greater risk of degradation if left unrestored or greater benefit (i.e., reduced degradation) if restored. Tier I category scores were combined into a total score, allowing subreaches to be grouped and ranked according to four prioritization classes, as shown in Table 5.

Table 5. Tier I scoring priority status.

| Score | Priority Class | Description |
|---|---|---|
| ≤12 | Low | Lowest priority, no restoration efforts needed; <50% of possible points |
| 13–17 | Moderate | Low priority, possible benefit from restoration in scattered subreaches of main reach; 50–74% of possible points |
| 18–21 | High | Restoration needed and could notably reduce infrastructure risk or improve the stream; 75–90% of possible points |
| ≥22 | Severe | Highest priority, immediate stabilization and/or restoration project needed; >90% of possible points |

## Tier II Categories and Scoring

Once priority status of each stream subreach was identified by the Tier I process ("severe," "high," "moderate," or "low"), Tier II categories were used to apply additional considerations for prioritization, allowing a finer level of detail to differentiate between stream subreaches of a similar priority level. Tier II categories are used to reprioritize the subreaches within each of the Tier I defined priority status. Tier II categories included watershed benefits, public education, partnership opportunities, and project cost per pound of phosphorus. The simple addition of the Tier II scores with all categories weighted equally provided the most clear and simple means of incorporating all categories. Below is a list of the Tier II categories and their scoring methodology.

### I. Watershed Benefits

Some projects have notable benefits that extend beyond the individual stream subreach and across the watershed. Watershed benefit was scored based on the percent of the watershed downstream from a subreach. As shown in Table 6, a higher score in this category corresponds to sites closer to the headwaters of a stream, which may have greater positive effects for the entire watershed if improved. The more potential benefits a project on a particular subreach could generate, the higher the score.

Table 6. Watershed benefits scoring criteria.

| Score | Ratio Range | Description |
|---|---|---|
| 1 | <25% | Limited benefits |
| 3 | 25–49% | Low to middle |
| 5 | 50–74% | Middle to high |
| 7 | ≥75% | Significant, headwater site location |

### II. Public Education

The ability to create conversations and engage the public about how the District is improving water resources has the potential to increase water resource stewardship and implementation of best management practices within the community. The potential for project sites to serve as educational resources to the public (through use of signage and interpretive materials) and increase overall awareness of District efforts was another consideration in prioritizing stabilization and/or restoration efforts. Public education potential is highest at the most visible and accessible stream reaches, specifically those located on or adjacent to public lands. As shown in Table 7, sites with greater public education potential are ranked higher.

Table 7. Public education scoring criteria.

| Score | Description |
|---|---|
| 1 | Entirely on private property; no public access |
| 3 | Partially accessible by public |
| 5 | On public land but not easily accessible |
| 7 | On public land that is highly visible and accessible |

### III. Partnership Opportunities

The ability to collaborate with local groups and agencies within the District is important because it distributes costs, builds working relationships between different groups, and allows additional resources for larger and more comprehensive projects to be implemented and effectively managed. Partnership scoring criteria are outlined in Table 8.

Table 8. Partnership opportunities scoring criteria.

| Score | Description |
|---|---|
| 1 | No partners |
| 3 | Single partner |
| 5 | Multiple partners |
| 7 | Partner(s) with financial support |

### IV. Project Cost per Pound of Phosphorus per Foot

The cost associated with a project on each reach/subreach may vary significantly and is a factor to consider when deciding which projects to implement. Similarly, the volume of erosion occurring on each subreach varies significantly, as well. The cost to complete construction in one particular subreach may be high; however, it may have significant benefits because the sediment loading from that reach is also high. Similarly, a low-cost reach may have very low sediment loading and provide limited benefit if restored. To develop a means to compare the costs between subreaches, erosion and cost estimates were developed to generate an estimated cost per cubic yard of sediment for each subreach. Each estimate includes a potential for error, so using multiple estimates has the potential to compound estimate errors. The measurement of cost per pound of phosphorus per foot (cost/lb of P/ft) was established for planning purposes only and has been normalized to allow for relative comparison across reaches. The estimates for sediment loading and costs both include ranges. To keep the analysis from being overly complicated, averages from the respective ranges were used to generate a single estimate for this category. It was assumed that the life of a stream restoration project is 20 years; therefore, the sediment loading per foot per year was multiplied by 20 to account for sediment loading prevented through the life of the project. It was also assumed that each cubic yard of sediment contains 0.04 pounds of phosphorus, which is the computed quantity of phosphorus from 1 cubic yard of silt in 1 year in the Pollution Reduction Estimator spreadsheet from the Minnesota Board of Water and Soil Resources (2010). Additionally, a bulk density value of 70 pounds per cubic foot was assumed. The result of these assumptions and simplifications resulted in the cost/lb of P/ft as shown in Table 9.

Table 9. Project cost/pound of phosphorus/foot scoring criteria.

| Score | Project Cost |
|---|---|
| 1 | High estimated cost/cubic yard of sediment/foot of stream; >$100/pound of phosphorus/foot of stream |
| 3 | Moderate-high cost/cubic yard of sediment/foot of stream; $50–$99/pound of phosphorus/foot of stream |
| 5 | Moderate-low cost/cubic yard of sediment/foot of stream; $25–$49/pound of phosphorus/foot of stream |
| 7 | Low cost/cubic yard of sediment/foot of stream; <$25/pound of phosphorus/foot of stream |

### a) Sediment Loading Rates

During the assessment of each subreach, field staff took notes to document the erosion present along each subreach, including bank heights, height of erosion, the percentage of each subreach that appeared to be actively eroding, and the dimensions of any mass wasting locations where adjacent hill slopes or tall banks had experienced larger failures that were notably larger than typical bank erosion at each location. These estimates provided an area of erosion for each subreach. Table 10 shows erosion and channel stability scores from Tier I correlated to estimated erosion rates such that Tier I erosion and channel stability scores of 1, 3, 5, and 7 were given the erosion rates of "slight," "moderate," "severe," and "very severe," respectively. Erosion rates from Natural Resources Conservation Service Wisconsin (2003) were modified to be consistent with erosion rates measured by the City of Eden Prairie using bank pins (Wenck Associates, Inc. 2014a, 2014b). Modifications included the adjustment of the boundaries of the erosion classifications (slight, moderate, severe, very severe) as seen in Table 10 and the reduction of the moderate and severe rates by one-half. The modifications helped to better match the ratings that were given to each of the sites and allowed for more accurate estimates of erosion from the entire subreach rather than a specific bank.

### b) Screening Level Cost Estimates

Screening level cost estimates were developed for the subreaches assessed in the CRAS. The 20 year life cycle cost estimates are an anticipated cost per foot of stream stabilization/restoration and include design, permitting, construction, and construction management in 2015 US dollars. The cost per foot is based on Barr Engineering's (Barr) project experience and guidelines from ASTM International (2006) and AACE International (2005). The key considerations include: site access, bank height, riparian vegetation, floodplain topography, infrastructure risks/components, and potential for significant geotechnical input and solutions. The screening costs were developed on a per-foot basis because specific potential project extents have not yet been defined. Furthermore, subreaches in the CRAS are not of uniform length, so a cost-per-foot basis was the most appropriate way to compare costs between subreaches.

Costs associated with base planning engineering and design are based on percentages of estimated construction cost and are within a range similar to those used in past projects designed by Barr. Costs associated with construction management are based on estimated costs to manage the construction process, based on Barr's experience with similar

Table 10. Correlation between erosion and channel stability and erosion rates.

| Erosion Category | Erosion and Channel Stability Score | Erosion Rate Range (foot/year) | Description |
|---|---|---|---|
| Slight | 1 | 0.01–0.05 | Some bare banks, little active erosion |
| Moderate | 3 | 0.035–0.1 | Banks mostly bare with some rills and vegetative overhang; some exposed tree roots |
| Severe | 5 | 0.075–0.25 | Banks are bare with rills and severe vegetative overhang; exposed tree roots and some fallen trees |
| Very Severe | 7 | 0.1–0.5 | Banks are bare with gullies and severe vegetative overhang; many fallen trees; obvious bank erosion common |
| Note: Assumed erosion rates based on limited bank pin data (Wenck Associates, Inc. 2014a, 2014b) and published rates from Natural Resources Conservation Service Wisconsin (2003). | | | |

projects, but may change depending on the services that are provided during construction. The cost estimates also include percentage-based costs for permitting and regulatory approvals, which are intended to account for additional planning, coordination, and mitigation costs that are likely to be incurred as the project is permitted with environmental agencies. The screening costs include tasks and items related to engineering and design, permitting, constructing each conceptual design, and vegetation monitoring. The opinions of cost do not include other tasks following construction of each alternative presented such as operations and maintenance, or other forms of monitoring.

Industry resources for cost estimating (AACE International 2005; ASTM International 2006) provide guidance on cost uncertainty, depending on the level of project design developed. The screening costs for the CRAS generally corresponds to a Class 5 estimate characterized by completion of limited engineering and use of deterministic estimating methods. As the level of design detail increases, the level of uncertainty is reduced. Figure 2 provides a graphic representation of how uncertainty (or accuracy) of cost estimates can be expected to improve as more detailed design is developed.

At this early stage of design, the range of uncertainty of total project cost is very high. Due to the high uncertainty, it is standard practice to place a broad accuracy range around the point cost estimate. The accuracy range is based on professional judgment considering the level of design completed, the complexity of the project, and the uncertainties in the project scope; the accuracy range does not include costs for future scope changes that are not part of the project as currently defined or risk contingency. The estimated accuracy range for this point estimate is -50% to +100%. The screening level cost estimate per foot of stream can be seen in (Table 11).

## Results

### Tier I Results

Tier I scoring was applied to all subreaches with available data, which totaled 87. Table 12 provides a summary of the number and percentages of subreaches rating within each category. The majority of the subreaches (72%) had overall Tier I scores within the moderate and poor rating, meaning notable benefits could be derived from stream improvements at these locations. A total of 10 subreaches assessed by the CRAS were identified as exceptional candidates for restoration/stabilization where an immediate project could dramatically improve both the subreach and downstream water resources. Table 13 provides a sample of four individual subreaches and the how each category was scored, followed by the summed total score for Tier 1. A complete table can be found in the CRAS Technical Report (Barr and RPBCWD 2017). The final Tier 1 scores are visually represented in Figure 3.

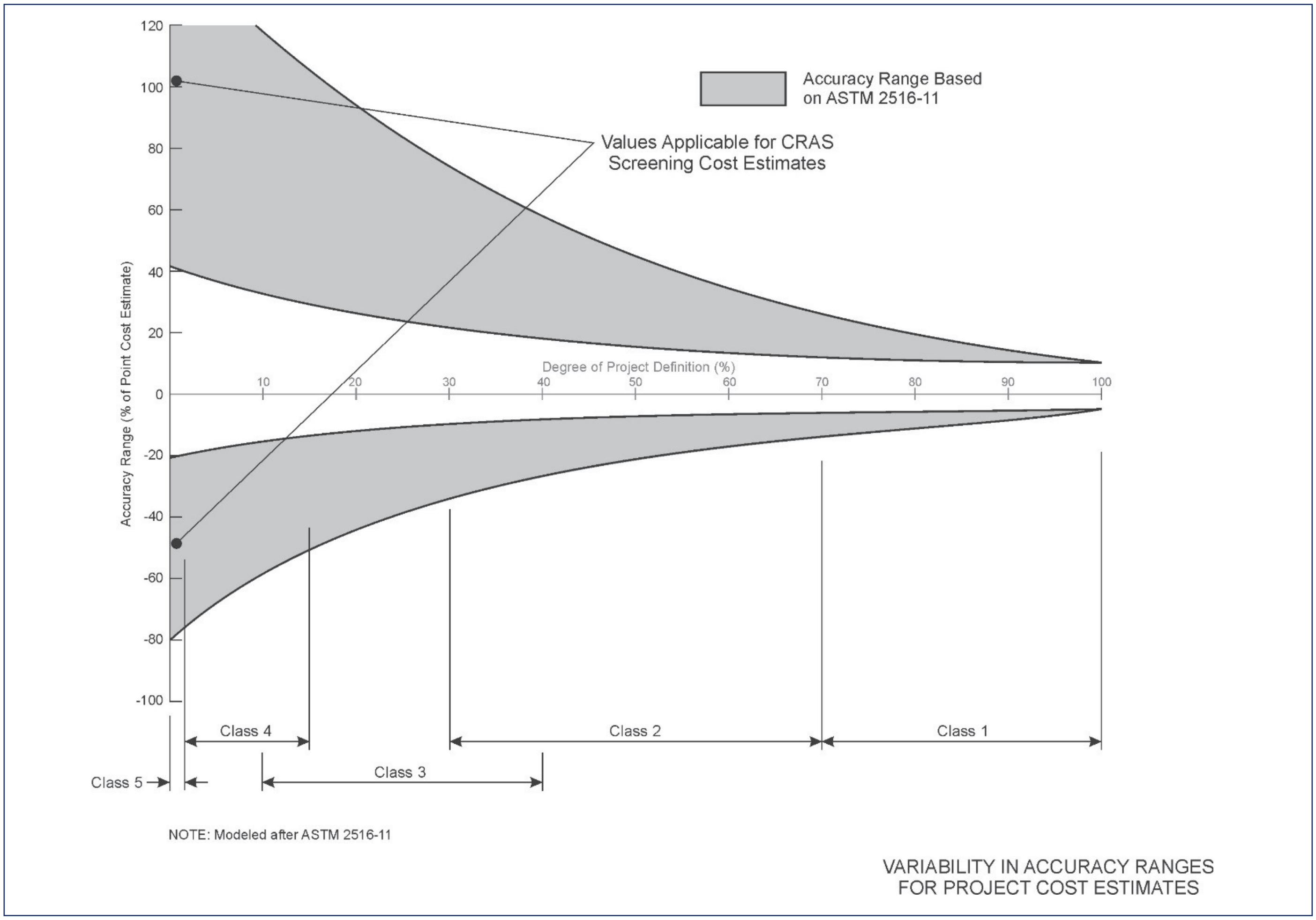


*Figure 2. Relationship between cost accuracy and degree of project definition.*

Table 11. Cost estimates per foot for stream restoration projects over a 20 year life cycle.

| Cost Range per Foot | Considerations |
|---|---|
| $200–250 | Uncomplicated project; low eroded bank heights; easy access |
| $250–300 | Uncomplicated project; low to moderate eroded bank heights; easy to moderate access difficulty |
| $300–350 | Moderate effort for design and construction, minor geotechnical or other technical considerations; moderate to high eroded bank heights; moderate to difficult access |
| >$350 | High effort for design and construction, major geotechnical, or other technical considerations; moderate to high eroded bank heights; difficult access |

Table 12. Summary of Tier I results by priority status and total score.

| Rating | Infrastructure Risk | Erosion and Channel Stability | Ecological Benefit | Water Quality | Tier I Score |
|---|---|---|---|---|---|
| Low | 54 (62%) | 18 (21%) | 1 (1%) | 1 (1%) | 15 (17%) |
| Moderate | 25 (29%) | 22 (25%) | 19 (22%) | 11 (13%) | 38 (44%) |
| Poor | 4 (5%) | 26 (30%) | 61 (70%) | 42 (48%) | 24 (28%) |
| Severe | 4 (5%) | 21 (24%) | 6 (7%) | 33 (38%) | 10 (11%) |

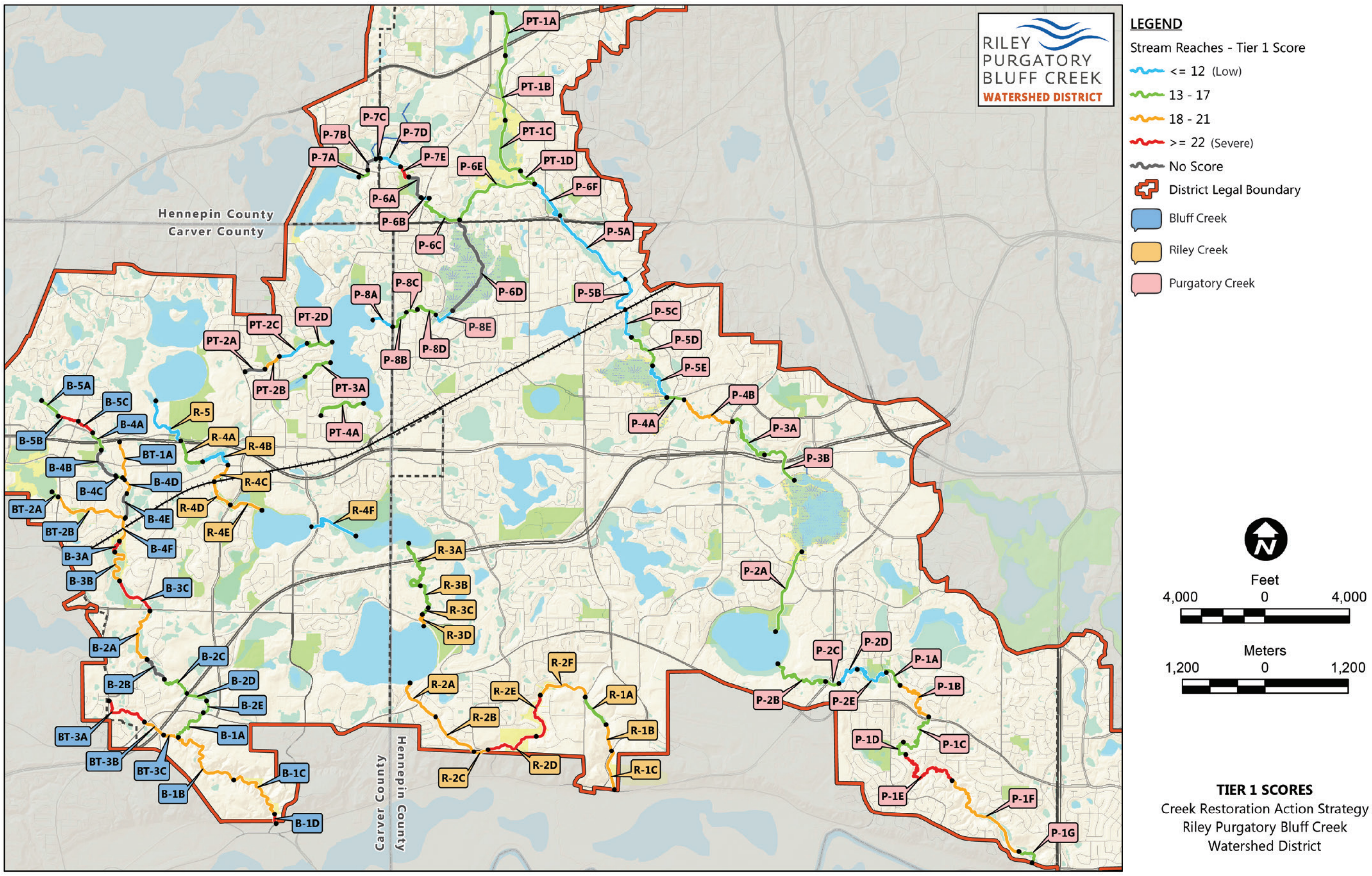


*Figure 3. Summary of Tier I scores.*

Of the 10 severe subreaches evaluated, infrastructure scores were classified as one of the two highest (worst; i.e., score of 7 or 5) ratings, highlighting the importance of infrastructure risk in this assessment. Most of the subreaches assessed scored in the moderate or poor category for erosion and channel stability (48 subreaches, or 56% of all subreaches). The most downstream quarter of each creek often scored poor or severe for stability and erosion because of the increased steepness of the surrounding slopes as the streams make their way to Minnesota River, combined with the presence of easily erodible soil types at these locations. As shown in Table 12, most subreaches scored moderate for ecological benefits (66, or 75% of all subreaches). Overall, the ecological benefit scores were similar to what can be expected for urban streams with much impervious surface and nutrient inputs. Several factors influenced the moderate scores throughout the watershed. Land uses surrounding the creeks were primarily residential and urban/industrial. Riparian areas were generally narrow with moderate to severe bank erosion. Many of the subreaches lacked diverse in-channel substrate and both type and level of cover needed to provide diverse habitat for aquatic species. Floating or submerged aquatic vegetation within the creeks was absent from most subreaches. Table 12 also highlights that most of the subreaches scored in the poor or severe category for water quality (75 subreaches, or 86% of all subreaches). Subreaches receiving water quality scores in these categories frequently exceed the MPCA's established thresholds (The Office of the Revisor of Statutes 2015b). Subreaches of Bluff and Riley Creeks generally had the most water quality threshold exceedances.

## Tier II Results

As described earlier, Tier II categories are intended to provide additional considerations to assist in prioritizing projects on subreaches. Tier I results determined the categorical ranking of "severe," "high," "moderate," and "low" rankings for each subreach. Once Tier II scores are added to the Tier I scores, the subreaches within each priority category are rearranged to reflect their Tier II scores. Table 14 provides Tier II results of four subreaches each within a different priority class. The table includes how each subreach was scored and how the

Table 13. Tier I CRAS example scoring table.

| Reach | Subreach | Rank | Location | Infrastructure Risk | Pfankuch Summary | MSHA Summary | Water Quality Summary | Tier I Scores | | Legend<br>Tier 1 Scoring |
|---|---|---|---|---|---|---|---|---|---|---|
| B1 | B1D | 1 | 475 feet upstream of Great Plains Boulevard to Great Plains Boulevard | 7 | 7 | 5 | 7 | 26 | | Severe |
| R4 | R4D | 11 | Railroad Bridge to Powers Boulevard | 5 | 7 | 5 | 3 | 20 | | Poor |
| P1 | P1D | 35 | 2,950 feet downstream of Pioneer Trail to 1,350 feet Downstream of Pioneer Trail | 1 | 7 | 3 | 5 | 16 | | Moderate |
| P2 | P2E | 74 | 1,725 feet downstream of Creek Knoll Road to Homeward Hills Road | 1 | 3 | 5 | 3 | 12 | | Low |
| Note: Complete table available in the Creek Restoration Action Strategy Technical Report (Barr and RPBCWD 2017). | | | | | | | | | | |

Table 14. Final CRAS scoring table.

| Tier II Rank | Tier I Rank | Reach | Subreach | Location | Public Education | Watershed Benefits | Partnerships | Cost/Lb. of Phosphorous | Final Score | | Legend<br>Final Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 1 | B1 | B1D | 475 feet upstream of Great Plains Boulevard to Great Plains Boulevard | 1 | 1 | 7 | 7 | 42 | | Severe |
| 18 | 11 | R4 | R4D | Railroad Bridge to Powers Boulevard | 1 | 5 | 1 | 7 | 34 | | Poor |
| 41 | 35 | P1 | P1D | 2,950 feet downstream of Pioneer Trail to 1,350 feet downstream of Pioneer Trail | 5 | 1 | 1 | 7 | 30 | | Moderate |
| 81 | 74 | P2 | P2E | 1,725 feet downstream of Creek Knoll Road to Homeward Hills Road | 3 | 3 | 1 | 1 | 20 | | Low |
| Note: Complete table available in the Creek Restoration Action Strategy Technical Report (Barr and RPBCWD 2017). | | | | | | | | | | | |

Tier I and Tier II ranks compare. A complete table can be found in the CRAS Technical Report (Barr and RPBCWD 2017).

## Discussion

Overall, the CRAS tool provides a solid foundation to help guide project implementation within the RPBCWD. However, the assessments required subjective scoring, so caution should be used when changing users, as different users may develop different scores. Persons utilizing the CRAS should carefully read and follow the tool methodology for the MSHA and Pfankuch channel assessment. An experienced team leader who would ideally go in the field on every assessment or consistently compare scores with field staff should be assigned. The CRAS was designed to be a "living document" that can be updated continuously as more information is gathered, projects are implemented, and partnership opportunities arise. From 2013 to 2017, District staff were able to assess all stream subreaches that until that point had very little information available. Field assessments took 1 week each for Riley and Bluff Creeks and approximately 2 weeks for Purgatory Creek. Now that all subreaches have been fully assessed and identified within the District, continual monitoring is recommended on a rotational basis (creek/year) to evaluate the success of projects that were implemented, assess damage after severe storms, and monitor temporal changes within each subreach.

The CRAS criteria will also be updated and revised as other methodologies are added to the analysis. One such methodology that is currently being considered is the Index of Biological Integrity (IBI) for macroinvertebrates. The IBI would measure the health of water creatures, help diagnose the type of stressors damaging a water body, define management approaches to protect and restore the water's biological communities, and evaluate how effective protection and restoration activities are (MPCA 2014b). Additionally, bank pins have been added to each major reach at representative erosion sites to more accurately capture erosion rates across the District.

While the CRAS identified stream bank erosion areas along the creeks, identifying the underlying causes of the problems was beyond the current scope of the assessment tool. Future work should include efforts to improve the understanding of why erosion is occurring at individual locations (e.g., changes in watershed hydrology, loss of vegetation, groundwater seepage, development). This could be accomplished through application of more detailed tools, such as the stream function pyramid (Harman et al. 2012), Unified Stream Assessment (Kitchell and Schueler 2005), WARSS, enhancements to the District's Storm-water Management Models modeling, subwatershed assessments, groundwater monitoring program, and feasibility studies. That said, once a severe project site is identified, more intensive monitoring efforts are applied within the channel and watershed before implementation to ensure success of the project. These include the tools mentioned above, the comparison with representative stable stream sections, and other channel design assessment tools, including Mecklenburg stream modules (Ward et al. 2011). More information about the CRAS can be found on the District's website at http://www.rpbcwd.org.

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