Appendix E

Fluvial Geomorphology Existing Conditions Report

SHIRLEY'S BROOK AND KIZELL DRAIN/WATTS CREEK

FLUVIAL GEOMORPHOLOGY

EXISTING CONDITIONS REPORT

Submitted by

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1.0 EXECUTIVE SUMMARY

JTB Environmental Systems were retained to undertake a fluvial geomorphology assessment of the Shirley's Brook and Kizell Drain/Watts Creek systems to document existing conditions and to determine what, if any, possible impacts might occur if transfer of minor and/or major system flows from proposed headwater development lands were to happen.

The study looked at the watercourses over the summer and fall of 2012 and in that time three separate assessments were done. General reach features were noted and used to delineate reaches that would be used for detailed analysis. In all, fifteen detailed reaches were identified for more intensive study: six on Shirley's Brook, five on Kizell Drain, and four on Watts Creek (though two of the Watts Creek reaches were upstream of the connection with Kizell Drain and assumed to be outside the zone of influence for any possible diversions: these represented control reaches).

General reach characteristics, bed, bank and channel characteristics, general sedimentology, planform and rapid geomorphic assessments were made, as were detailed measurements of width and depth at bankfull stage and 'normal' water stage. Calculations of velocity, shear, and other parameters were made and compared to threshold values for erosion.

Prior development and land use change in the Shirley's Brook and Kizell Drain/Watts Creek subwatersheds have resulted in change in both systems as a consequence of alteration of natural flow volumes and timing. Because of this, the systems are trying to equilibrate to those past changes by eroding and depositing sediment in a manner which will allow these systems to function properly (from a fluvial geomorphic [perspective). This study has found the systems to be out of sync (sediment and flow regimes are not working together), indicating that the process of equilibration is on-going and the channels are continuing to evolve. While this is not an ideal situation and it has led to degradation along some reaches in the watercourses, over time the evolution will complete itself and the Shirley's Brook and Kizell Drain/Watts Creek systems will stabilize. Further development in the watersheds will result in further change: additional flow volumes will have to be absorbed by the system receiving this flow and the process of equilibration will further change in response. This is a consequence of land use change and will be unavoidable, though measures to reduce impacts using stormwater management strategies can mitigate these impacts.

Should diversion of runoff from one subwatershed to another occur, for example, from Shirley's Brook to the Kizell/Watts system as proposed by previous servicing studies completed in support of the Kanata Lakes North plan, impacts would be expected to occur in both the "receiving" and the "losing" system. Because both Shirley's Brook and Kizell Drain/Watts Creek have both erosion and sedimentation problems at different locations, both systems will be subject to impacts from a diversion of runoff. The receiving system would be subject to exacerbated erosion of existing eroding banks.

Increased flow volumes to the receiving system would also be expected to result in remobilization of existing silt deposits on the bed. At locations in the system where aggradation is now occurring, this redistribution of previously eroded material from upstream would be anticipated to exacerbate the existing sedimentation problem. The losing system would be less able to flush accumulated sediment through the system and would be expected to continue to aggrade and lose function. This would be

expected to have implications for impacts at existing infrastructure (for instance at road crossings), where channel area expansion to meet culvert walls could result in additional deposition, as well as possibly having an impact on floodlines as channel areas are filled in (losing capacity). There may also be impacts on aquatic biota. These anticipated impacts have been derived from the improved understanding of the existing watercourses provided by this assessment and are intended to inform the preparation of a stormwater management strategy that will appropriately mitigate these potential impacts.

Based on the results of this study it is evident that the Shirley's Brook and Kizell Drain/Watts Creek systems are currently responding to changes in flow and sediment regimes that have arisen from prior changes to land use activity. While it will require considerable time to achieve this evolution (already underway), additional changes to land use (with or without a diversion) will delay that recovery as the receiving system responds to impacts of development. Should diversion of flows from Shirley's Brook to Kizell Drain/Watts Creek occur, it will also take longer for the systems to respond to these additional changes, as the interbasin transfer would create a greater change in fluvial process compared to changes what would result by development of lands without a diversion.

While it is not fully understood by this level of study, it would be incumbent on the development proponent to develop a plan to determine the appropriate level of mitigation needed, and ensure that mitigation plan is put in place, to manage the Shirley's Brook and Kizell Drain/Watt's Creek systems.

This study concludes that the Shirley's Brook and Kizell Drain/ Watts Creek systems are in a relatively fragile state and trying to equilibrate to changes induced by past land use change which over time have altered their flow and sediment regimes, which have been induced by land use change. Further altering of flow regimes will interrupt this on-going process with the potential to further impair the systems' ability to synchronize the relationship between flow and sediment transport. This has the potential to further affect fluvial functioning of the watercourses and by association may have an effect on infrastructure, floodlines, and aquatic biota.

Based upon this assessment of existing conditions, it can be concluded that additional development in these watersheds has the potential to exacerbate existing rates and locations of erosion, sedimentation and remobilization of existing silt deposits. It will be the responsibility of the development proponent to mitigate these anticipated impacts through an appropriate stormwater management strategy.

This study, while relying on direct measurements, represents a snapshot in time as far as existing conditions are concerned. It would have been prudent to have a larger database of information over a wider time period to fully understand the potential impacts of additional land use change on the systems; however that was not possible due to time constraints in completing this study.

Therefore it is recommended that a comprehensive monitoring program be put in place, with appropriate and measurable objectives, targets and responses (should targets be exceeded) in conjunction with further development proceeding.

2.0 INTRODUCTION

A geomorphology assessment of Shirley's Brook, Kizell Drain and Watts Creek has been commissioned to determine the existing conditions of these watercourses and to identify the potential impacts of altering flow regimes through potential inter-basin transfers of flow in the headwater areas of Shirley's Brook and Kizell Drain.

The assessment included a review of background information, creek walks, detailed measurement of channel parameters within representative reaches, determination of channel stability (through use of high-level metrics such as the RGA, RSAT as well as through direct assessment), and determination of preliminary thresholds for erosion.

3.0 REACH DELINEATION

The watercourse systems were divided into two types of reaches for analysis. The overall reach represents a longer watercourse distance and generally has boundaries at road crossings. These reaches are used to determine general conditions in the watercourse as it crosses the landscape. The detailed reaches are where specific data was collected and analyzed; these reaches are located in sensitive areas of the overall reach.

Not all reaches were walked (for instance SBG-1, WG-1) as those lands were restricted access. These two reaches in particular were long stretches of the watercourses as they entered the Ottawa River; considering how far downstream they are located from the proposed diversion area this was not considered to be a detriment to the analysis.

Other portions of the watercourses were not walked due to access limitations; however upstream and downstream sections of these sections were walked and air photos were used to view the conditions between the walked sections. For the most part those smaller parcels appeared to be consistent with upstream and downstream sections so there was no major concern around not accessing them, though we were unable to determine if there was a suitable sensitive site within those parcels that would have warranted detailed analysis.

Table 1 shows the Reach Identifier, upstream and downstream limits, and the identifier of any detailed study reach that may be within the overall reach. Figures showing the location of the reaches are found in Appendix 1.

Table 1: Location of Overall and Detailed Reaches for Geomorphic Assessment. This information is shown graphically in Appendix 1.

Overall Reach	Creek	Downstream Limit	Upstream Limit	Detailed Reach
SBG-1	Shirley's Brook	Ottawa River	March Valley Road	
SBG-2		March Valley Road	Marconi Street	SBDR-1, SBDR-2
SBG-3		Marconi Street	Shirley's Brook Drive	
SBG-4		Shirley's Brook Drive	Terry Fox Drive	SBDR-3
SBG-5		Terry Fox Drive	Leggett Drive	
SBG-6		Leggett Drive	Hines Drive	
SBG-7		Hines Drive	Rail Crossing	SBDR-4, SBDR-5
SBG-8		Rail Crossing	Golbourne Forced Dr	
SBG-9		Golbourne Forced Dr	Upper Limit	SBDR-6
KDG-1	Kizell Drain	Watts Creek Confluence	Carling Ave	KDR-1
KDG-2		Carling Ave	Hertzberg Ave	
KDG-3		Hertzberg Ave	Leggett Drive	
KDG-4		Leggett Drive	Leggett Drive	KDR-2
KDG-5		Leggett Drive	March Road	KDR-3
KDG-6		March Road	Rail Crossing	
KDG-7		Rail Crossing	Walden Road	KDR-4
KDG-8		Walden Road	Golbourne Forced Dr	
KDG-9		Golbourne Forced Dr	Upper Limit	KDR-5
WG-1	Watts Creek	Ottawa River	Carling Ave	WDR-1
WG-2		Carling Ave	Rail Crossing	WDR-3
WG-3		Rail Crossing	Corkstown Road	WDR-3, WDR-4
WG-4		Corkstown Road	Upper Limit	

SBG-1: Slope = 0.0022; Maximum Meander Belt = 44m; Sinuosity Index = 1.125

This reach was inaccessible due to access restrictions. Using air photo analysis the lower reach at the Ottawa River can be classified as a flat embayment with wetland features and wide riparian corridor vegetation. The channel meander as it moves upstream for a distance of approximately 400 metres, then straightens out and follows March Valley Road. There are a few bends in the alignment, though not appearing natural. Riparian vegetation along the road section is non-existent. There appear to be some mid-channel bars in places downstream of the March Valley Road culvert crossing, indicating a high sediment load and loss of competence of flow to maintain transport.

SBG-2: Slope = 0.0018; Maximum Meander Belt = 55m; Sinuosity Index = 1.210

This reach meanders through a corridor which initially follows March Valley Road but quickly turns to the west, flowing between two stormwater ponds. There are two connection channels to the reach; one immediately upstream of March Valley Road and the other about 100 metres upstream. Erosion is a dominant process in the lower reach, with high banks on outside bends actively cutting. Moving upstream, the bank erosion problem disappears (downstream of the rail line); the riparian corridor remains strong in this area. Upstream of the tracks the meandering continues but the riparian vegetation is replaced with grasses and some small shrubs (few trees planted by landowners). The

dominant process in this section becomes deposition of sediment from upstream reaches with little or no bank erosion.

SBG-3: Slope = 0.0029; Maximum Meander Belt = 28m; Sinuosity Index = 1.077

This reach flows through an urban residential corridor. The width of the corridor is smaller than downstream and while there are trees along the margins of the watercourse, the width of the buffer is very narrow. Meandering is more controlled here as the belt and sinuosity is much smaller. There is a tributary which enters from the north across Maxwell Bridge Road; this trib provides flow and sediment to the main branch of Shirley's Brook. Upstream of Klondike Road the riparian vegetation is replaced with grasses and the channel is more entrenched and straighter. The reach ends in a constructed pond in Shirley's Brook Park. Deposition is not as prevalent in this reach as the slope is somewhat greater than downstream; there is some deposition on the margins and some erosion on the banks (minimal). Therefore the reach can be classified as being a transfer-dominated process reach.

SBG-4: Slope = 0.0021; Maximum Meander Belt = 26m; Sinuosity Index = 1.062

This is a short reach and represents the last section of channel with some 'natural' features for some distance. The watercourse is essentially straight and flows in a narrow corridor between houses. Initially as it moves upstream the gradient is strong, but it flattens out quickly as the corridor widens. Where the gradient is lower deposition is the primary process; otherwise there is some minor bank erosion in the steeper section.

SBG-5: Slope = 0.0037; Maximum Meander Belt = 18m; Sinuosity Index = 1.018

This reach is completely altered as it flows upstream of constructed ponds through the golf course and then adjacent to commercial/industrial infrastructure. The alignment of the watercourse is straight in places and very sinuous in others, indicating the sinuous section may have been part of a realignment strategy for the golf course. Riparian vegetation is limited to a short section downstream of Legett Drive, and that vegetation is primarily long grasses. Along the golf course vegetation is very low to the ground and the watercourse is completely exposed. Some bank erosion is seen upstream of the golf course as the watercourse tries to initiate some meandering.

SBG-6: Slope = 0.0067; Maximum Meander Belt = 27m; Sinuosity Index = 1.082

This is a short section between major roads and adjacent to commercial properties to the east. The channel is actively meandering across a narrow corridor and there is evidence of rapid erosion as well as deposition in this upper section of the reach. In the lower section the channel is straight and confined.

SBG-7: Slope = 0.0081; Maximum Meander Belt = 38m; Sinuosity Index = 1.231

This is the most actively meandering section on Shirley's Brook. The lower reaches flow through a wide riparian corridor with climax vegetation and is relatively steep; the upper reaches are more reflective of a lowland marsh with reed canary grass vegetation and multiple side channels. Erosion is significant in the lower section of the reach, while deposition is dominant in the upper section. There are on-line

ponds (natural) which range in size from very small to quite large. This reach has one section of bedrock outcrop located immediately downstream of the pedestrian trail crossing. This section, which is very steep, forms almost an escarpment-like feature between two flat wetlands.

SBG-8: Slope = 0.0173; Maximum Meander Belt = 19m; Sinuosity Index = 1.153

This is a very short, steep reach. The downstream section is controlled somewhat by the rail corridor and there is some ponding upstream. Banks are eroding and the channel appears to want to meander more than it does presently; however the riparian buffer is acting to limit the erosion. There is also some deposition in the margins and within the channel in the downstream reach. At the upstream limit there is little channel visible in the reed canary grass, though there is evidence of sediment deposition.

SBG-9: Slope = 0.0042; Maximum Meander Belt = 26m; Sinuosity Index = 1.006

At the lower limit the channel flows between rock outcrops on both sides of the watercourse for a distance of approximately 100 metres. Upstream of that the watercourse is a series of straight segments which jog across the landscape through agricultural fields. Sediment supply to this reach is high and there is no buffer adjacent to the watercourse.

WG-1: Slope = 0.0018; Maximum Meander Belt = 69m; Sinuosity Index = 1.308

This reach was inaccessible due to access limitations. Historical air photos were used in this summary. The reach is a highly sinuous and moderately entrenched (from views at road crossings) one which is wandering across the relatively flat landscape. Some of the more tortuous meanders appear to be associated with in-channel sediment deposits; however it is difficult to assess with photos whether the sediment was the cause of meandering or the effect (representing depositional bars). On the whole, this reach is a depositional one with erosion through lateral migration, which is expected as the elevation of the creek is very close to the elevation of the Ottawa River (which acts as local base level). The section downstream of Carling Avenue is relatively straight and there is evidence of one meander cutoff which would be consistent with the type of planform adjustment in the area. Even though this section of the reach is straight, it is highly depositional and is entrenched, with little floodplain connectivity under a normal, annual flow regime.

WG-2: Slope = 0.0026; Maximum Meander Belt = 29m; Sinuosity Index = 1.267

This reach is highly depositional with high rates of bank erosion. The stronger gradient limits the meandering when compared to the downstream reach, though there are some significant changes in channel direction along very long sweeping bends. In between these directional shifts there are smaller meanders forming; however they are limited to a tight amplitude. Surrounding land use is open space with some agriculture and recreation (golf driving range) and trails. Some climax vegetation occurs in spots but for the most part the vegetation is grasses and low shrubs. At the upper end of the reach the creek is controlled somewhat by the existing rail line; the creek comes in contact with the rail a number of times in a section of strong meandering. Prior to the rail culvert, the Kizell Drain enters Watts Creek.

WG-3: Slope = 0.0075; Maximum Meander Belt = 42m; Sinuosity Index = 1.176

This entire reach is in NCC Greenbelt lands and has no adjacent land use constraints with the exception of trails. There is a large block of agricultural land to the south-east of the creek and another one to the north-west; in only one location does the creek come close to farmed land. The creek itself continues a meandering path and there are a number of tortuous sections where cutoffs could occur over time. The channel itself is strongly disconnected from its floodplain and there is considerable bank erosion and deposition in multiple locations. Some interventions on the creek have occurred in the past, related to trail crossings, but there is no direct evidence of large-scale realignments (though there is at least one long, straight reach). The primary processes here are erosion and deposition; the sediment loading is so high that the creek has difficulty mobilizing and sorting this sediment.

Note: Reach WG-3 is outside the influence of future upstream changes resulting from development (as it is upstream of the confluence with the Kizell Drain).

WG-4: Slope = 0.0042; Maximum Meander Belt = 19m; Sinuosity Index = 1.086

This reach is in the headwaters of Watts Creek. The surrounding area is urban residential with a large-scale transportation corridor. The creek is heavily entrenched and disconnected and while for the most part it is straight, there are some minor meanders and some significant bank erosion sites in the reach. The creek disappears at Hearst Way and does not daylight any further upstream.

Note: Reach WG-4 is outside the influence of future upstream changes resulting from development (as it is upstream of the confluence with the Kizell Drain).

KD-1: Slope = 0.0026; Maximum Meander Belt = 48m; Sinuosity Index = 1.103

This reach begins where the Kizell Drain merges with Watts Creek. The reach itself is rather straight in the lower sections, meandering somewhat along straight sections, with the exception of that area where the Drain is in contact with the rail line. With the exception of one trail crossing and the rail line contact, there is no other constraint on this section. Riparian areas are primarily grasses with some shrubs on the south side; the presence of in-channel woody debris at a couple of locations indicates there may have been some areas of climax vegetation at some point in the past. The reach is primarily depositional; there is some bank erosion along sections of the reach which creates some undercutting, but there is a clear disconnect between the volume of sediment in the channel and the bank supply. This indicates that the reach is responding to sediment delivery from upstream. The bed profile is very consistent with few pools, and the channel is entrenched and somewhat disconnected from the floodplain.

KD-2: Slope = 0.0022; Maximum Meander Belt = NONE; Sinuosity Index = 1.00

This is a straight reach bordered by road crossings at both ends. The Drain is not meandering here at all; it is pinched between agricultural fields that go right to the edge of the watercourse. Sediment delivery from overland sources would be high at times of bare soil and, depending on the crop, even at times in the summer when the land is under crop.

KD-3: Slope = 0.0040; Maximum Meander Belt = NONE; Sinuosity Index = 1.00

This is a short, straight section of Drain which flows at the base of a narrow, trapezoidal channel block. Storm drains from adjacent parking lots enter the drain along this reach; there is some minor erosion at those locations. Riparian vegetation is comprised of grasses. Sediment supply into the reach is from upstream sources rather than from within the reach.

KD-4: Slope = 0.0025; Maximum Meander Belt = NONE; Sinuosity Index = 1.09

Access to a portion of this reach was limited, however air photo interpretation shows the lower portion of the reach to be rather straight with some slight twists to the channel planform; it is not discernible whether the drain is trying to meander here or whether the slight changes in planform were established through purposeful channel realignment over time. Upstream of the limited access the drain flows through a portion of the golf club, where it is allowed to meander across a broader floodplain area. Riparian cover in the golf club is very low and includes cut fairways. Upstream of the golf club the drain is again a straight feature as it flows between commercial properties.

KD-5: Slope = 0.0295; Maximum Meander Belt = NONE; Sinuosity Index = 1.02

This is another short reach between major roads where the Drain flows adjacent to commercial properties in a narrow, trapezoidal channel block. There is one stormwater pond on the south-east side of the channel which has an emergency spillway directed at the Drain as well as a well-protected outflow connection. Riparian vegetation is limited to grasses with a few trees.

KD-6: Slope = 0.0081; Maximum Meander Belt = 39m; Sinuosity Index = 1.12

The downstream end of this reach at March Road is a long culvert which extends upstream for a distance onto the commercial property. When daylighted, it appears that the drain has been realigned somewhat into a curved path, with tree plantings along both sides of the channel. At the upstream end of this curve (which coincides with the hydro right-of-way) the channel returns to a natural, sinuous path through a wooded area. At the upstream limit the channel flows through a meadow as it exists from beneath the rail line and Station Road.

KD-7: Slope = 0.0022; Maximum Meander Belt = 11m; Sinuosity Index = 1.04

This is a short section through Lismer Pine Park where the channel flows in a meadow in the lower reaches. Approximately 200 metres upstream of the reach break there is a bedrock outcrop where the drain flows down a tight corridor with steep drops. Limestone bedrock comprises the bed and banks of the drain in this location. Upstream, the drain flows through a corridor bounded by residential yards on the east side and forest on the west; this area appears to be used for recreation purposes. In most cases the residents cut their lawns to the edge of the Drain, leaving no buffer, which has resulted in some erosion in locations.

KD-8: Slope = 0.0008; Maximum Meander Belt = 19m; Sinuosity Index = 1.09

This section contains the Beaver Pond and marsh through the entire reach.

KD-9: Slope = 0.0014; Maximum Meander Belt = 12m; Sinuosity Index = 1.10

This section is bounded by Goulbourn Forced Road at the downstream limit, where there is an inlet pipe that allows water from the upstream marsh to drain to the other side of the road while maintaining a minimum water level in the upper reach. From that point upstream the drain flows through multiple informal channels within the marsh area.

4.0 DETAILED STUDY REACHES

The creek walk was used to identify detailed study reaches where specific channel measurements were made relating to channel form and function. The detailed study reaches were identified to be a combination of unstable sections of the watercourses (where either active erosion or deposition was occurring) and relatively stable sections which were on the cusp of tipping into an instability condition.

In total, six reaches were identified on Shirley's Brook, five on Kizell Drain, and four on Watts Creek. Two of the sections on Watts Creek were upstream of the connection with the Kizell Drain. One reach (SBDR-3 is a straight reach with minimal meandering and represents straighter sections in the vicinity of SBDR-1; the other reach (SBDR-4) is an actively meandering reach which is heavily entrenched and represents meandering reaches downstream of the connection with the drain (ie SBDR-2). These were selected for comparison purposes: these reaches are on the creek which may be affected by a change of flows but are upstream of the potential area of impact. The two reaches located on Watts Creek downstream of the connection with the drain are representative of the lower portions of the creek and were considered to be sufficient for this analysis.

Following are summary sheets showing the reach Identifier, location of the reach (GPS coordinates), general condition of the reach, and a series of photos.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Watts Creek
REACH	WDR-1
GPS COORDINATES	431486, 5021968

This reach is immediately downstream of Carling Avenue and represents the furthest downstream section of channel where access was permitted. The creek is rather straight in this section, with some bank erosion occurring moreso as a gentle process (considered natural), though some clumps are found. The bed is a combination of very loose sediment as silty bars with some consolidated clay sections. Banks are steeply sloped but there appear to be no undercuts, indicating the channel is not trying to widen. Depth to floodplain elevation is high, indicating disconnection under more frequent flows.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Watts Creek
REACH	WDR-2
GPS COORDINATES	431018, 5021119

This reach is within NCC lands and begins immediately downstream of the connection with the drain. The channel is very entrenched, is actively meandering (although within a tight meander belt), and there is considerable bank erosion. The bed is comprised of silt deposits which are deep in sections; there are some pools at a couple of bends (but not at all as would be expected). Rapid clump erosion appears the be the principle means of sediment delivery to the channel. Riparian cover is exclusively grasses.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Watts Creek
REACH	WDR-3
GPS COORDINATES	430568, 5020834

This reach is a straight section of channel which is approximately 60 metres upstream of the pedestrian trail crossing. It is upstream of the connection with the drain and was selected to represent a control reach with straight planform. The channel is somewhat disconnected from the floodplain, though not as much as downstream. Bank erosion is minimal and where it is occurring it appears to be as a result of natural processes. No undercutting is evident, indicating the creek is not trying to widen. The bed is a combination of silt deposits and consolidated clays. There are a few pools along the reach, some quite deep, though they are not associated with the outside bank of meanders. Riparian vegetation is primarily grasses with some large trees; there is one small woody debris feature along this reach.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Watts Creek
REACH	WDR-4
GPS COORDINATES	430487, 5020481

This reach is an actively meandering reach with strong cut banks on the outside bends. There is a lack of pool features at the bends which reflects the high sediment loading; however there is also a lack of point bar development on the inside bends which is reflective of the disconnect between flow and the floodplain. The bed is heavily silted. Riparian vegetation is primarily grasses with some climax vegetation (trees). This reach is a control reach for the actively meandering reaches downstream of the connection with Kizell Drain.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Shirley's Brook
REACH	SBDR-1
GPS COORDINATES	427811, 5023886

This reach is the farthest downstream reach where access was permitted. It is located at the March Road crossing and extends upstream between the two existing stormwater ponds. The lower section of the reach is actively meandering within a tight meander belt; at one location it is within a few metres of the road and actively cutting in that direction. Eroding banks on outside bends are near vertical in most places, but not so in others (more gently sloped). The bed is comprised of silt accumulations in spots, primarily associated with inside bends, and exposed cohesive clay in other locations. Some point bar development occurs on bends, which allows for some floodplain connection and energy dissipation. Farther upstream the brook is joined by two stormwater connection channels and further upstream the channel is relatively straight. In this straight section there is accumulating silts from upstream and bank erosion is evident along the banks.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Shirley's Brook
REACH	SBDR-2
GPS COORDINATES	427288, 5023369

This reach is in a corridor surrounded by residential development. The channel itself is rather straight and there is good connection to the floodplain along the reach. The floodplain is wide and is comprised of a mixture of meadow grasses and some mature trees. There are no tight constraints with the exception of one culvert at the upstream end of the reach, which is open-bottomed and does not appear to confine normal flow. Bank erosion is evident in some locations but it appears to be occurring at a normal, expected rate—there are no clumps of eroded bank along the reach. In the downstream section of the reach there is some meandering and there are pools associated with the outside bends, which is natural and expected. The substrate in the straight reach is comprised of thick deposits of silt over 90% of the bed, with the remaining substrate consolidated clays.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Shirley's Brook
REACH	SBDR-3
GPS COORDINATES	427690, 5022518

This reach is upstream of a road crossing (Shirley's Brook Drive). It is located in a rather tight residential corridor for the first 100 metres or so and then widens out to a grassland/marsh floodplain area which has a number of channel pathways. Meandering is limited to the grassland/marsh area; the remainder of the reach is straight. Floodplain connection is strong throughout the reach. Substrate in the straight section is primarily exposed consolidated clays with some silt overlain in some locations. In the grassland/marsh area the substrate is primarily trapped silts, in some cases to a thickness of more than 0.30m. Erosion of the banks is not an issue in this reach. The culvert is a twin-cell concrete box with little clearance. The channel upstream is not eroding as a result of the presence of the culvert. On the downstream side of the road crossing is an online pond feature.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Shirley's Brook
REACH	SBDR-4
GPS COORDINATES	427873, 5021371

This is a natural reach upstream of Hines Road where the brook flows through a well-vegetated floodplain and corridor. The alignment of the channel is natural, with meandering occurring and bank erosion. Outside bend erosion is evident on all meanders and in most can be considered extreme; however there is also erosion on some of the inside bends which indicates the channel wants to widen under higher flows. That said, there are also properly forming point bars on some inside bends that are well connected to the floodplain. The substrate is comprised of some clumps of recently eroded bank material as well as silt deposits that are significant in places.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Shirley's Brook
REACH	SBDR-5
GPS COORDINATES	427502, 5020939

This is a natural reach which flows through a marshy area at the upstream end and then flows into and through a bedrock outcrop. Banks of the channel are a mixture of clay and limestone in the upper section of the channel. The bed is comprised of silts and clays in the upper portion of the reach, however there does not appear to be any significant accumulations such as are found in other locations of the brook. In the section which is completely controlled by limestone there are no deposits on the bed. This reach was selected as a control reach as it functions as a transfer reach (meaning it neither supplies nor accumulates sediment—any sediment that meets the upper end of the reach is transported through to downstream sections) which can be used for long-term monitoring.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Shirley's Brook
REACH	SBDR-6
GPS COORDINATES	426892, 5020263

This is the furthest upstream reach studied. The lower portion of the reach flows through a short, confined bedrock outcrop and then flows as a straight channel through cleared land which has been used for agriculture. Banks in the outcrop section are a combination of clays and rock, as is the bed. There are no significant silt deposits in the bed along this section; however the upper sections do have accumulated silts possibly related to the land use activity. There is no buffer along the brook in the upper reaches, and the brook flows straight with some purposeful changes in direction as it nears the outcrop location.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Kizell Drain
REACH	KDR-1
GPS COORDINATES	430680, 5021166

This reach begins upstream of the connection with Watt's Creek. The drain is very straight and narrow here, and is quite disconnected from the floodplain. Floodplain areas are heavily vegetated in grasses; there are few trees though there is some wood debris in the channel at a couple of locations. The bed is comprised of deposits of silt ranging in thickness from about 0.10 to 0.45m. Banks are consolidated clays and are near vertical. Bank erosion is evident in some locations through undercutting, indicating the drain is trying to create a sinuous pattern.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Kizell Drain
REACH	KDR-2
GPS COORDINATES	429426, 5021362

This reach is located in a confined corridor within the commercial land use area. The valley form is trapezoidal and the drain flows in a somewhat sinuous pattern across the bottom of the valley. Riparian vegetation is primarily grasses with the occasional tree. The bed is comprised of accumulated silts of varying thickness delivered from upstream. Banks are not very high, there is good connection to the floodplain however the floodplain is not very wide so confinement of higher flows does occur. Bank erosion is somewhat limited by the rooting strength of the grassy vegetation; however there are the occasional scars along the bank and a couple of clumps of bank material, with grasses still attached, were found. This reach is rather flat and as a consequence there is some stagnancy to the water under normal water levels, this is evidenced by the wafting odour of decomposition of vegetation in the bed as the silts are disturbed.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Kizell Drain
REACH	KDR-3
GPS COORDINATES	428515, 5021424

This is a very straight section exhibiting similar constraints as KDR-2 with the exception that the reach is steeper and there is less stagnancy to the water under normal water conditions. Banks are well protected by grasses however in this section there is some undercutting indicating the drain is trying to alter its path. Some larger clump bank erosion is evident in the reach. Sediment on the bed consists of accumulated silt deposits from upstream, however they are not as thick as found in the downstream study reach.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Kizell Drain
REACH	KDR-4
GPS COORDINATES	428146, 5020429

This reach extends from Walden Road downstream to the bedrock outcrop location. The reach was selected as it represents the first formal drain section downstream of the Beaver Pond and this is where it is anticipated change will be noticed first if flows are altered. Residential yards on the east side extend to the edge of the drain with no buffer and some bank erosion is occurring in these sections. Floodplain connection is strong here as the banks are not too high on either side of the drain. Flow under normal water levels varies from still to rapid; this range is ideal as it provides for natural transfer of sediment. Bed material ranges from clays to limestone and there are minimal silt deposits on the bed.

PROJECT	Shirley's Brook and Watts Creek/Kizell Drain
CREEK	Kizell Drain
REACH	KDR-5
GPS COORDINATES	427109, 5019855

This reach is upstream of the Beaver Pond in the area referred to as the Kizell Wetland. There is no formal channel in through here as there are multiple channel paths accessed under different flow conditions. Silt deposits in the wetland occur along channel margins and are quite deep in locations (up to 0.45m thick). The entire length of the watercourse along here has silt deposits; there are no exposures of rock or consolidated clays. Sands found in the deposits have their probable source in roadside applications along Golbourne Forced Road during winter. Channel banks are indeterminate for the most part. While not considered a formal part of the Drain, this location was assessed to provide context for comparison to downstream wetland sections which could be impacted by proposed diversions.

5.0 ANALYSIS AND INTERPRETATION OF EXISTING CONDITIONS

Each of the reaches were walked three times over the summer and fall of 2012. The purpose of multiple visits was to review the function of the reaches under different flow conditions if at all possible. One visit was during a summer rain event and the watercourses were flowing at higher-than normal water levels but also at less-than-bankfull flows. A second visit was during extreme low flows (no rain within the previous week during the summer) and the third visit was in the fall when water levels appeared to be at 'normal' levels. It was during the fall visit that the specific channel measurements were made.

5.1 Methodology

A number of parameters were analyzed during the site data collection with the intent of documenting the existing conditions in the watercourses and determining, based on the findings, overall sensitivity to alterations in flow regime.

At a high level, general information about the detailed reaches in the context of the valley, bed/bank/channel characteristics and general sedimentology information was collected. In addition, information relating to general channel planform and high-level stability assessments were carried out in order to classify the reaches. Finally, detailed measurements were made at each reach which included wetted and bankfull width and depth, sediment calibre (bed material), bank characteristics (height, structure, angle and in-situ strength), and estimated manning's 'n'. From those results, critical values for velocity and shear stress were calculated.

Specific details relating to the methodology used are as follows:

- General Information (Conservation Status, Reach Class, Valley Form and Land Use): the method used was a mixture of desktop analysis using air photos, previous reports and other mapping, combined with field validation of the initial findings.
- Bed/Bank/Channel Characteristics: the principal method used here was field based observation.
    - Bed material was classed according to the Udden-Wentworth scale at major boundaries (clay, silt, sand, gravel, cobble, boulder) and represents the dominant materials and any obvious mixes.
    - In-channel vegetation is a presence/absence assessment and where present, degree of emergence (submerged being only in the water, emergent being within the active channel but also extending above the waterline, and algae being present on rocks or wood debris).
    - Channel flow type is an observation of unobstructed flow in pools and riffles/runs across the three site visits.
    - Bank material is also based on the Udden-Wentworth scale at major boundaries and represents the dominant material and obvious mixes.
    - Bank face vegetation is observational.
    - Bank protection relates to artificial stabilization techniques and is classed as present or absent.

  - Bank stratigraphy is based on visual assessment of the bank after a vertical scrape is made to expose the nature of the bank in situ.
  - Bank profile is observational across major classes (vertical, steep, gentle) and notes of undercutting and/or presence of toe materials is made.
- General Sedimentology (Sediment Sources, Sediment Sinks, Channel Sinks and Floodplain Deposits) are observational across three site visits.
  - Sediment sources are distinguished as either bed or banks (noted by erosion scars on either) or from tributaries.
  - Sediment sinks are areas where sediment is forced to settle out because of in-channel features (ie wood debris, widened banks for culverts, grade control features such as bedrock outcrops).
  - Channel sinks are those areas, apart from sediment sinks, where transporting sediment is settling out and accumulating. Natural locations include point bars; mid-channel and side bars indicate high sediment loading. The is the material that may be remobilized and transported under higher flows.
  - Floodplain deposits are observational and require searching for fine sediment accumulations attached to plants, presence of larger sediment classes (such as overbank deposits of gravels) and presence of woody debris (large sizes) or organic debris (smaller sizes) rafted to the site from upstream.
- Riparian vegetation is observational.
- Channel length, valley length and sinuosity are determined using mapping of the watercourse and the valley. Channel length is the total measured length along the channel centreline for the reach; valley length is the straight line length of the reach (or straight line segments if the reach has shifts in orientation); sinuosity is the relationship between channel length and valley length. Sinuosity values of 1.0 mean the channel is straight throughout the entire reach, values from 1.0 to 2.5 represent sinuous channels, and over 2.5 represent meandering channels.
- Maximum meander belt is an indication of the lateral distance along the floodplain that the channel wanders. Determination of maximum meander belt is done using air photos to trace the path of the watercourse along the reach. The belt represents a line following the down-valley path adjacent to the widest extending point the watercourse reaches on each side of the centreline of the valley. The distance between these lines represents the maximum floodplain distance used by the watercourse along the reach. Individual meander amplitudes might be smaller than this value; individual meanders are measures from one side of the bend to the other along the same meander, which represents the width of the meander wave (referred to as the amplitude). The difference between the two (maximum belt and meander amplitude) is the meander amplitude is measured on each individual meander, and the maximum belt is measured using the furthest outside bends, which usually are not found on the same meander. Therefore it is common to find that the maximum meander belt is wider than the individual meander amplitude values; though there have been instances on some systems where one meander can represent the maximum belt as well. This is shown graphically in Figure 1.

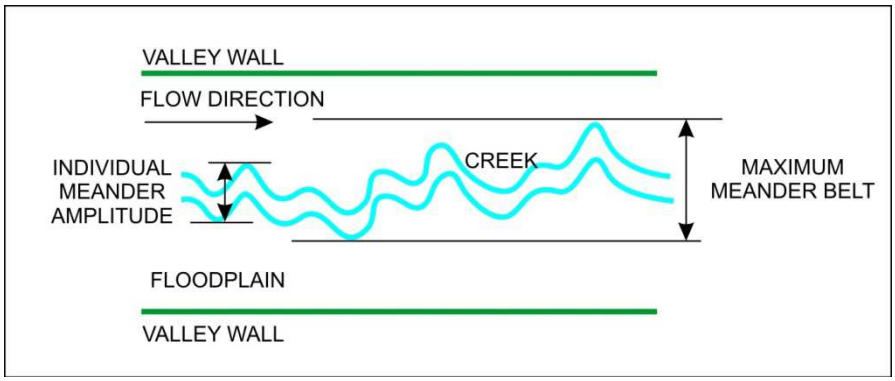


Figure 1: Graphic depiction of maximum meander belt and meander amplitude

- RGA, RSAT and RRAF Scores are high-level geomorphic classification tools that allow for general classification of reaches. They are filled in while walking the reach and represent the entire reach as a whole, as opposed to the individual cross-sections within each reach.
- Channel dimensions of width and depth are made at wetted width stage at the time of survey and at bankfull stage using natural bankfull indicators which are identified in the field. Width to depth rations are a representation of those measurements and generally indicate a wide, shallow channel (high width to depth ratio) or a narrow, deep channel (low width to depth ratio). There are no standards for width to depth ratio to compare to; results are compared from reach to reach.
- In-channel scour is a direct measurement of the depth of scour of pools which are not located at meanders and appear to be located in areas where they would not normally occur (ie near woody debris jams). Depth of scour is the maximum depth from the local bed level where there is no scour occurring.
- Channel Bank characteristics (Type, Height, Angle, in-situ Shear Strength) are direct measurements and observations.
    - Type is based on observation.
    - Height is directly measured using a tape.
    - Angle is directly measured using a carpenters device which allows for a flat surface to be placed on the bank and the exact angle to be read off a scale.
    - In-situ shear strength is using a torvane device. This device uses rotational force to initiate a failure, and records the force required to cause that failure. The result is converted to a shear strength which can be compared to shear stress on the banks created by the force of flowing water.
- Manning's 'n' (an estimate of channel roughness) was estimated from field evidence.
- Average Values for Velocity and Shear Stress are modelled results that use the channel dimensions identified earlier, the average slope for the reach (as determined by mapping) and the estimated Manning roughness value. Each parameter is entered into a hydraulic model (in this case and for this level of investigation Flowmaster was used) and through the run velocity in

the channel was determined. Using the depth and the Shields equation shear stress on the bed was also calculated. This was done for low flow and bankfull dimensions.

- Critical Values for Velocity and Shear Stress used the results of the average conditions modelling above and incorporated the bank and substrate material classes (both consolidated and unconsolidated). Results were compared to the Hjulstrom Diagram to determine critical values for velocity and the Shields function was used to determine the critical values for shear stress. Critical velocity was determined for the banks and substrate materials.
- Assessed risk to altered flow regime is a general assessment of impacts which may be created by altered flow regimes in the reach, and are not tied specifically to any specific diversion scheme.

5.2 General Information

Table 2 shows the results, by reach, for each of the classes under the General Information assessment.

Table 2: Results of General Information Classification, detailed reaches.

DETAILED STUDY REACH	CONSERVATION STATUS	REACH CLASS	VALLEY FORM	LAND USE
SBDR-1	8	SOURCE	LOWLAND FLOODPLAIN	GREENSPACE/ ROAD CORRIDOR
SBDR-2	5	SINK	SHALLOW VALLEY	RESIDENTIAL CORRIDOR
SBDR-3	5	EXCHANGE	NO OBVIOUS SIDES	RESIDENTIAL CORRIDOR
SBDR-4	8	SINK	LOWLAND FLOODPLAIN	FOREST CORRIDOR
SBDR-5	10	TRANSFER	SHALLOW VALLEY	FOREST CORRIDOR
SBDR-6	10	EXCHANGE	GORGE	FOREST
KDR-1	4	SINK	LOWLAND FLOODPLAIN	GREENSPACE MEADOW
KDR-2	2	SINK	NO OBVIOUS SIDES	URBAN CORRIDOR
KDR-3	2	SINK	NO OBVIOUS SIDES	URBAN CORRIDOR
KDR-4	6	TRANSFER	SHALLOW VALLEY	URBAN CORRIDOR
KDR-5	10	SINK	SHALLOW VALLEY	WETLAND
WDR-1	6	SINK	NO OBVIOUS SIDES	PRIVATE
WDR-2	9	TRANSFER	SHALLOW VALLEY	GREENBELT
WDR-3	5	SINK	LOWLAND FLOODPLAIN	GREENBELT
WDR-4	8	EXCHANGE	U OR V SHAPED	GREENSPACE/ AGRICULTURE

Conservation Status

Conservation Status is a means of identifying susceptibility to disturbance based on descriptors found in the following table. A score of 10 represents resilience in the system and the reach is able to accept a certain amount of disruption and still retain its function; as the score decreases the susceptibility to disturbance becomes greater (meaning the response to disturbance is more significant). Channelized sections represent the lowest possible score for daylighted channels (1/10), while culverts rate a 0 because they are completely disrupted and not natural in any way (open bottom culverts with a low flow channel would score as a 2 because the low flow is considered somewhat natural).

The source is located in Britain; the status results are used across the UK and have been adopted here in Ontario on a number of projects. This method is used in this study to complement the standard RGA and RSAT tests, which are known to be somewhat limiting in their applicability.

Table 3: Conservation Status Classes

STATUS	SCORE	DESCRIPTION
High	**8-10**	Conforms most closely to natural, unaltered state and will often exhibit signs of free meandering and possess well-developed bedforms (point bars and pool-riffles sequences) and abundant bank side vegetation.
Moderate	**5-7**	Shows signs of previous alteration but still retains many natural features, or may be recovering towards conditions indicative of higher category.
Low	**2-4**	Substantially modified by previous engineering works and likely to possess an artificial cross-section (e.g. trapezoidal) and will probably be deficient in bedforms and bank side vegetation.
Channelized	**1**	Awarded to reaches whose bed and banks have hard protection (e.g. concrete walls or sheet piling).
Culverted	**0**	Totally enclosed by hard protection.
Navigable	**-**	Classified separately due to their high degree of flow regulation and bank protection, and their probable strategic need for maintenance dredging.
(Department for Environment, Food and Rural Affairs, 2003)		

Results show the middle reaches of the Kizell Drain as having the lowest scores (reach 3 and 2 having scores of 2/10), indicating these are the least-functioning reaches in these systems. By comparison, the upper reaches of Shirley's Brook and Kizell Drain score 10/10.

Of interest in the results is the score for reach SBDR-1 (8/10), which is a naturally eroding reach with steep banks and some risk to road infrastructure—the erosion that is occurring indicates a sensitivity to disturbance, however the fact that the bed is relatively clean indicates the brook is able to deal with additional sediment along that reach, making it adaptable.

Reach Class

Reach Class categories are shown in the following table. The purpose of this designation is to identify sediment dynamics throughout the entire reach.

Table 4: Reach Class Designations

REACH FUNCTION	DESCRIPTION
Sediment Source	Sediment output from the reach is greater than sediment supply from upstream.
Sediment Transfer	Sediment output is approximately equal to input from upstream. Sediment is transmitted through the reach, which features few sites of active erosion, or deposition either because the channel is adjusted and naturally stable or because the bed and banks have been stabilized artificially.
Sediment Exchange	Sediment output is approximately equal to input from upstream (as for a transfer reach), but incoming sediment is exchanged with that derived within the reach, which features active erosion and depositional sites.
Sediment Sink	Sediment input to the reach is greater than sediment output to the next reach downstream.
Winterbourne	Flow expected only at high flow, therefore the balance of sediment inputs and outputs is seasonally dependent.
	(adapted from Thorne and Skinner, 2002)

Results show that more than half the reaches are classified as sinks (8/15). This means that these reaches are storing sediment that enters the reach and are not, under the existing range of flows, able to move that sediment through and self-clean the reach. It is not known at this level of study whether the large silt deposits are remobilized under higher flows and then replaced as flows recede with sediment from upstream; however given the thickness and positioning of some of the deposits, that condition (mobilization and replacement in one single event) does not seem probable. Three reaches were classified as transfer reaches and three were classified as exchange reaches. Only one reach (SBDR-1) was classified as a source reach.

Valley Form and Land Use

These parameters are used as a means of understanding possible inputs to the systems from the adjacent land. For example, a lowland floodplain within a forest corridor (ie SBDR-4) will receive runoff in a completely different manner than a shallow valley in an urban corridor (ie KDR-4). The manner in which runoff is directed to the channels indicates the processes operating on the channels and it also explains to a certain degree how the reach is classified (using the examples, SBDR-4 is a sink and KDR-4 is a transfer reach).

For the most part there are shallow valleys and flat floodplains throughout the study area, with the exception of a couple of locations where bedrock gorges dominate or there is a well-defined U or V shaped valley. Land use ranges from urban (residential and commercial) to Greenbelt open space, as would be expected.

5.3 Bed/Bank/Channel Characteristics

Table 5 and 6 show the results, by reach, for each of the classes under the Bed/Bank/Channel Characteristics assessment.

Table 5: Characteristics of the bed, bank materials, flow types and in-channel vegetation for the detailed study reaches.

DETAILED STUDY REACH	Bed Material	In-Channel Vegetation	Channel Flow Types	Bank Material
SBDR-1	CLAY	SUBMERGED	RIPPLED FLOW SMOOTH	CLAY/SILT/SAND
SBDR-2	CLAY	SUBMERGED ALGAE	SMOOTH	CLAY/SILT
SBDR-3	CLAY/SANDS	ALGAE	SMOOTH	CLAY/SILT/SAND
SBDR-4	CLAY	NONE	SMOOTH	CLAY/SILT
SBDR-5	CLAY BEDROCK	ALGAE	FREE FALL CHUTES STANDING WAVES RIPPLED FLOW	CLAY BEDROCK
SBDR-6	CLAY	SUBMERGED ALGAE	RIPPLED FLOW UPWELLING	CLAY/SILT/SAND BEDROCK
KDR-1	CLAY/ SILT/ SAND	NONE	SMOOTH	CLAY/SILT
KDR-2	CLAY/ SILT/ SAND	SUBMERGED EMERGENT ALGAE	SMOOTH	SILT SAND
KDR-3	CLAY/ SILT/ SAND	SUBMERGED EMERGENT ALGAE	SMOOTH	SILT SAND
KDR-4	CLAY TO BOULDERS	NONE	CHUTES RIPPLED FLOW	CLAY/SILT/SAND BOULDERS BEDROCK
KDR-5	SILT AND CLAY, SOME SAND	SUBMERGED EMERGENT	NOT VISIBLE	NOT VISIBLE (VEGETATION)
WDR-1	CLAY	SUBMERGED	SMOOTH	CLAY/SILT
WDR-2	CLAY TO BOULDERS	SUBMERGED EMERGENT ALGAE	SMOOTH	CLAY/SILT/SAND
WDR-3	CLAY TO COBBLES	SUBMERGED ALGAE	SMOOTH	CLAY/SILT/SAND
WDR-4	CLAY/ SILT/ SAND	SUBMERGED EMERGENT	SMOOTH	CLAY/SILT/SAND

The results show that bed material for the most part is clay, with some silts. Sands are found nearer to road crossings and have their likely source in winter applications of road sand, as no large deposits of sands were found in the banks (though some banks did have sandy characteristics). Cobbles and boulders are found within some sections but are not dominant, they may be remnant features from glacial deposits or they may be imported for other purposes (ie cobbles for culvert protection) and have mobilized over time.

There is also a wide range of in-channel vegetation as either algae or submerged vegetation, which can be an indicator of water quality. Generally speaking the presence of algae is indicative of poor water quality; however that was not a focus of this study so no conclusions are made. Emergent vegetation is found along some of the margins and is associated with silt deposits.

With respect to flow regimes, most reaches have smooth flow. Smooth flow indicates a lack of in-channel diversity and is usually found in long runs or deep pools; in these watercourses they are found in a wide range of situations. Upwelling and rippled flow was noted in the upper reaches of Shirley's Brook, rippled flow was noted in the lower reaches of Shirley's Brook and cascading/chutes/freefall flow was found in the bedrock controlled section of Shirley's Brook and Kizell Drain.

Bank material was determined to be primarily silts and clays with some sands.

Table 6: General bank characteristics for the detailed study reaches.

DETAILED STUDY REACH	Bank Face Vegetation	Bank Protection	Bank Stratigraphy	Bank Profile
SBDR-1	GRASS	NONE	HOMOGENEOUS	VERTICAL/UNDERCUT VERTICAL WITH TOE STEEP, COMPOSITE
SBDR-2	GRASS	NONE	HOMOGENEOUS	VERTICAL/UNDERCUT
SBDR-3	GRASS	NONE	HOMOGENEOUS	VERTICAL WITH TOE GENTLE
SBDR-4	GRASS	NONE	HOMOGENEOUS	VERTICAL/UNDERCUT VERTICAL WITH TOE STEEP
SBDR-5	GRASS	NONE ROCKWALL	HOMOGENEOUS	GENTLE
SBDR-6	GRASS/SCRUB TREES	NONE ROCKWALL	HOMOGENEOUS	STEEP GORGE OTHERWISE GENTLE
KDR-1	GRASS/REEDS SEDGES	NONE	HOMOGENEOUS	VERTICAL/UNDERCUT STEEP
KDR-2	GRASS/REEDS SEDGES	NONE	HOMOGENEOUS	VERTICAL/UNDERCUT
KDR-3	GRASS/REEDS SEDGES	NONE	HOMOGENEOUS	VERTICAL/UNDERCUT
KDR-4	GRASS	NONE ROCKWALL	HOMOGENEOUS	STEEP GENTLE
KDR-5	GRASS/REEDS	NONE	HOMOGENEOUS (ASSUMED)	GENTLE
WDR-1	GRASS/REEDS SEDGES	NONE	HOMOGENEOUS	VERTICAL/UNDERCUT VERTICAL WITH TOE
WDR-2	GRASS	NONE	HOMOGENEOUS	VERTICAL/UNDERCUT VERTICALWITH TOE STEEP
WDR-3	GRASS/REEDS SEDGES	NONE	HOMOGENEOUS	VERTICAL/UNDERCUT VERTICALWITH TOE STEEP
WDR-4	GRASS	NONE	VARIABLE	VERTICAL WITH TOE STEEP

For the most part bank face vegetation was grasses with some sedges. The survey did not find any examples of artificial banks / bank protection. In only one location was there some noted stratigraphy in the bank (WDR-4), where tight clays comprised the lower bank and the upper bank was a composite sandy clay loam. With respect to steepness, for the most part banks were steep and contained some undercutting or toe sapping, though there were areas where the banks were gentle and no erosion was occurring.

5.4 General Sedimentology

Table 7 shows the results, by reach, for each of the classes under the General Sedimentology assessment.

Table 7: Sedimentological characteristics (sources, sinks, channel sinks and floodplain deposits) for the detailed study reaches.

DETAILED STUDY REACH	Sediment Sources	Sediment Sinks	Channel Sinks	Floodplain Deposits
SBDR-1	BANK EROSION	WOODY DEBRIS	SIDE BARS MEDIAL BARS POINT BARS MARGINAL DEPOSITS	FINE DEPOSITS WOODY DEBRIS
SBDR-2	BANK EROSION	GRADE CONTROL	POINT BARS MEDIAL BARS MARGINAL DEPOSITS	FINE DEPOSITS
SBDR-3	BANK EROSION	WOODY DEBRIS	SIDE BAR MARGINAL DEPOSITS	WOODY DEBRIS
SBDR-4	BANK EROSION VALLEY EROSION	WOODY DEBRIS	SIDE BARS POINT BARS MEDIAL BARS MARGINAL DEPOSITS	FINE DEPOSITS WOODY DEBRIS
SBDR-5	BANK EROSION VALLEY EROSION	WOODY DEBRIS	MARGINAL DEPOSITS	WOODY DEBRIS
SBDR-6	VALLEY EROSION	WOODY DEBRIS	NONE	WOODY DEBRIS
KDR-1	BANK EROSION	POOLS	MEDIAL BARS MARGINAL DEPOSITS	FINE DEPOSITS
KDR-2	DRAINS CROSSINGS BANK EROSION	GRADE CONTROL CROSSINGS/ CULVERTS	SIDE BAR MARGINAL DEPOSITS	FINE DEPOSITS
KDR-3	DRAINS CROSSINGS BANK EROSION	GRADE CONTROL CROSSINGS/ CULVERTS	SIDE BAR MARGINAL DEPOSITS	FINE DEPOSITS
KDR-4	BANK EROSION	GRADE CONTROL	SIDE BARS MEDIAL BARS MARGINAL DEPISITS	FINE DEPOSITS COARSE DEPOSITS WOODY DEBRIS
KDR-5	VALLEY EROSION	ORGANIC DEBRIS	MARGINAL DEPOSITS	FINE DEPOSITS ORGANIC DEBRIS
WDR-1	TRIBUTARIES	CROSSINGS	POINT/MEDIAL BARS	FINE DEPOSITS
WDR-2	BANK EROSION	WOODY DEBRIS	SIDE BAR POINT BARS MEDIAL BARS	***ND***
WDR-3	BANK EROSION VALLEY EROSION	WOODY DEBRIS	RIFFLES SIDE BAR POINT BAR MEDIAL BARS MARGINAL DEPOSITS	WOODY DEBRIS
WDR-4	BANK EROSION VALLEY EROSION	WOODY DEBRIS	SIDE BAR MEDIAL BARS	FINE DEPOSITS

Of particular interest in assessing channel form and function is the source of sediment to the system, and where that sediment is stored as it moves downstream. In properly functioning systems sediment delivery is slow and continual, and that sediment moves through the channel to the downstream reaches during high flow events, to be replaced by sediment from upstream. This balance limits erosion and also prevents sedimentation on the bed.

There do not appear to be any unexpected sources of sediment in these systems. Natural delivery of sediment from valley erosion and bank erosion occurs; however the high volumes of sediment indicate that either the delivery of sediment is excessive or the flow regime in the systems is insufficient to remobilize and transport sediment downstream. It is possible that what is being observed is historic sediment sourced from urban development which has not been mobilized through the system in the post-development condition. It is anticipated with further upstream development will result in new sources of sediment and as a consequence the developer should be required to ensure that existing problems are not exacerbated due to development activities.

In some locations there is agricultural sediment delivery, but these areas are small and confined to the upper reaches (with the exception of the Kizell Drain between Hertzberg Road and Carling Avenue). Erosion at road crossings is another source; however the survey did not note many eroding culvert sections. This means that the main source of sediment is from the banks, however again the volume estimated from in-channel sinks appears to be higher than estimates of bank erosion volumes.

This indicates that a combination of factors are working here; the sediment sourcing appears to be greater than normally would be expected, and the flow regime is not functioning sufficiently to work the sediment through the systems.

Sediment sinks (not necessarily in-channel) tend to be around woody debris accumulations and where there are culverts (and channel widening to meet the culvert walls). Upstream of grade control structures (in this case natural as there did not appear to be any constructed grade control structures) was another 'forced' sink.

In-channel sinks are everywhere. Side channel and mid channel bars of accumulated silts and clays are found in places where they would not be normally found in functioning systems, and the scale of these deposits is considered large. In other locations, where you would expect deposits (for instance point bars on inside banks of meanders) there are none: this is because the channel is entrenched and flow energy is not able to dissipate naturally on inside bends and deposit sediment. This is another indicator that the systems are not functioning properly.

Where there is floodplain connection there are deposits of silt and woody debris, indicating overbank flows do occur and the watercourses are carrying volumes of suspended sediment, some of which is left on the overbank areas.

5.5 Channel Planform And Rapid Assessment

Table 8 shows the results, by reach, for each of the classes under Channel Planform and Rapid Assessment.

Riparian vegetation adjacent to the study reaches ranges from grasses (low cut, manicured lawns) to grassland shrubs and woodland areas. While most of these riparian types are preferable, the width of the riparian zones varies widely. Riparian buffer width is important as the vegetation protects the channel from inputs of sediment and nutrients via overland flow routes, and acts as a roughness

element which slows velocity. When riparian cover width is less than floodplain width, it is normal to see relatively high rates of erosion and sediment inputs to a channel. Riparian width is factored into the Rapid Reach Assessment Form results which follow in Table 9.

Table 8: General channel parameters (channel length, reach length and sinuosity) and riparian vegetation cover for the detailed study reaches.

DETAILED STUDY REACH	Riparian Vegetation	Channel Length (m)	Overall Reach Length (m)	Sinuosity
SBDR-1	WOODLOT, ROAD CORRIDOR	1100	909	1.210
SBDR-2	GRASSLAND SHRUBS	1100	909	1.210
SBDR-3	FOREST COVER MEADOW	479	451	1.062
SBDR-4	FOREST COVER	1600	1300	1.077
SBDR-5	FOREST COVER MEADOW/WETLAND	1600	1300	1.077
SBDR-6	FOREST COVER MEADOW/WETLAND	2400	2385	1.003
KDR-1	MEADOW	784	711	1.103
KDR-2	GRASS URBAN CORRIDOR, GOLF COURSE	1200	1100	1.091
KDR-3	GRASS URBAN CORRIDOR	271	265	1.023
KDR-4	CUT LAWNS, FOREST, TRAIL	455	436	1.044
KDR-5	CANARY GRASS	707	645	1.096
WDR-1	GRASSES (80%), MATURE TREES	1900	1500	1.267
WDR-2	GRASSES	2000	1700	1.176
WDR-3	GRASSES (60%), MATURE TREES	2000	1700	1.176
WDR-4	OLD FIELD GRASSES AND SEGDGES WITH 10% CANOPY	2000	1700	1.176

Reach lengths are subjective and in this case reach boundaries were associated with crossings.

Channel sinuosity (the relationship between channel length in a reach and the straight-line length of the same reach) is a measure of how much the channel is meandering, with sinuosities greater than 2.5 being the formal boundary for meandering (sinuosity > 2.5 = meandering; < 2.5 = sinuous). For the most part sinuosity in the reaches is less than 1.10, meaning the difference in length between the channel and the straight line is less than 10%. While some meandering does occur in these reaches with low sinuosity, that meandering tends to be quite limited and within a very narrow band (amplitude) around a central axis.

Maximum sinuosity (1.267) is found in lower Watts Creek, downstream of Carling Avenue to the confluence with the Ottawa River. This land is flat and has no constraints (either land use or confining valley) which allows the creek to wander over a wide area.

Table 9: Maximum meander belt and geomorphic assessment tool results (RGA, RSAT, RRAF) for the detailed study reaches.

DETAILED STUDY REACH	Maximum Meander Belt (m)	RGA Score	RSAT Score	RRAF Score
SBDR-1	44	0.413 ADJUSTING	22 FAIR	36 LOW STABILITY
SBDR-2	44	0.340 ADJUSTING	18 FAIR	57 MODERATE STABILITY
SBDR-3	26	0.291 TRANSITIONAL	17 FAIR	54 MODERATE STABILITY
SBDR-4	28	0.428 ADJUSTING	17 FAIR	45 LOW STABILITY
SBDR-5	28	0.268 TRANSITIONAL	33 GOOD	87 HIGH STABILITY
SBDR-6	26	0.193 IN REGIME	37 GOOD	81 HIGH STABILITY
KDR-1	48	0.183 IN REGIME	17 FAIR	65 STABLE
KDR-2	5	0.261 TRANSITIONAL	7 POOR	36 LOW STABILITY
KDR-3	5	0.302 TRANSITIONAL	6 POOR	36 LOW STABILITY
KDR-4	11	0.319 TRANSITIONAL	29 FAIR	75 STABLE
KDR-5	12	0.328 TRANSITIONAL	28 FAIR	88 HIGH STABILITY
WDR-1	29	0.336 TRANSITIONAL	11 POOR	36 LOW STABILITY
WDR-2	42	0.687 ADJUSTING	11 POOR	37 LOW STABILITY
WDR-3	42	0.602 ADJUSTING	16 POOR	43 LOW STABILITY
WDR-4	42	0.524 ADJUSTING	19 FAIR	50 MODERATE STABILITY

For the most part the maximum belt can be considered to be narrow, particularly in the lower reaches of Shirley's Brook and Watts Creek, where the channel flows in the flatter Ottawa River floodplain. Not unexpectedly, areas along Kizell Drain where the drain flows within the urban area the meander belt is very narrow (KDR-2, KDR-3). That condition is not seen on the urban reaches of Shirley's Brook, where stream setback corridors are wider. This distinction is likely because drains are subject to a different set of conditions than natural streams are.

The Rapid Geomorphic Assessment (RGA) is a high-level classification tool which looks for indicators of widening, aggradation, degradation and planimetric adjustment. The assessment, which is binary (presence/absence) is tallied and a stability index is determined which is one of three classes, in regime, transitional and adjusting.

Results of the assessment indicate that only two reaches are 'in regime' (the most stable class) and the rest are split equally between transitional and adjusting. The results of this assessment tool do not always coincide with field evidence, indicating the assessment tool is not detailed enough to properly interpret actual field conditions.

A second assessment tool was used for comparison. This tool, the Rapid Stream Assessment Tool (RSAT) adds some biological indicators to the assessment and uses classes such as Channel Stability as a means of capturing the same information that the RGA does (but in a more general manner). The fact that this assessment tool is not based on presence/absence makes the results more in tune with field evidence; however the focus is on biological factors which limits geomorphic interpretation.

The RSAT values (refer to Table 9) range from 6 and 7 (poor) along the confined sections of Kizell Drain (KDR-2 and KDR-3) to 33-37 (good) in the upper reaches of Shirley's Brook (SBDR5, SBDR-6) where riparian habitat conditions are strong (which is a limiting factor in a lot of the reaches).

General Reach Assessment tools (RGA, RSAT) are standard assessment tools used in geomorphic and biologic analysis. As they are somewhat limited in their application, a further assessment tool is also used (Rapid Reach Assessment Form: RRAF). The RRAF, originally developed in Ohio and modified for use in Ontario by Dr. Beebe, assesses sensitivity to erosion using five geomorphic parameters. Each parameter is given a score out of twenty based on a matrix of condition categories. Higher scores reflect optimal conditions and lower sensitivity to erosion, and lower scores reflect less-optimal conditions and higher sensitivity to erosion. The categories for individual parameters are: optimal (16-20), suboptimal (11-15) marginal (6-10) and poor (0-5). Parameters are scored by both quantitative and qualitative features. For example, bank stability is scored on the percentage of eroding/failing bank area as well as by a qualitative assessment of potential future erosion.

The parameter assessment matrix is shown below. It states that the optimal condition for instream substrates includes a mixture of materials with a variety of well-formed deposits and minimal embeddedness. Optimal morphological diversity includes closely spaced riffles and pools, fewer runs and a variety of velocity/depth patterns. A reach with optimal channel stability has minimal evidence of incision or bank failure, and optimal bank stability is indicated by minimal eroded or failed bank area. An optimal riparian vegetative zone is wide (>100 m) and has no human impacts.

The five parameter scores are summed to give a total overall score out of 100 for the reach. Total overall score categories are: optimal condition (75-100), moderate condition (50-74), and poor condition (0-49). By being able to spread the scores up to 20 (as opposed to presence/absence in the RGA or 11 in the RSAT) it is possible to see exactly what parameter leads to weakness in the reach and which is strongest, which factors into interpretation of process and leads to effective restoration (if that is the overall goal of the study).

Results show that for the most part these systems are unstable, again with the exception of the upper reaches of both Shirley's Brook and Kizell Drain. The greatest instability is in the Kizell Drain (KDR-2, KDR-3) and lower Shirley's Brook (SBDR-1), and almost all of Watts Creek (with the exception of WDR-4) which is classed as moderately stable.

Rapid Reach Assessment Form

Stream_____ _____Site_____Sheet#_____

Date_____Rain last 24h_____Completed by_____

Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank instability	Unstable; entrenched; active headcuts; impending or active bank failures
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Total Overall Score: _____

5.6 Detailed Reach Assessment

Each of the reaches were assessed using direct measurements to determine channel dimensions at the time of survey. These dimensions represent current conditions and allow for future measurements as a means of possibly monitoring change in the reaches over time. The measurements are not exhaustive and a detailed monitoring plan would require more parameters; the ones selected for this assessment are used to understand general channel conditions.

Table 10 shows the results, by reach, of channel width, depth and width/depth ratios under bankfull conditions and conditions at the time of survey (which represent 'normal' water levels). The results in the table represent averages for each of the parameters based on seven individual measurements per reach.

Table 10: Average bankfull and wetted width, depth and width/depth ratios for the detailed study reaches. The average is based on seven individual cross-section measurements at each reach.

DETAILED STUDY REACH	BANKFULL CHANNEL			WETTED CHANNEL AT TIME OF SURVEY (FALL, 2012)		
	Width (m)	Depth (m)	W/D Ratio	Width (m)	Depth (m)	W/D Ratio
SBDR-1	5.34	0.66	8.10	3.17	0.23	14.02
SBDR-2	5.25	0.83	6.33	3.79	0.31	6.33
SBDR-3	2.11	0.29	7.24	1.85	0.16	11.85
SBDR-4	3.30	0.61	5.41	1.81	0.16	11.31
SBDR-5	3.05	0.52	5.87	1.15	0.15	7.48
SBDR-6	2.88	0.47	6.12	1.34	0.16	8.38
KDR-1	3.36	0.77	4.36	2.20	0.21	10.37
KDR-2	2.34	0.55	4.23	2.10	0.22	9.41
KDR-3	2.11	0.47	4.52	1.56	0.22	7.12
KDR-4	3.76	0.55	6.86	2.25	0.15	14.89
KDR-5	INDETERMINATE	INDETERMINATE	INDETERMINATE	INDETERMINATE	INDETERMINATE	INDETERMINATE
WDR-1	5.25	0.655	8.03	3.89	0.15	25.55
WDR-2	4.70	0.97	4.84	3.45	0.23	14.67
WDR-3	4.72	0.93	5.06	3.19	0.29	10.96
WDR-4	4.39	1.09	4.04	2.56	0.28	9.09

Generally bankfull widths and depths follow anticipated patterns, with an increase in width and depth as distance from the headwaters increases. A notable difference is found in Shirley's Brook (SBDR-3) where the channel appears to narrow and become shallower: this is explained by the fact that this reach has strong floodplain connections, and as such there is no pressure on downcutting or widening during high-energy events. Depth in this section under 'normal' flow conditions is low (0.16m); depth in these conditions at SBDR-4, 5 and 6 are also this low; the distinction is these reaches (4, 5, and 6) have heavy silt deposits in some of the cross-sections which is affecting the average condition.

A low width-depth ratio indicates a deep channel (incised), which is evident moreso under 'normal' flow conditions. When bankfull results are compared to these lower flow results, bankfull ratios are more representative of conditions in a functioning system, particularly in this type of surficial material.

The fact that bankfull ratios and 'normal' ratios are not similar indicates the watercourses are adjusting to upstream pressures and conditions which are more recent than when bankfull conditions were formed.

Table 11 shows the results, by reach, for the substrate calibre and in-channel scour assessment.

Table 11: Bed material composition (visual analysis) and average depth of in-channel scour (direct measurements) for the detailed study reaches.

DETAILED STUDY REACH	BED MATERIAL				
	% Cobble	% Gravel	% Sands	% Fines	In-Channel Scour (m)
SBDR-1	0.00	0.00	3.57	96.43	0.39
SBDR-2	0.00	0.00	0.00	100.00	0.21
SBDR-3	0.00	7.50	57.50	35.00	NIL
SBDR-4	0.00	0.00	12.50	87.50	NIL
SBDR-5	10.00	20.00	50.00	20.00	NIL
SBDR-6	0.00	10.00	60.00	30.00	NIL
KDR-1	0.00	0.71	9.29	90.00	NIL
KDR-2	0.00	0.00	10.00	90.00	NIL
KDR-3	0.00	0.00	11.43	88.57	NIL
KDR-4	1.43	2.86	63.57	32.14	NIL
KDR-5	0.00	0.00	10.00	90.00	INDETERMINATE
WDR-1	3.33	6.67	6.67	92.86	NIL
WDR-2	1.43	5.00	7.85	86.43	0.67
WDR-3	2.86	4.29	20.71	72.14	0.33
WDR-4	1.43	2.86	11.43	84.29	NIL

Results show that for the most part sands and finer materials make up the bed matrix. Presence of gravels and cobbles at these percentages indicates sporadic deposits that may have their origin in other locations or are remnant features from glacial activity.

The scour results are interesting in that for most sections there is no scour. Recalling that these results are based on seven cross-sections in each reach, and the sections include runs/riffles and pools, the lack of scour depth shows that sediment accumulation is high (even angular force and momentum in pools cannot create and maintain scour).

Table 12 shows the results, by reach, for the bank material assessment and an indication of the estimated Manning roughness coefficient based on field evidence under 'normal' flow conditions.

Banks have no gravels or larger materials, which furthers the interpretation put forth earlier that the presence of these materials in the substrate matrix is a result of historic activity.

Bank heights range from quite low (again, refer to reach SBDR-3) which indicates locations where floodplain connectivity is strong and erosion is low, to quite high banks (0.50m and above) where floodplain connection is limited to lower frequency, higher energy events. These areas of high bank also have more noted erosion on the banks. Average bank angles are gradual (26.5 degrees) to steep (>50 degrees); in some sections bank angle topped 80 degrees.

Table 12: Channel bank material, average height and angle, in-situ *bank strength and estimated Manning 'n' roughness values for the detailed study reaches.*

DETAILED STUDY REACH	CHANNEL BANKS				ESTIMATED MANNING 'n'
	Type	Height (m)	Angle (degrees)	*In-Situ* Bank Strength (N m^{-2})	
SBDR-1	CLAY	0.51	53.71	2695.0	0.032
SBDR-2	CLAY	0.57	50.89	5213.6	0.030
SBDR-3	SANDY CLAY	0.23	26.50	5145.0	0.032
SBDR-4	CLAY	0.32	44.50	2940.0	0.032
SBDR-5	CLAY, BEDROCK	0.27	30.00	4586.4	0.035
SBDR-6	SANDY CLAY	0.23	26.50	5027.4	0.035
KDR-1	CLAY	0.64	46.91	4978.4	0.030
KDR-2	SANDY CLAY	0.33	49.86	4576.6	0.040
KDR-3	SANDY CLAY	0.30	47.00	5027.4	0.040
KDR-4	SANDY CLAY	0.31	42.40	5478.2	0.032
KDR-5	SANDY CLAY, ORGANICS	INDETERMINATE	INDETERMINATE	INDETERMINATE	0.080
WDR-1	CLAY	0.56	58.57	4096.4	0.030
WDR-2	CLAY	0.79	60.29	6654.2	0.030
WDR-3	CLAY	0.72	44.00	1900.0	0.030
WDR-4	CLAY	0.84	47.42	4900.0	0.030

Values for shear strength range from 1900 to 6654 N m^{-2} which, when compared to the channel shear stresses shown in the following table (Table 13), are considerably higher than existing stresses. This normally would indicate that bank erosion is not caused only by flowing water and excess energy in the flow, but is a combination of factors including weakening by freeze-thaw, presence of weaker lenses, and other factors.

Under existing flow conditions bank erosion is occurring even though the bank shear strength is orders of magnitude greater than shear stresses acting on the bank. Under future development conditions, increased volumes of flow created by impervious surfaces will result in longer periods of contact between flowing water and these erosive banks. Even though the future development conditions will still result in stresses well below the strength threshold, that additional contact between flowing water and the banks will result in additional erosion, as the water will have greater time to wash away any loose material and will also have more time to enter cracks created by other processes and work away at these weak points, exacerbating erosion.

Table 13 shows the results, by reach, for velocity and shear stress under bankfull and surveyed flow conditions. Note these results are modelled results and require full confirmation in the field under a range of flow conditions. Also note these are average results for each of the seven sections at each reach.

Table 13: Results showing average velocity and shear stress for bankfull and low flow stages for the detailed study reaches.

DETAILED STUDY REACH	Estimated Slope (m/m)	Average Velocity: Bankfull ($m\ sec^{-1}$)	Average Velocity: Low Flow ($m\ sec^{-1}$)	Shear Stress: Bankfull ($N\ m^{-2}$)	Shear Stress: Low Flow ($N\ m^{-2}$)
SBDR-1	0.0018	0.86	0.46	11.63	4.05
SBDR-2	0.0018	0.58	1.02	14.62	5.46
SBDR-3	0.0021	0.55	0.39	5.96	3.29
SBDR-4	0.0081	1.76	0.82	48.37	12.69
SBDR-5	0.0081	1.39	0.68	41.23	11.89
SBDR-6	0.0014	0.54	0.29	6.44	2.19
KDR-1	0.0026	1.09	0.54	19.59	5.33
KDR-2	0.0025	0.63	0.38	13.46	5.38
KDR-3	0.0295	2.01	1.34	135.72	63.53
KDR-4	0.0022	0.82	0.38	11.84	3.23
KDR-5	0.0014	INDETERMINATE	INDETERMINATE	INDETERMINATE	INDETERMINATE
WDR-1	0.0026	1.09	0.46	16.67	3.81
WDR-2	0.0075	2.21	1.00	71.21	16.88
WDR-3	0.0042	1.64	0.85	38.23	11.92
WDR-4	0.0042	1.68	0.82	44.81	11.51

Velocity and shear stress are driven by slope so it is not surprising to see the model showing higher velocities and shear where the slopes are greatest. That said, under bankfull conditions velocities can exceed 1 metre/second (and in some cases 2 metres/second), which is quite rapid flow. Those velocity relationships hold under low flow conditions as well, with the exception of SBDR-2, where low flow velocity is higher than bankfull because the roughness of the bank at bankfull stage is considerably higher than at low flow stage.

Based on these results, and viewing results in the following table (Table 14), the sediment on the bed of the watercourses should be in transport even under low flow conditions as the critical velocity is exceeded; however there was little or no evidence of transporting sediment at the time of the low flow measurements. The reason for this is found in the size of the material comprising the bed: smaller grains in the silt and clay fraction can be attracted to one another by electro-static and/or chemical processes, which makes the individual grains act as clumps (formally referred to as 'flocs' in the literature) which have significantly greater strength until those electric or chemical bonds are broken. These bonds are fragile and are generally broken by turbulent flow so under higher flow regimes transport is initiated.

Table 14 shows the critical velocity required to mobilize sediment in the bed and banks, by reach, and a general statement about the conditions of the reach.

Table 14: Results showing critical velocity for erosion of bed substrate and bank materials for the detailed study reaches.

DETAILED STUDY REACH	Critical Velocity: Substrate ($m\ sec^{-1}$)	Critical Velocity: Banks ($m\ sec^{-1}$)	General Summary of Channel Assessment
SBDR-1	0.020	1.00	Very active erosion, susceptible to additional flow
SBDR-2	0.020	1.00	Susceptible to erosion under higher flow, otherwise fairly resilient
SBDR-3	0.271	0.550	Good connection to floodplain, low sensitivity to erosion
SBDR-4	0.020	1.00	Very active erosion, susceptible to additional flow
SBDR-5	0.020 (CLAY ONLY)	1.00 (CLAY ONLY)	Very stable reach, subject to sedimentation rather than erosion
SBDR-6	0.271	0.550	Very stable reach, subject to sedimentation rather than erosion
KDR-1	0.020	1.00	Overall stable reach, susceptible to deposition more than erosion
KDR-2	0.271	0.550	Accelerated erosion risk with additional flow, potential risk to infrastructure (culverts) through erosion or sedimentation
KDR-3	0.271	0.550	Accelerated erosion risk with additional flow, potential risk to infrastructure (culverts) through erosion or sedimentation
KDR-4	0.271	0.550	Bank erosion due to increased velocity possible, depends on volume
KDR-5	INDETERMINATE	INDETERMINATE	No formal channel, highly stable despite RGA score
WDR-1	0.020	1.00	Moderate to high for erosion if additional flow added
WDR-2	0.020	1.00	High erosion potential if additional flow added
WDR-3	0.020	1.00	Susceptible to erosion under higher flow, otherwise fairly resilient
WDR-4	0.020	1.00	High erosion potential if additional flow added

6.0 EROSION

6.1 Natural Erosion

Erosion is a natural feature in streams. In numerous locations on Kizell Drain/Watts Creek and Shirley's Brook there is evidence of natural bank erosion. Attempting to limit this erosion is problematic in that doing so robs the watercourse of the means in which it deals with turbulent energy: by slowly picking up and transporting small quantities of eroded bed and bank material the watercourse balances the forces acting on it, and allows the watercourse to function properly. When no erosion occurs, a system is stable for the flows incident on it (meaning the channel is able to resist the flow energy that water exerts on its boundaries). Conversely, when natural erosion occurs, the watercourse is trying to modify its cross-section, albeit slowly and in a controlled manner, to the natural range of flows that it experiences. When an area in a watershed is developed and the flow regime is altered (greater impervious cover results in addition volume of flow over the course of storm and melt events), a watercourse will adjust its cross-section to meet the additional energy. If stormwater off the developed site is managed properly, the watercourse will make small adjustments and erosion will not be problematic.

6.2 Accelerated Erosion

However, there are locations on Shirley's Brook and Watt's Creek where accelerated erosion is occurring. In these areas the watercourses are adjusting rapidly to changes in flow regime and this erosion results in overloading of the system with sediment the watercourse must now deal with through transport and re-deposition downstream. This series of factors results in an unstable channel which will continue to change over time; the time frame required to equilibrate to these new conditions depends on whether additional changes to flow regimes (through development) are occurring and the magnitude of change that the watercourse needs to overcome.

6.3 Risk to Land and Infrastructure by Accelerated Erosion on Shirley's Brook and Watts Creek

Based on the field assessment, a total of 16 sites were identified on Watt's Creek (10 upstream of the connection with Kizell Drain and 6 downstream of the connection with Kizell Drain) where accelerated erosion was occurring based on existing flows. In each of those locations the creek is attempting to find a new path in response to stresses and while there is no direct risk to infrastructure, loss of land is occurring.

On Shirley's Brook, six (6) sites were identified as having accelerated erosion where loss of adjacent land is occurring, and one (1) site where there is loss of land and risk to infrastructure is occurring.

Locations of these sites for both systems are identified in the figures in Appendix 1.

Loss of land is problematic for the landowner and may, in time, require some intervention. It would be prudent to establish baseline conditions for these sites and establish a monitoring plan to observe changes.

One location where there is a real risk to infrastructure occurs on Shirley's Brook where it flows alongside March Valley Road (within the lower reaches and located at SBDR-1). At this site the watercourse is eroding a large bank directly toward the road; this bank is on an outside bend and will continue to migrate in the direction of the road under existing conditions (as well as under proposed future conditions). Figure 2 is a photo of the site.

Figure 2: Eroding bank on Shirley's Brook adjacent to March Valley Road, GPS Coordinates 427832, 5023893.

7.0 SUMMARY OF EXISTING CONDITIONS

Recognizing that these are three separate systems (Shirley's Brook, Kizell Drain and Watts Creek), the analysis is clearly showing that similar existing pressures are currently exerted on each of them and that they are responding in a similar manner. Therefore, the following summary statements can be made for all three systems:

- Erosion of banks along the watercourses is occurring at rates which reflect current flow conditions and is not excessive at this point in time when considering these systems as a whole; however there are site-specific areas where erosion is threatening infrastructure (ie Shirley's Brook at March Valley Road) which require further attention;
- The fact that the reaches are entrenching is resulting in downcutting in all reaches except one (SBDR-3), which is leading to floodplain disconnection and an increase in energy during less-frequent storm events;
- The sediment load in the watercourses appears to exceed the natural rate of delivery of sediment from banks, therefore leading to the conclusion that flow energy during storm events and spring freshet is not sufficient to flush the system;

- Over time if flows become lower than the current condition in any of the systems the aggradation problem anticipated to worsen, potentially to the point where flushing of sediment under higher flows may not occur;
- None of the systems are currently functioning well as there is an apparent lack of synchronization between the sediment regime and the flow regime under current conditions; and
- Under existing conditions, it is anticipated that overall functioning of all systems will worsen and that those reaches currently identified as stable will destabilize. This process (on-going under existing conditions) represents a lengthy evolution to a new form in response to existing flow conditions.

8.0 SENSITIVITY TO INTERBASIN FLOW DIVERSIONS

Prior development and land use change in the Shirley's Brook and Kizell Drain/Watts Creek subwatersheds have resulted in change in both systems as a consequence of alteration of natural flow volumes and timing. Because of this, the systems are trying to equilibrate to those past changes by eroding and depositing sediment in a manner which will allow these systems to function properly (from a fluvial geomorphic [perspective). This study has found the systems to be out of sync (sediment and flow regimes are not working together), indicating that the process of equilibration is on-going and the channels are continuing to evolve. While this is not an ideal situation and it has led to degradation along some reaches in the watercourses, over time the evolution will complete itself and the Shirley's Brook and Kizell Drain/Watts Creek systems will stabilize. Further development in the watersheds will result in further change: additional flow volumes will have to be absorbed by the system receiving this flow and the process of equilibration will further change in response. This is a consequence of land use change and will be unavoidable, though measures to reduce impacts using stormwater management strategies can mitigate these impacts.

Should diversion of runoff from one subwatershed to another occur, for example, from Shirley's Brook to the Kizell/Watts system as proposed by previous servicing studies completed in support of the Kanata Lakes North plan, impacts would be expected to occur in both the "receiving" and the "losing" system. Because both Shirley's Brook and Kizell Drain/Watts Creek have both erosion and sedimentation problems at different locations, both systems will be subject to impacts from a diversion of runoff. The receiving system would be subject to exacerbated erosion of existing eroding banks.

Increased flow volumes to the receiving system would also be expected to result in remobilization of existing silt deposits on the bed. At locations in the system where aggradation is now occurring, this redistribution of previously eroded material from upstream would be anticipated to exacerbate the existing sedimentation problem. The losing system would be less able to flush accumulated sediment through the system and would be expected to continue to aggrade and lose function. This would be expected to have implications for impacts at existing infrastructure (for instance at road crossings), where channel area expansion to meet culvert walls could result in additional deposition, as well as possibly having an impact on floodlines as channel areas are filled in (losing capacity). There may also be

impacts on aquatic biota. These anticipated impacts have been derived from the improved understanding of the existing watercourses provided by this assessment and are intended to inform the preparation of a stormwater management strategy that will appropriately mitigate these potential impacts.

Based on the results of this study it is evident that the Shirley's Brook and Kizell Drain/Watts Creek systems are currently responding to changes in flow and sediment regimes that have arisen from prior changes to land use activity. While it will require considerable time to achieve this evolution (already underway), additional changes to land use (with or without a diversion) will delay that recovery as the receiving system responds to impacts of development. Should diversion of flows from Shirley's Brook to Kizell Drain/Watts Creek occur, it will also take longer for the systems to respond to these additional changes, as the interbasin transfer would create a greater change in fluvial process compared to changes what would result by development of lands without a diversion.

While it is not fully understood by this level of study, it would be incumbent on the development proponent to develop a plan to determine the appropriate level of mitigation needed, and ensure that mitigation plan is put in place, to manage the Shirley's Brook and Kizell Drain/Watt's Creek systems.

9.0 CONCLUSIONS

This study concludes that the Shirley's Brook and Kizell Drain/ Watts Creek systems are in a relatively fragile state and trying to equilibrate to changes induced by past land use change which over time have altered their flow and sediment regimes, which have been induced by land use change. Further altering of flow regimes will interrupt this on-going process with the potential to further impair the systems' ability to synchronize the relationship between flow and sediment transport. This has the potential to further affect fluvial functioning of the watercourses and by association may have an effect on infrastructure, floodlines, and aquatic biota.

Based upon this assessment of existing conditions, it can be concluded that additional development in these watersheds has the potential to exacerbate existing rates and locations of erosion, sedimentation and remobilization of existing silt deposits. It will be the responsibility of the development proponent to mitigate these anticipated impacts through an appropriate stormwater management strategy.

This study, while relying on direct measurements, represents a snapshot in time as far as existing conditions are concerned. It would have been prudent to have a larger database of information over a wider time period to fully understand the potential impacts of additional land use change on the systems; however that was not possible due to time constraints in completing this study.

Therefore it is recommended that a comprehensive monitoring program be put in place, with appropriate and measurable objectives, targets and responses (should targets be exceeded) in conjunction with further development proceeding.

APPENDIX 1

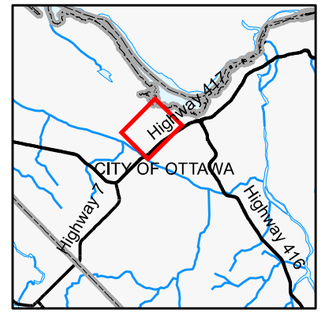
LOCATION OF DETAILED STUDY REACHES

Legend

- Subwatershed Boundary
- Hydraulic Structure Location
- Extent of 100-Year Flood Line
- Extent of 100-Year Flood Line (Routed Water Level)

Geomorphology Assessment

- KDR-1 — Detailed Study Reach
- KDG-1 — Overview Reach
- Individual Section Location
- Location of Identified Erosion



Basemapping and orthophotography provided by the City of Ottawa.

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NAD 83, MTM 9

Shirley s Brook & Watt s Creek Phase 2 SWM Study

Geomorphology Assessment Location - Watt's Creek

February 2015
60264539

AECOM

Figure 5

Path: P:\60264539\000-CADD\050 GIS WIP\MXDs\WorkingMXDs\20150204 - Revised Rep Figs\60264539_Geomorphology_Assessment-Watts 11x17.mxd
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MALEY
MARCHVALE
SECOND LINE
WILD ACRE
MARCH
HEDGE
HOUSTON
ROLSTON
SHARNE
NASH
REGIONAL ROAD 49
MARCHBROOK
OLD CARP
WHERNSIDE
HALTON
BRECHIN
KLONDIKE
SANDHILL
CATTERICK
IPSWICH
TERRY FOX
HINES
SHIRLEY
SOLANDT
GOULBOURN FORCED
FARRAR
LEGGET
STATION
MARCH VALLEY
Shirleys Brook
Watts Creek
Carp River

SBG-1
SBDR-1
SBG-3
SBDR-2
SBG-2
SBG-4
SBDR-3
SBG-5
SBG-9
SBDR-6
SBDR-5
SBG-7
SBG-6
SBDR-4
SBG-8
SBG-7

893000 894000 895000 896000 897000

5034000 5033000 5032000 5031000

5039000 5038000 5037000 5036000

898000 899000 900000

5031000 897000 5032000 898000 5033000 899000 5034000 900000 5035000

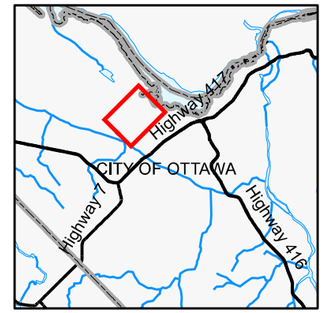
Legend

- Subwatershed Boundary
- Hydraulic Structures Location
- Extent of 100-Year Flood Line

Geomorphology Assessment

- KDR-1 — Detailed Study Reach
- KDG-1 — Overview Reach
- Individual Section Location
- Location of Identified Erosion
- Location of Bank Erosion With Potential Risk to Infrastructure

Ottawa



Basemapping and orthophotography provided by the City of Ottawa.

W N S E

m
0 95 190 380 570 760

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NAD 83, MTM 9

Shirley s Brook & Watt s Creek Phase 2 SWM Study

Geomorphology Assessment Location - Shirley's Brook

February 2015
60264539

AECOM

Figure 6

Path: P:\60264539\000-CADD\050 GIS WIP\MXDs\WorkingMXDs\20150204 - Revised Rep Figs\60264539_Geomorphology_Assessment-Shirleys 11x17.mxd
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APPENDIX 2

SUMMARY DATA SHEETS FOR RGA, RSAT AND RRAF

Creek Shirley Brook
Reach SBDR-1

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded	1	
	3	Siltation in pools		1
	4	Medial bars		1
	5	Accretion on point bars		1
	6	Poor longitudinal sorting of bed materials	1	
	7	Deposition in the overbank zone		1
		Sum	3	4
		Factor Value		0.57
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		
	2	Exposed sanitary / storm sewer / pipeline / etc.		
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets		
	6	Cut face on bar forms	1	
	7	Head cutting due to knick point migration	1	
	8	Terrace cut through older bar material		1
	9	Suspended armour layer visible in bank	1	
	10	Channel worn into undisturbed overburden/ bedrock	1	
		Sum	4	1
		Factor Value		0.2
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		1
	2	Occurrence of large organic debris		1
	3	Exposed tree roots		1
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle		1
	6	Gabion baskets / concrete walls / etc. out flanked		
	7	Length of basal scour >50% through subject reach		1
	8	Exposed length of previously buried pipe/ cable/ etc		
	9	Fracture lines along top of bank	1	
	10	Exposed building foundation		
		Sum	2	5
		Factor Value		0.71
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)		1
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed		
		Sum	5	1
		Factor Value		0.17

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.41**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **ADJUSTING**

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
10	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
8	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
3	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
3	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
12	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

TOTAL SCORE:
36

Creek Shirley Brook

Reach SBDR-1

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Shirley Brook

Reach SBDR-1

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	3
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	3
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	5
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	3
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	4
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	4

Verbal Ranking: FAIR

Total Score
22

Total Points

42-50 = Excellent

30-41 = Good

16-29 = Fair

<16 = Poor

Creek Shirley's Brook
Reach SBDR-2

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded		
	3	Siltation in pools		1
	4	Medial bars		1
	5	Accretion on point bars		1
	6	Poor longitudinal sorting of bed materials		
	7	Deposition in the overbank zone	1	
		Sum	2	3
		Factor Value		0.6
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	1	
	2	Exposed sanitary / storm sewer / pipeline / etc.		
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets	1	
	6	Cut face on bar forms		
	7	Head cutting due to knick point migration		
	8	Terrace cut through older bar material		
	9	Suspended armour layer visible in bank		1
	10	Channel worn into undisturbed overburden/ bedrock		
		Sum	2	1
		Factor Value		0.33
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	1	
	2	Occurrence of large organic debris		1
	3	Exposed tree roots	1	
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle		1
	6	Gabion baskets / concrete walls / etc. out flanked		
	7	Length of basal scour >50% through subject reach	1	
	8	Exposed length of previously buried pipe/ cable/ etc		
	9	Fracture lines along top of bank	1	
	10	Exposed building foundation		
		Sum	5	2
		Factor Value		0.29
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)	1	
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed		1
		Sum	6	1
		Factor Value		0.14

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.34**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **TRANSITIONAL**

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
12	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
8	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
10	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
13	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, “raw” areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
14	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

TOTAL SCORE:
57

Creek Shirley's Brook

Reach SBDR-2

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Shirley's Brook

Reach SBDR-2

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	3
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	3
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	2
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	2
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	4
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	4

Verbal Ranking	FAIR

Total Score
18

Total Points
42-50 = Excellent
30-41 = Good
16-29 = Fair
<16 = Poor

Creek Shirley's Brook
Reach SBDR-3

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded		
	3	Siltation in pools		1
	4	Medial bars	1	
	5	Accretion on point bars	1	
	6	Poor longitudinal sorting of bed materials	1	
	7	Deposition in the overbank zone	1	
		Sum	5	1
		Factor Value		0.17
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		
	2	Exposed sanitary / storm sewer / pipeline / etc.	1	
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets	1	
	6	Cut face on bar forms	1	
	7	Head cutting due to knick point migration		
	8	Terrace cut through older bar material		
	9	Suspended armour layer visible in bank		
	10	Channel worn into undisturbed overburden/ bedrock		
		Sum	3	0
		Factor Value		0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		1
	2	Occurrence of large organic debris		1
	3	Exposed tree roots		1
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle		1
	6	Gabion baskets / concrete walls / etc. out flanked		
	7	Length of basal scour >50% through subject reach	1	
	8	Exposed length of previously buried pipe/ cable/ etc		
	9	Fracture lines along top of bank		1
	10	Exposed building foundation		
		Sum	2	5
		Factor Value		0.71
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form		1
	4	Cut-off channel(s)	1	
	5	Formation of island(s)		1
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed	1	
		Sum	5	2
		Factor Value		0.29

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.29**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **TRANSITIONAL**

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 11	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 8	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 9	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 14	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 12	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
TOTAL SCORE:	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
54					

Creek Shirley's Brook

Reach SBDR-3

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Shirley's Brook

Reach SBDR-3

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	3
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	4
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	2
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	2
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	3
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	3

Verbal Ranking	FAIR

Total Score
17

Total Points
42-50 = Excellent
30-41 = Good
16-29 = Fair
<16 = Poor

Creek Shirley's Brook
Reach SBDR-4

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar		1
	2	Coarse materials in riffles embedded	1	
	3	Siltation in pools		1
	4	Medial bars		1
	5	Accretion on point bars		1
	6	Poor longitudinal sorting of bed materials	1	
	7	Deposition in the overbank zone		1
		Sum	2	5
		Factor Value		0.71
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	1	
	2	Exposed sanitary / storm sewer / pipeline / etc.		
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets	1	
	6	Cut face on bar forms		
	7	Head cutting due to knick point migration		
	8	Terrace cut through older bar material		
	9	Suspended armour layer visible in bank		
	10	Channel worn into undisturbed overburden/ bedrock		
		Sum	2	0
		Factor Value		0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		1
	2	Occurrence of large organic debris		1
	3	Exposed tree roots		1
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle		1
	6	Gabion baskets / concrete walls / etc. out flanked		
	7	Length of basal scour >50% through subject reach		1
	8	Exposed length of previously buried pipe/ cable/ etc		
	9	Fracture lines along top of bank	1	
	10	Exposed building foundation		
		Sum	2	5
		Factor Value		0.71
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)		1
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed		1
		Sum	5	2
		Factor Value		0.29

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.43**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **ADJUSTING**

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
9	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
13	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
4	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
7	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, “raw” areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
12	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

TOTAL SCORE:
45

Creek Shirley's Brook

Reach SBDR-4

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Shirley's Brook

Reach SBDR-4

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	2
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	3
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	1
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	1
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	6
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	4

Verbal Ranking: FAIR

Total Score
17

Total Points

42-50 = Excellent

30-41 = Good

16-29 = Fair

<16 = Poor

Creek Shirley' s Brook
Reach SBDR-5

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded	1	
	3	Siltation in pools		1
	4	Medial bars	1	
	5	Accretion on point bars	1	
	6	Poor longitudinal sorting of bed materials	1	
	7	Deposition in the overbank zone		1
		Sum	5	2
		Factor Value		0.29
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		
	2	Exposed sanitary / storm sewer / pipeline / etc.		
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets		
	6	Cut face on bar forms		
	7	Head cutting due to knick point migration		
	8	Terrace cut through older bar material		
	9	Suspended armour layer visible in bank		
	10	Channel worn into undisturbed overburden/ bedrock	1	
		Sum	1	0
		Factor Value		0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		1
	2	Occurrence of large organic debris		1
	3	Exposed tree roots		1
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle	1	
	6	Gabion baskets / concrete walls / etc. out flanked		
	7	Length of basal scour >50% through subject reach	1	
	8	Exposed length of previously buried pipe/ cable/ etc		
	9	Fracture lines along top of bank		
	10	Exposed building foundation		
		Sum	3	3
		Factor Value		0.5
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		1
	2	Single thread channel to multiple channel		1
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)	1	
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed	1	
		Sum	5	2
		Factor Value		0.285714286

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.27**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **TRANSITIONAL**

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
18	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
16	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
18	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
15	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, “raw” areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
20	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

TOTAL SCORE:
87

Creek Shirley' s Brook

Reach SBDR-5

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Shirley' s Brook

Reach SBDR-5

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	8
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	5
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	5
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	3
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	7
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	5

Verbal Ranking	GOOD

Total Score
33

Total Points
42-50 = Excellent
30-41 = Good
16-29 = Fair
<16 = Poor

Creek Shirley's Brook
Reach SBDR-6

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded	1	
	3	Siltation in pools	1	
	4	Medial bars		1
	5	Accretion on point bars	1	
	6	Poor longitudinal sorting of bed materials	1	
	7	Deposition in the overbank zone		1
		Sum	5	2
		Factor Value		0.29
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		
	2	Exposed sanitary / storm sewer / pipeline / etc.		
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets		
	6	Cut face on bar forms	1	
	7	Head cutting due to knick point migration	1	
	8	Terrace cut through older bar material	1	
	9	Suspended armour layer visible in bank		1
	10	Channel worn into undisturbed overburden/ bedrock	1	
		Sum	4	1
		Factor Value		0.2
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		1
	2	Occurrence of large organic debris		1
	3	Exposed tree roots	1	
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle	1	
	6	Gabion baskets / concrete walls / etc. out flanked		
	7	Length of basal scour >50% through subject reach	1	
	8	Exposed length of previously buried pipe/ cable/ etc		
	9	Fracture lines along top of bank	1	
	10	Exposed building foundation		
		Sum	5	2
		Factor Value		0.29
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)	1	
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed	1	
		Sum	7	0
		Factor Value		0

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.19**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **IN REGIME**

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
17	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
15	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
16	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
15	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, “raw” areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
18	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

TOTAL SCORE:
81

Creek Shirley's Brook

Reach SBDR-6

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Shirley's Brook

Reach SBDR-6

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	8
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	8
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	6
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	4
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	7
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	4

Verbal Ranking: GOOD

Total Score
37

Total Points

42-50 = Excellent

30-41 = Good

16-29 = Fair

<16 = Poor

Creek Kizzel Drain
Reach KDR-1

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded	1	
	3	Siltation in pools		1
	4	Medial bars		1
	5	Accretion on point bars		
	6	Poor longitudinal sorting of bed materials	1	
	7	Deposition in the overbank zone	1	
		Sum	4	2
		Factor Value		0.33
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	1	
	2	Exposed sanitary / storm sewer / pipeline / etc.		
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets		
	6	Cut face on bar forms		
	7	Head cutting due to knick point migration		
	8	Terrace cut through older bar material		
	9	Suspended armour layer visible in bank		
	10	Channel worn into undisturbed overburden/ bedrock		
		Sum	1	0
		Factor Value		0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		
	2	Occurrence of large organic debris	1	
	3	Exposed tree roots		1
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle	1	
	6	Gabion baskets / concrete walls / etc. out flanked		
	7	Length of basal scour >50% through subject reach		
	8	Exposed length of previously buried pipe/ cable/ etc		
	9	Fracture lines along top of bank		1
	10	Exposed building foundation		
		Sum	3	2
		Factor Value		0.4
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)	1	
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed	1	
		Sum	7	0
		Factor Value		0.00

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.18**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **IN REGIME**

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
8	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
10	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
16	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
13	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
18	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

TOTAL SCORE:
65

Creek Kizzel Drain

Reach KDR-1

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Kizzel Drain

Reach KDR-1

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	6
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	2
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	2
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	4
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	2
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	1

Verbal Ranking: FAIR

Total Score
17

Total Points

42-50 = Excellent

30-41 = Good

16-29 = Fair

<16 = Poor

Creek Kizzel Drain
Reach KDR-2

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded		
	3	Siltation in pools	0	1
	4	Medial bars		1
	5	Accretion on point bars	1	
	6	Poor longitudinal sorting of bed materials		1
	7	Deposition in the overbank zone	1	
		Sum	3	3
		Factor Value		0.5
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	1	
	2	Exposed sanitary / storm sewer / pipeline / etc.	1	
	3	Elevated storm sewer outfall(s)	1	
	4	Undermined gabion baskets / concrete aprons / etc	1	
	5	Scour pools d/s of culverts / storm sewer outlets		1
	6	Cut face on bar forms	1	
	7	Head cutting due to knick point migration	1	
	8	Terrace cut through older bar material		1
	9	Suspended armour layer visible in bank		1
	10	Channel worn into undisturbed overburden/ bedrock	1	
		Sum	7	3
		Factor Value		0.3
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	1	
	2	Occurrence of large organic debris	1	
	3	Exposed tree roots	1	
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle		1
	6	Gabion baskets / concrete walls / etc. out flanked	1	
	7	Length of basal scour >50% through subject reach	1	
	8	Exposed length of previously buried pipe/ cable/ etc	1	
	9	Fracture lines along top of bank	1	
	10	Exposed building foundation	1	
		Sum	9	1
		Factor Value		0.1
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)	1	
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed		1
		Sum	6	1
		Factor Value		0.14

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.26**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **TRANSITIONAL**

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 5	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 6	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 11	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 12	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 2	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
TOTAL SCORE:	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
36					

Creek Kizzel Drain

Reach KDR-2

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Kizzel Drain

Reach KDR-2

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	3
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	1
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	1
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	1
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	0
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	1

Verbal Ranking: POOR

Total Score
7

Total Points

42-50 = Excellent

30-41 = Good

16-29 = Fair

<16 = Poor

Creek Kizzel Drain
Reach KDR-3

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded		
	3	Siltation in pools		1
	4	Medial bars		1
	5	Accretion on point bars	1	
	6	Poor longitudinal sorting of bed materials		1
	7	Deposition in the overbank zone		1
		Sum	2	4
		Factor Value		0.67
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	1	
	2	Exposed sanitary / storm sewer / pipeline / etc.	1	
	3	Elevated storm sewer outfall(s)	1	
	4	Undermined gabion baskets / concrete aprons / etc	1	
	5	Scour pools d/s of culverts / storm sewer outlets		1
	6	Cut face on bar forms	1	
	7	Head cutting due to knick point migration	1	
	8	Terrace cut through older bar material		1
	9	Suspended armour layer visible in bank		1
	10	Channel worn into undisturbed overburden/ bedrock	1	
		Sum	7	3
		Factor Value		0.3
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	1	
	2	Occurrence of large organic debris	1	
	3	Exposed tree roots	1	
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle		1
	6	Gabion baskets / concrete walls / etc. out flanked	1	
	7	Length of basal scour >50% through subject reach	1	
	8	Exposed length of previously buried pipe/ cable/ etc	1	
	9	Fracture lines along top of bank	1	
	10	Exposed building foundation	1	
		Sum	9	1
		Factor Value		0.1
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)	1	
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed		1
		Sum	6	1
		Factor Value		0.14

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.30**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **TRANSITIONAL**

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 5	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 6	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 11	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 12	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 2	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
TOTAL SCORE:	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
36					

Creek Kizzel Drain

Reach KDR-3

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Kizzel Drain

Reach KDR-3

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	2
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	1
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	1
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	1
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	0
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	1

Verbal Ranking: POOR

Total Score
6

Total Points

42-50 = Excellent

30-41 = Good

16-29 = Fair

<16 = Poor

Creek Kizzel Drain
Reach KDR-4

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded		1
	3	Siltation in pools	1	
	4	Medial bars		1
	5	Accretion on point bars	1	
	6	Poor longitudinal sorting of bed materials	1	
	7	Deposition in the overbank zone		1
		Sum	4	3
		Factor Value		0.43
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		
	2	Exposed sanitary / storm sewer / pipeline / etc.		
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets		1
	6	Cut face on bar forms	1	
	7	Head cutting due to knick point migration	1	
	8	Terrace cut through older bar material	1	
	9	Suspended armour layer visible in bank	1	
	10	Channel worn into undisturbed overburden/ bedrock		1
		Sum	4	2
		Factor Value		0.33
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		1
	2	Occurrence of large organic debris	1	
	3	Exposed tree roots		1
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle	1	
	6	Gabion baskets / concrete walls / etc. out flanked	1	
	7	Length of basal scour >50% through subject reach	1	
	8	Exposed length of previously buried pipe/ cable/ etc		
	9	Fracture lines along top of bank		1
	10	Exposed building foundation		
		Sum	5	3
		Factor Value		0.38
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		1
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)	1	
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed	1	
		Sum	6	1
		Factor Value		0.14

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.32**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **TRANSITIONAL**

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
16	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
15	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
20	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
14	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
10	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

TOTAL SCORE:
75

Creek Kizzel Drain

Reach KDR-4

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Kizzel Drain

Reach KDR-4

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	6
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	7
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	5
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	4
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	3
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	4

Verbal Ranking	FAIR

Total Score
29

Total Points

42-50 = Excellent

30-41 = Good

16-29 = Fair

<16 = Poor

Creek Kizzel Drain
Reach KDR-5

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar		1
	2	Coarse materials in riffles embedded		
	3	Siltation in pools		1
	4	Medial bars		1
	5	Accretion on point bars	1	
	6	Poor longitudinal sorting of bed materials	1	
	7	Deposition in the overbank zone		1
		Sum	2	4
		Factor Value		0.67
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		
	2	Exposed sanitary / storm sewer / pipeline / etc.		
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets		1
	6	Cut face on bar forms	1	
	7	Head cutting due to knick point migration	1	
	8	Terrace cut through older bar material	1	
	9	Suspended armour layer visible in bank		
	10	Channel worn into undisturbed overburden/ bedrock		
		Sum	3	1
		Factor Value		0.25
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	1	
	2	Occurrence of large organic debris		1
	3	Exposed tree roots	1	
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle	1	
	6	Gabion baskets / concrete walls / etc. out flanked		
	7	Length of basal scour >50% through subject reach	1	
	8	Exposed length of previously buried pipe/ cable/ etc	1	
	9	Fracture lines along top of bank	1	
	10	Exposed building foundation	1	
		Sum	8	1
		Factor Value		0.11
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel		1
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)		1
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed	1	
		Sum	5	2
		Factor Value		0.29

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 **0.33**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting **TRANSITIONAL**

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 18	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 10	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 20	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 20	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 20	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
TOTAL SCORE:	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
88					

Creek Kizzel Drain

Reach KDR-5

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Kizzel Drain

Reach KDR-5

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	9
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	5
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	2
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	2
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	4
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	6

Verbal Ranking	FAIR

Total Score
28

Total Points
42-50 = Excellent
30-41 = Good
16-29 = Fair
<16 = Poor

Creek Watts Creek
Reach WDR-1

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded	1	
	3	Siltation in pools		1
	4	Medial bars		1
	5	Accretion on point bars		1
	6	Poor longitudinal sorting of bed materials		1
	7	Deposition in the overbank zone	1	
		Sum	3	4
		Factor Value		0.57
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		
	2	Exposed sanitary / storm sewer / pipeline / etc.		
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets		1
	6	Cut face on bar forms	1	
	7	Head cutting due to knick point migration	1	
	8	Terrace cut through older bar material	1	
	9	Suspended armour layer visible in bank		1
	10	Channel worn into undisturbed overburden/ bedrock	1	
		Sum	4	2
		Factor Value		0.33
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	1	
	2	Occurrence of large organic debris	1	
	3	Exposed tree roots	1	
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle		1
	6	Gabion baskets / concrete walls / etc. out flanked	1	
	7	Length of basal scour >50% through subject reach		1
	8	Exposed length of previously buried pipe/ cable/ etc	1	
	9	Fracture lines along top of bank		1
	10	Exposed building foundation	1	
		Sum	7	3
		Factor Value		0.30
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)	1	
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed		1
		Sum	6	1.00
		Factor Value		0.14

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4

0.34

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting

Transitional

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
6	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
4	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
7	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
4	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, “raw” areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
15	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

TOTAL SCORE:
36

Creek Watts Creek

Reach WDR-1

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Watts Creek

Reach WDR-1

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	3
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	2
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	1
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	2
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	2
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	1

Verbal Ranking: Poor

Total Score
11

Total Points

42-50 = Excellent

30-41 = Good

16-29 = Fair

<16 = Poor

Creek Watts Creek
Reach WDR-2

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded		
	3	Siltation in pools		1
	4	Medial bars		1
	5	Accretion on point bars		
	6	Poor longitudinal sorting of bed materials		1
	7	Deposition in the overbank zone		
		Sum	1	3
		Factor Value		0.75
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		
	2	Exposed sanitary / storm sewer / pipeline / etc.		
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets		
	6	Cut face on bar forms		1
	7	Head cutting due to knick point migration		
	8	Terrace cut through older bar material		
	9	Suspended armour layer visible in bank		
	10	Channel worn into undisturbed overburden/ bedrock		1
		Sum	0	2
		Factor Value		1.00
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		1
	2	Occurrence of large organic debris		1
	3	Exposed tree roots	1	
	4	Basal scour on inside meander bends		1
	5	Basal scour on both sides of channel through riffle		1
	6	Gabion baskets / concrete walls / etc. out flanked		
	7	Length of basal scour >50% through subject reach		1
	8	Exposed length of previously buried pipe/ cable/ etc		
	9	Fracture lines along top of bank		1
	10	Exposed building foundation		
		Sum	1	6
		Factor Value		0.86
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)	1	
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed		1
		Sum	6	1
		Factor Value		0.14

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.69**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **Adjusting**

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 6	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 5	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 4	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 7	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 15	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

TOTAL SCORE:
37

Creek Watts Creek

Reach WDR-2

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Watts Creek

Reach WDR-2

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	1
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	2
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	1
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	3
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	3
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	1

Verbal Ranking: Poor

Total Score
11

Total Points

42-50 = Excellent

30-41 = Good

16-29 = Fair

<16 = Poor

Creek Watts Creek
Reach WDR-3

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded	1	
	3	Siltation in pools		1
	4	Medial bars		1
	5	Accretion on point bars		
	6	Poor longitudinal sorting of bed materials		1
	7	Deposition in the overbank zone		
		Sum	2	3
		Factor Value		0.60
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		
	2	Exposed sanitary / storm sewer / pipeline / etc.		
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets		
	6	Cut face on bar forms		1
	7	Head cutting due to knick point migration		
	8	Terrace cut through older bar material		
	9	Suspended armour layer visible in bank		
	10	Channel worn into undisturbed overburden/ bedrock		
		Sum	0	1
		Factor Value		1.00
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	1	
	2	Occurrence of large organic debris		1
	3	Exposed tree roots	1	
	4	Basal scour on inside meander bends		
	5	Basal scour on both sides of channel through riffle		1
	6	Gabion baskets / concrete walls / etc. out flanked		
	7	Length of basal scour >50% through subject reach		1
	8	Exposed length of previously buried pipe/ cable/ etc		
	9	Fracture lines along top of bank		1
	10	Exposed building foundation		
		Sum	2	4
		Factor Value		0.67
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)	1	
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed		1
		Sum	6	1
		Factor Value		0.14

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.60**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **Adjusting**

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 11	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 7	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 6	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 9	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
Value: 10	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
TOTAL SCORE:	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
43					

Creek Watts Creek

Reach WDR-3

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Watts Creek

Reach WDR-3

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	1
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	1
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	3
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	2
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	6
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	3

Verbal Ranking

Total Score
16

Total Points

42-50 = Excellent

30-41 = Good

16-29 = Fair

<16 = Poor

Creek Watts Creek
Reach WDR-4

FORM / PROCESS	Num	GEOMORPHIC INDICATOR Description	Present? No	Yes
Evidence of Aggradation (AI)	1	Lobate Bar	1	
	2	Coarse materials in riffles embedded	1	
	3	Siltation in pools		1
	4	Medial bars		1
	5	Accretion on point bars		1
	6	Poor longitudinal sorting of bed materials		1
	7	Deposition in the overbank zone	1	
		Sum	3	4
		Factor Value		0.57
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		
	2	Exposed sanitary / storm sewer / pipeline / etc.		
	3	Elevated storm sewer outfall(s)		
	4	Undermined gabion baskets / concrete aprons / etc		
	5	Scour pools d/s of culverts / storm sewer outlets		
	6	Cut face on bar forms		1
	7	Head cutting due to knick point migration		
	8	Terrace cut through older bar material	1	
	9	Suspended armour layer visible in bank		1
	10	Channel worn into undisturbed overburden/ bedrock		
		Sum	1	2
		Factor Value		0.67
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	1	
	2	Occurrence of large organic debris		1
	3	Exposed tree roots		1
	4	Basal scour on inside meander bends	1	
	5	Basal scour on both sides of channel through riffle		1
	6	Gabion baskets / concrete walls / etc. out flanked		
	7	Length of basal scour >50% through subject reach	1	
	8	Exposed length of previously buried pipe/ cable/ etc		
	9	Fracture lines along top of bank		1
	10	Exposed building foundation		
		Sum	3	4
		Factor Value		0.57
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1	
	2	Single thread channel to multiple channel	1	
	3	Evolution of pool-riffle form to low bed relief form	1	
	4	Cut-off channel(s)	1	
	5	Formation of island(s)		1
	6	Thalweg alignment out of phase meander form	1	
	7	Bar forms poorly formed / reworked / removed		1
		Sum	5	2
		Factor Value		0.29

Stability Index:

* STABILITY INDEX (SI) = (AI+DI+WI+PI)/4 — **0.52**

Condition:

SI < 0.20 = In regime, 0.21-0.40 = Transitional, >0.41 = Adjusting — **ADJUSTING**

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
8	Instream Substrate Characterization	Mixture of substrate materials, with gravel and cobbles prevalent; sand deposits are firm; several shoals and gravel bars; LWD > 10%; embeddedness minimal	Mixture of sand and gravel with silts at margins; some shoals and gravel bars; emergent vegetation present or not; LWD > 10%; gravels and cobbles only slightly embedded	Primarily sands and silts; few shoals or gravel bars; little emergent vegetation; LWD < 10%; gravels are highly embedded	Shifting fine sands, silts and clays; no shoals or gravel bars; mostly runs; no emergent vegetation; little or no LWD; embeddedness not relevant
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
7	Morphological Diversity and Flow Conditions	Predominantly riffles and pools; few tranquil runs; distance btw riffles = 5-10 channel widths; more than 4 distinct velocity/depth patterns present	Approximately equal distribution of riffles, pools and runs; distance btw riffles > 10 channel widths; more than 3 distinct velocity/depth patterns present	Occasional riffle; tranquil runs > 25% of reach; pools associated primarily with LWD; distance btw riffles >25 channel widths; only 1-3 distinct velocity/depth patterns present	Generally all tranquil runs; a few pools near LWD; poor habitat; distance btw riffles >25 channel widths; dominated by one velocity/depth pattern
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
10	Channel Stability (Base Level)	Naturally stable; evidence of incision or bank failure absent or minimal; limited potential for future problems	Stabilized; grade control present and evidence of incision or bank failure absent or minimal; some potential for future problems	Moderately unstable; some entrenchment and/or impending entrenchment; long-term channel stability in question; impending bank	Unstable; entrenched; active headcuts; impending or active bank failures
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
11	Bank Stability	Banks stable; evidence of bank erosion or bank failure absent or minimal; limited potential for future problems; <5% of bank affected	Moderately stable; infrequent, small areas of erosion mostly healed over; 5-30% of bank in reach has areas of erosion	Moderately unstable; 30-60% of the bank in reach has areas of erosion; high erosion potential during floods	Unstable; many eroded areas, "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Value:	Parameter	Category			
		Optimal	Suboptimal	Marginal	Poor
14	Riparian Vegetative Zone Width	Width of riparian zone > 100m for at least 90% of the bankline; human activities have not impacted zone	Width of riparian zone exceeds 30m for at least 90% of bank length; human activities have impacted zone for less than 10% of banks	Width of riparian zone less than 30m for 10-50% of bank; human activities have impacted zone for more than 10% of banks	Width of riparian zone less than 30m for at least 50% of bank; little or no riparian vegetation due to human activities for at least 10% of banks
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

TOTAL SCORE:
50

Creek Watts Creek

Reach WDR-4

RAPID REACH ASSESSMENT FORM (RRAF)

Creek Watts Creek

Reach WDR-4

RSAT Scoring Sheet					
	Date		Assessors		
RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9 to 11	6 to 8	3 to 5	0 to 2	4
2. Channel Scouring/Deposition	7 to 8	5 to 6	3 to 4	0 to 2	1
3. Physical Instream Habitat	7 to 8	5 to 6	3 to 4	0 to 2	3
4. Water Quality	7 to 8	5 to 6	3 to 4	0 to 2	3
5. Riparian Habitat Conditions	6 to 7	4 to 5	2 to 3	0 to 2	6
6. Biological Indicators	7 to 8	5 to 6	3 to 4	0 to 2	2

Verbal Ranking: POOR

Total Score
19

Total Points

42-50 = Excellent

30-41 = Good

16-29 = Fair

<16 = Poor