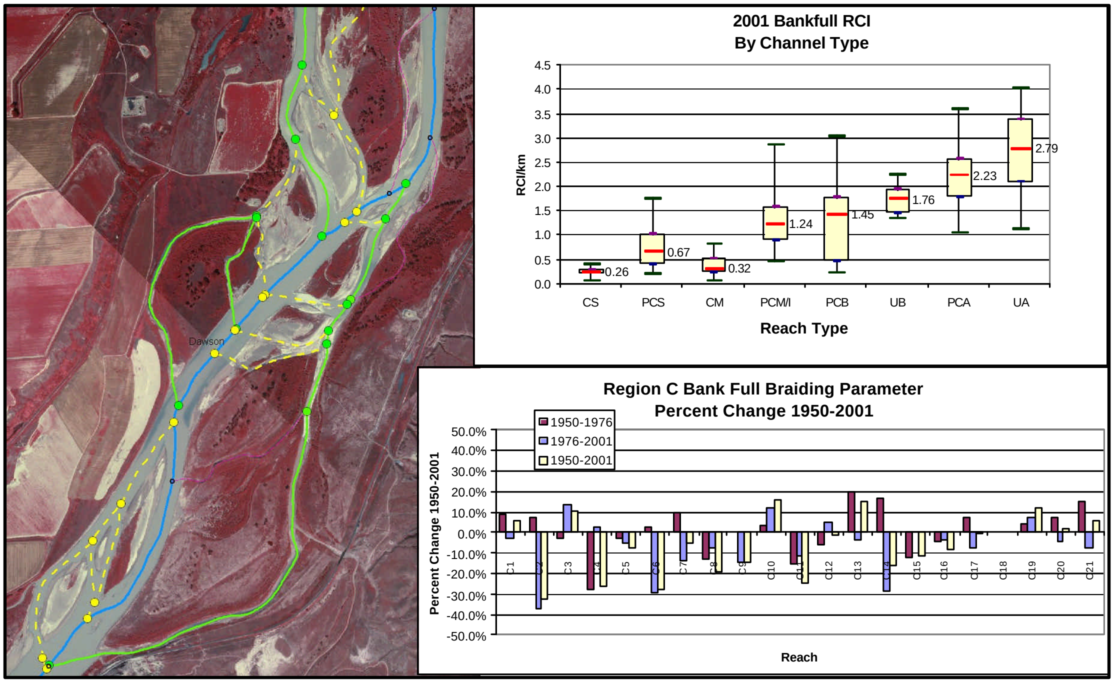
Work Order #3:
Geomorphic Parameters and GIS Development
Yellowstone River



Yellowstone River Conservation Districts Council
Billings, MT
406-635-5586

May 21, 2007

Prepared by:

Tony Thatcher
211 N. Grand; Suite J
Bozeman, MT 59715

Karin Boyd
211 N. Grand; Suite C
Bozeman, MT 59715

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 Introduction

The following report describes the results of a data analysis performed in support of the geomorphic scope of work associated with the Yellowstone River Cumulative Effects Study. This work was performed for the Yellowstone River Conservation Districts Council under Work Order #3 of Custer County Conservation District contract YRCDC 012.

This effort consists of a GIS-based summary of geomorphic parameters of the Yellowstone River from Park County to the confluence with the Missouri River, a distance of approximately 560 miles. These parameters relate to channel planform as visible on aerial photography, and reflect a comparison of conditions from photos that have been incorporated into the GIS and are dated 1948-1950, 1976, 1995, and 1999-2001.

1.1 Previous Work

The results provided in this document are supported by several sources of information that have been presented in two supporting documents. The first document is a reconnaissance geomorphic assessment of the project reach, and the second is an initial analysis of GIS-derived geomorphic parameters.

1.1.1 Reconnaissance Geomorphic Assessment

Primary reach breaks and reach classification data reflect those presented in the Yellowstone River Geomorphic Reconnaissance Report (AGI and DTM, Inc., 2004). This report describes the approaches used to generate reach breaks and a geomorphic classification scheme for the project reach using 2001 infrared color imagery.

1.1.2 Work Order 1 Results

A preliminary summary of geomorphic parameters on the Yellowstone River is contained within the report entitled: ***Work Order 1: Geomorphic Parameters and GIS Development, Yellowstone River*** (DTM and AGI, 2006). That report includes descriptions of the following task items:

- Integration of Park County digitized channel centerline data into the main Middle and Lower River GIS project.
- Integration of General Land Office (GLO) maps for Park County.
- Generation of linear referencing indices for the primary channel traces.
- Adjustment of reach breaks to incorporate river behavior trends exhibited by historic channel traces.
- Development of reach breaks for Park County, and classification of those reaches using the categories developed in the reconnaissance assessment.
- Quantification and summarization of a series of geomorphic parameters by individual reach for several historic and recent time frames.

1.2 Project Objectives: Work Order 3

This report consists of an addendum to the Work Order 1 report. The objectives of this effort include the following:

- Reattribute flowlines to account for flow variations in aerial photography;
- Digitize 1948-1950 and 1998 banklines for Park County and integrate results into composite dataset;
- Digitize banklines and flowlines for 1977 photography from Intake to North Dakota state line to compliment 1976 data upstream; and,
- Statistically summarize reattributed and newly digitized flowlines to provide a preliminary assessment of spatial, temporal, and reach-type based trends in channel geomorphology.

2 Methodology

The following sections describe the methodologies used to complete this work scope. All GIS data developed in this effort reside in the project Personal Geodatabase. The specific geomorphic parameters included in the analysis and stored in the Geodatabase are described in Sections 3 and 4.

2.1 Flowline Reattribution

A significant portion of the effort associated with this Work Order has been the review and reattribution of flowlines to account for the range of flow conditions captured in the aerial photography. To account for flow variability, channels were reattributed as to their expected condition at bank full flow. The flowlines have been defined and attributed as follows (see Figure 2-1):

- ***Primary Channel:*** The main channel thread, digitized along the visible channel centerline.
- ***Secondary Channel:*** Channels that flow around gravel bars that support minimal woody vegetation. Because of the lack of woody vegetation, it is assumed that these bars are submerged under bank full flow conditions and are therefore low flow features. Summaries of the secondary channel densities provide useful measures of complexity for a given suite of photos, but care should be taken in comparing these datasets through time due to their dependence on water level.
- ***Anabranching Channel:*** Side channels that are separated from the main thread by islands colonized by woody vegetation such as trees or thick shrubs. These channels are normalized to a bank full flow condition, and thus can be compared through time
- ***Overflow Channel:*** Overflow channels are channel features within the river corridor that appear to have conveyed stream flow at some time in the past. These features may be abandoned channel remnants, or may be flood scars. Overflow channels were not included in the parameter summaries.

Examples of each attributed channel type are shown in Figure 2-1. Intersections between channels are mapped as nodes, which are used in calculating the River Complexity Index (Section 2.2). The nodes are attributed in terms of the types of channel segments that intersect at that location.

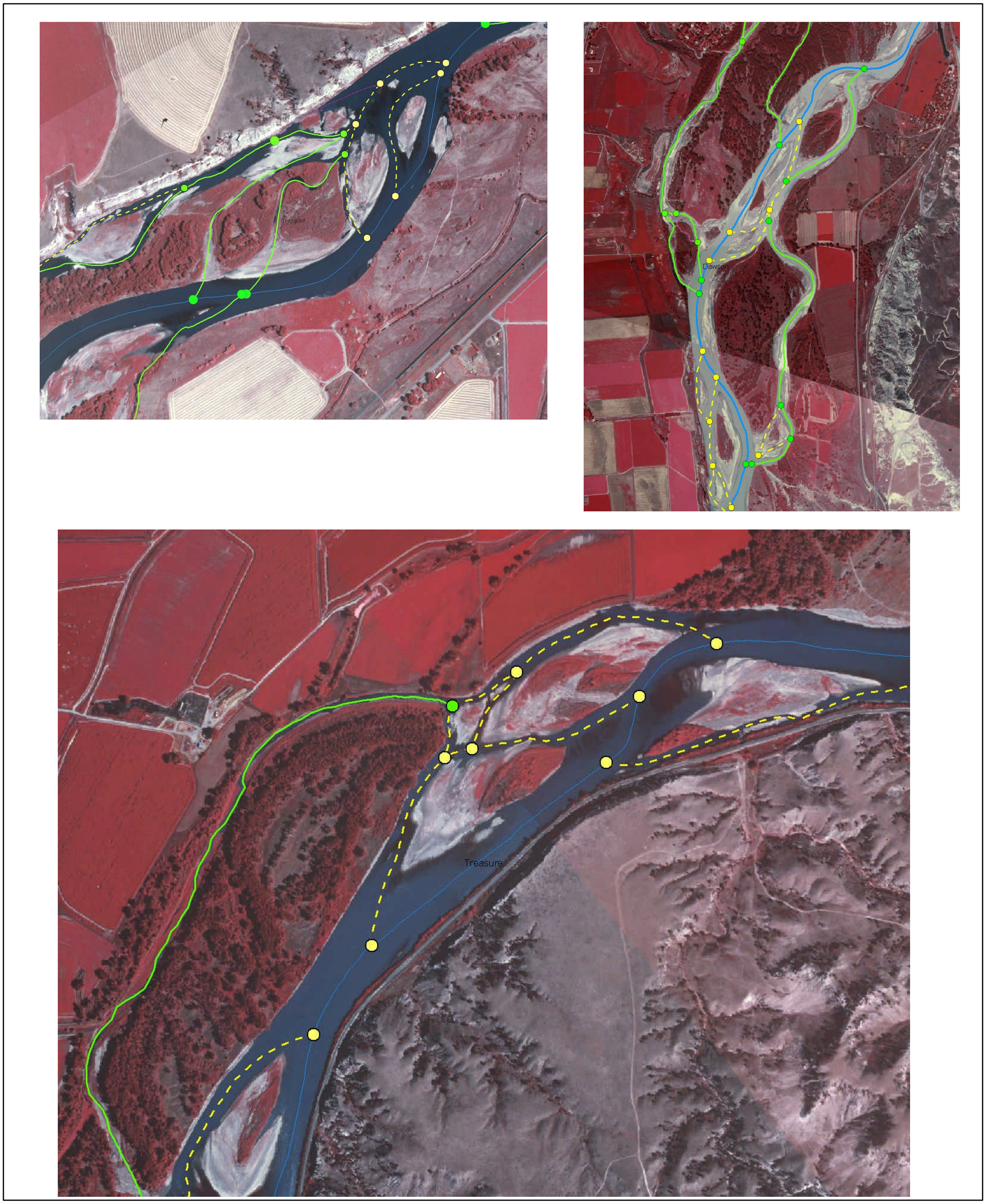


Figure 2-1. Attributed flowlines and nodes. Blue= Primary Channel, Green= Anabranching Channel and Yellow = Secondary Channel.

2.2 Flowline Parameter Summaries

The digitized flowlines were used to calculate a series of geomorphic parameters for each reach. First, each reach was enclosed within a polygon to allow a quantitative assessment of parameters within that polygon. The polygons were created by first generating a 5 mile buffer on either side of the 2001 primary channel trace. This resulted in a continuous corridor polygon. Next, line segments were added to the ends of each reach break line to extend it to be perpendicular to the 5 mile buffer. This technique is similar to defining cross section lines for hydraulic modeling such that they are both perpendicular to the flow of the channel and also perpendicular to the valley edge. The extended lines were used to split the 5 mile buffer polygon and resulting polygons were attributed with the reach identification (Figure 2-2). The channel flow lines for each year were split at each reach break, and each segment was then similarly attributed with its associated reach identification.

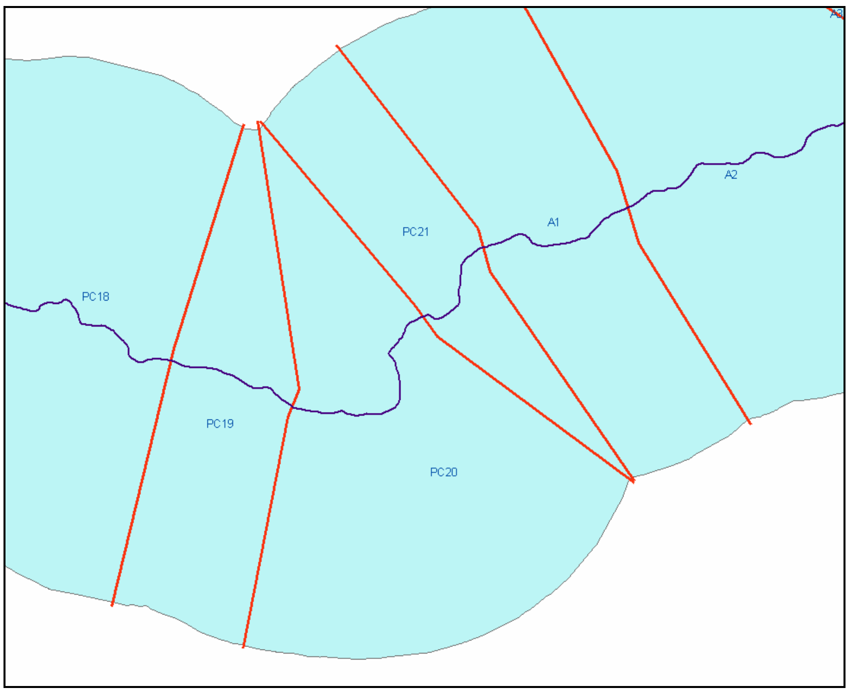


Figure 2-2. Adjusted reach breaks were extended to the edge of a five mile buffer on the 2001 primary channel trace. The buffer was then split to create reach areas.

The geomorphic parameters evaluated within each polygon using the digitized flowlines include the following:

- ***Primary channel length***: length of the main channel thread between reach break lines in kilometers.

- ***Sinuosity***: A ratio of primary channel length to valley distance, used to describe how "tortuous" a river course is. A sinuosity of 2 reflects a channel that is two times longer than the straight valley distance.

- ***Braiding parameter***: A ratio of the total channel length to the main channel length. Braiding parameter is used to describe the relative extent of secondary or anabranching channels; a braiding parameter of 1 reflects no side channels, and a braiding parameter of 3 reflects a total channel length that is three times that of the main channel.

- ***River Complexity Index (RCI)***: The RCI has been used to describe the complexity of hydraulic conditions within a reach (Brown, 2002). It is a calculated parameter that that is dependent on both sinuosity and number of side channel junctions. To account for variable reach lengths, the RCI has been unitized to valley distance:

  RCI = Sinuosity (1+nodes*)/valley distance

  Where nodes = the number of junctions between channels within a given reach. Examples of mapped nodes are depicted in Figure 2-1.

- ***Channel Displacement***: The channel displacement ratio describes the extent of primary channel migration over the last 50 years in square meters of displacement per meter of channel length. Channel displacement was calculated as the area of a polygon created by intersecting the primary channel threads from the 1950 and 2001 photography. The polygons were split at the reach break lines and attributed with the appropriate reach id. The polygon area per unit 2001 channel length was calculated for each reach (Figure 2-3).

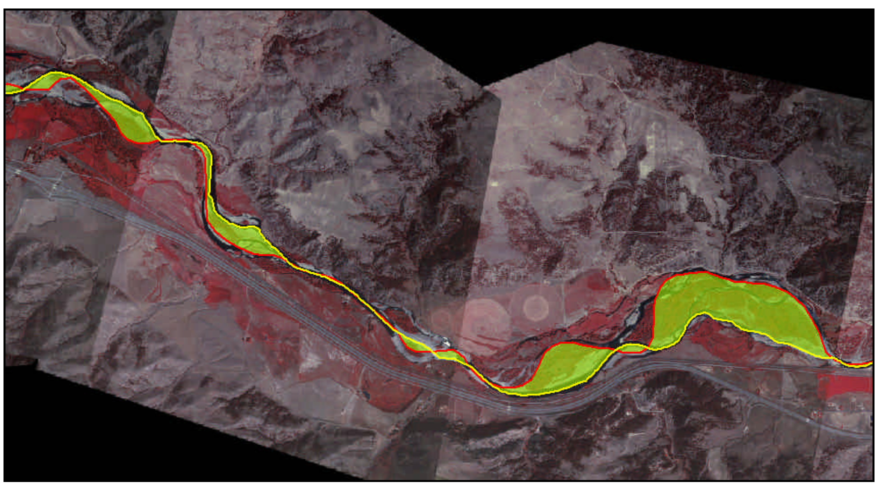


Figure 2-3. Channel displacement polygons created by intersecting the 1950s (red) and the 2001 (yellow) primary channel traces.

All channel traces are stored in the project Geodatabase. If the traces are modified and saved, revised segment lengths are automatically calculated and stored. The Geodatabase is linked to a Microsoft Access database, which allows the generation of a series of database queries to summarize the data. This allows a new summary table to be automatically created if any changes are made to the underlying GIS data. For example, if a channel type is changed from secondary to anabranching, the Access queries are automatically updated to reflect the change.

2.3 Disclaimer and Error Assessment

The data tables, graphs, and figures included in this report represent a basic compilation, presentation, and summarization of the data. The data have not been assessed in terms of potential cause and effect relationships, so no such interpretations are provided. The summary values reported in the following sections have not been proven to be statistically significant, as n-values for several of the groupings may not be sufficient for that level of analysis. Rather, summary statistics plotted as box and whisker plots are provided as a means to graphically present the data without inferring complete analysis of statistical significance.

The following topics should be noted prior to using these data:

- Errors associated with the base imagery-
    - The imagery for each of the four time periods has errors associated with it. With the exception of the 1995 DOQ photography, none of the photography has been ortho-rectified. In general, all photography has been georeferenced to the 1995 DOQs. This means that the georeferenced photography will assume the spatial errors associated with DOQs, in addition to the errors associated with the georeferencing process.
    - The photography was taken at a variety of scales with different cameras or sensors. This means that each image will have different distortion that is associated with its collection technique.
    - The imagery was scanned at a variety of resolutions and generally resampled to approximately 1 meter ground resolution.
    - The older imagery may contain additional errors associated with difficulties identifying common points to use for georeferencing.
- Data collection issues-
    - All digitizing of channel features associated with the Yellowstone River features was done at similar scales and have their own spatial errors. The image quality, shadows, and lighting make interpretation of bank lines difficult in places. To reduce error, each data set has been reviewed by a single individual to help ensure consistent levels of detail and feature attributes.

3 Framework for Data Summarization

In order to summarize the data in a way that will provide utility for future work, the data have been grouped in terms of region, general timeframe, and channel type.

3.1 Regional Summaries

Spatial and temporal trends have been summarized in terms of the following regions:

1. ***Park County*** extends from near Gardiner, Montana downstream to the Park/Sweetgrass County Line. This region includes the Paradise Valley, and the city of Livingston, and reflects the assessment reach addressed by the Upper Yellowstone River Task Force.
2. ***Region A*** extends from the Park/Sweetgrass County Line to the Clarks Fork of the Yellowstone confluence near Laurel. Similar to Park County, the Yellowstone River in Region A is a dynamic, coarse-grained river that supports a cold-water salmonid fishery. Sweetgrass and Stillwater Counties are within Region A.
3. Between the Clarks Fork and Bighorn Rivers, ***Region B*** lies entirely within Yellowstone County. Along this reach, the river supports both warm and cold water fish species. Increasing quantities of fine sediment occur in the downstream direction.
4. ***Region C*** extends from the Bighorn River confluence to the confluence of the Powder River. In this section, the Yellowstone River supports a plains warm-water fishery, which is characterized by a diverse variety of non-salmonid, warm water species. The channel slope is markedly less than that of upstream regions. The Region C plains zone includes Treasure, Rosebud, and Custer County.
5. Between the Powder River confluence and its terminus at the Missouri River the Yellowstone River in ***Region D*** is a prairie river similar to Region C. The river gradient is relatively flat, and the river is typically more turbid than upstream. Region D includes Prairie, Dawson, Wibaux, Richland, and McKenzie Counties.

3.2 Summaries of Change through Time

The timeframes evaluated for each parameter are variable. In Park County, only two suites of photography were analyzed, from 1948 and 1999. These data were folded into the 1950's and 2001 middle and lower river datasets, respectively (Table 3-1).

Table 3-1. Time frames used in the data summary.

Region	*Channel Length*	*Braiding Parameter*	*River Complexity Index*	*Channel Displacement*
Park County	1950-2001 (photos from 1948 and 1999)	1950-2001 (photos from 1948 and 1999)	1950-2001 (photos from 1948 and 1999)	1950-2001 (photos from 1948 and 1999)
Regions A-D	1950-1976, 1976-1995, 1995-2001, 1950-2001	1950's-1976, 1976-1995, 1995-2001	1950's-2001	1950's-2001

3.3 Reach Type Summaries

Between the southern Park County boundary and its confluence with the Missouri River, the Yellowstone River has been broken into a total of 88 reaches. These reach delineations are based on observable changes in general channel form. Each reach has been classified according to its general geomorphic character. The classification approach adopted reflects the overall channel pattern (straight, meandering, braided, or anabranching), as well as the relative role of the valley wall or inset high terraces in confining the river corridor (unconfined, partially confined, confined). A total of 10 channel types have been developed for the entire river (Table 3-2). In order to assess the trends within a given reach type, the geomorphic parameters have been summarized in terms of channel type as well as region.

The channel type datasets are presented in terms of calculated maximum, minimum, median, and quartile values. This allows a graphical presentation of the data in the form of box and whisker plots, which allow an easy comparison of data range (whiskers) and data clustering around the median (box) for a suite of channel type data (Figure 3-1). As discussed in Section 2.3, these data have not undergone analysis for statistical significance. N-values (number of data points) for each reach type are listed in Table 3-2.

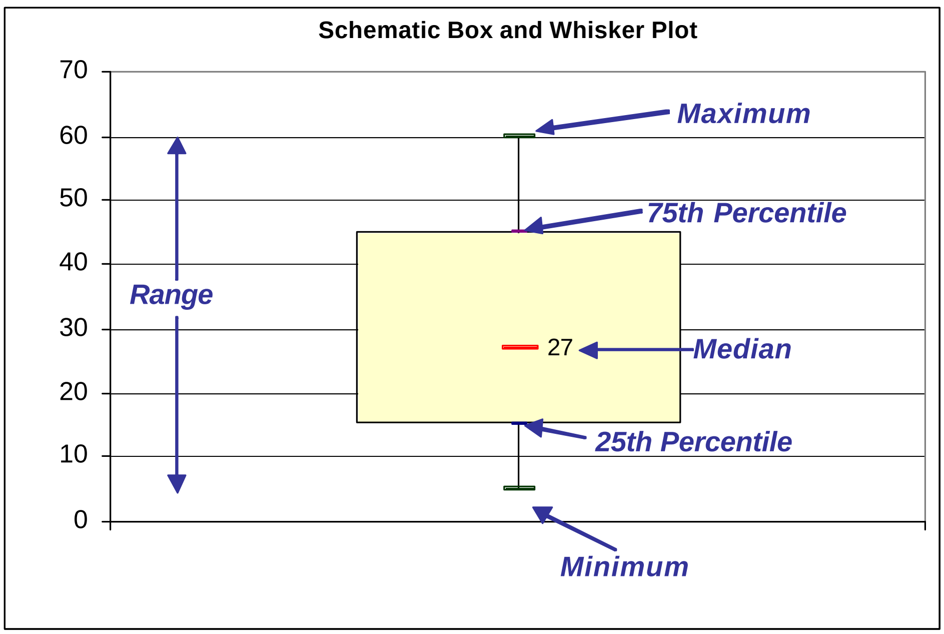


Figure 3-1. Schematic diagram of a box and whisker plot.

Table 3-2. Reach classification summary

Type Abbrev.	*Classification*	*n*	*Slope (ft/ft)*	*Planform/ Sinuosity*	*Major Elements of Channel Form*
UA	Unconfined anabranching	12	<.0022	Mult. Channels	Primary thread with vegetated islands that typically exceed 3X average channel width
PCA	Partially confined anabranching	18	<.0023	Mult. Channels	Partial bedrock control; Primary thread with vegetated islands that exceed 3X average channel width
UB	Unconfined braided	6	<.0024	Mult. Channels	Primary thread with unvegetated gravel bars; Average braiding parameter generally >2 for entire reach
PCB	Partially confined braided	13	<.0022	Mult. Channels	Partial bedrock control; primary thread with gravel bars; Average braiding parameter generally >2
PCM	Partially confined meandering	4	<.0014	>1.2	Partial bedrock control; main channel thread with point bars; average braiding parameter <2
PCS	Partially confined straight	11	<.0020	<1.3	Partial bedrock control; low sinuosity channel along valley wall
PCM/I	Partially confined meandering/islands	11	<.0007	Mult. Channels	Partial bedrock control; sinuous main thread with stable, vegetated bars
CS	Confined straight	5	<.0001	<1.2	Bedrock confinement; low sinuosity
CM	Confined meandering	7	<.0008	<1.5	Bedrock confinement; sinuous; uniform width; small point bars
US/I	Unconfined straight/islands	1	<.0003	<1.2	Low sinuosity with vegetated bars

A summary reach list, including length, type, and general location of each reach is provided in Appendix A.

4 Results

The geomorphic parameters have been quantified on the reach scale. A table listing the lengths, classification, and general locations for each reach are compiled in Appendix A. The geomorphic parameters collected for the each reach are presented in tabular format in Appendix B, and quantified changes through time are presented in Appendix C. Appendix D contains a series of plots depicting individual reach data. The information provided in this chapter consists of several types of data analysis and presentation. For several parameters, such as channel length, the change in measured length for each reach is presented, with plots broken down by major region. These data are intended to provide a sense of change within a given reach, as well as trends in an upstream/downstream direction. In order to provide information regarding the typical conditions or rates of change for each channel type, several parameters are presented as box and whisker plots that graphically display statistical summaries for each classification. These data are intended to provide a basis for generally assessing typical reach type conditions, to identify those reach types most prone to change, and to highlight any trends of change through time for a given reach type.

4.1 Channel Length

The primary channel length for each reach for each suite of air photos is listed in Appendix C, and these values are plotted as bar charts in Appendix D. The results of these measurements were used to compare primary channel length through time. Appendix C contains a table showing the results of this assessment, which are presented in terms of percent lengthening or shortening for each reach for various time frames. These values are graphically summarized below in Figure 4-1 through Figure 4-5. The plots indicate that in Park County, the most significant change in channel lengths occurred in PC9-PC13, which is between Mallard's Rest and Carters Bridge (Figure 4-1). In Region A, approximately 10% of channel length was lost in Reaches A9 (just upstream of Reed Point) and A18 (at Laurel) between 1950 and 2001 (Figure 4-2). The most significant changes in channel length in Regions B and C occurred between Reaches B9 (just below Pompey's Pillar; Figure 4-3) and C7 (Treasure/Rosebud County Line; Figure 4-4). Measured changes in Region D are typically less than 5% over 50 years; noted exceptions to this occurred in Reaches D7 (below Glendive) and D9 (below Intake; Figure 4-5).

From 1950 to 2001, reaches of a given reach type show both increases and decreases in total reach length (Figure 4-6). The reaches that show the greatest range in channel length changes are the (partially confined) meandering, braided, and anabranching channel segments.

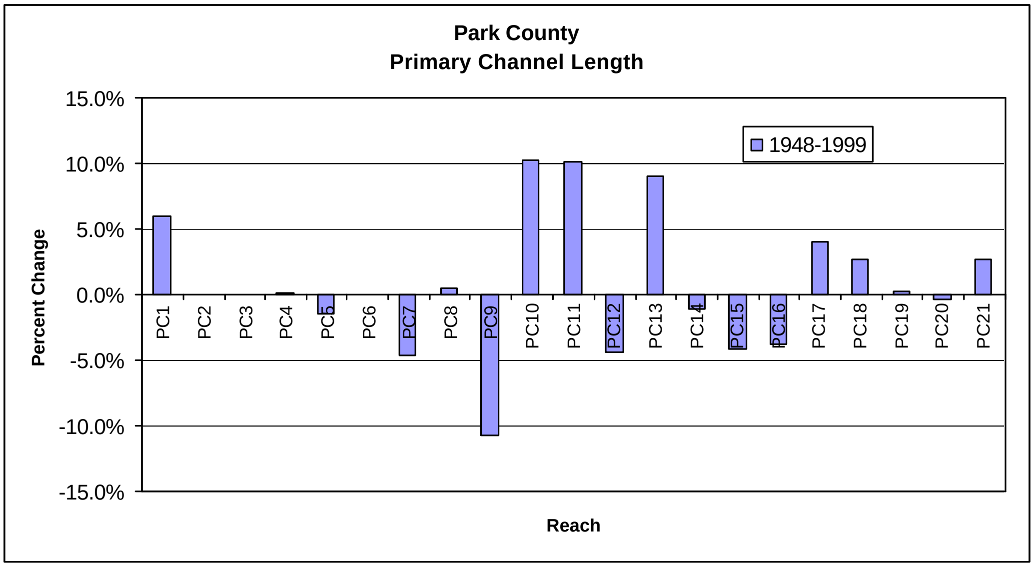


Figure 4-1. Percent change in primary channel length, 1948-1999, Park County

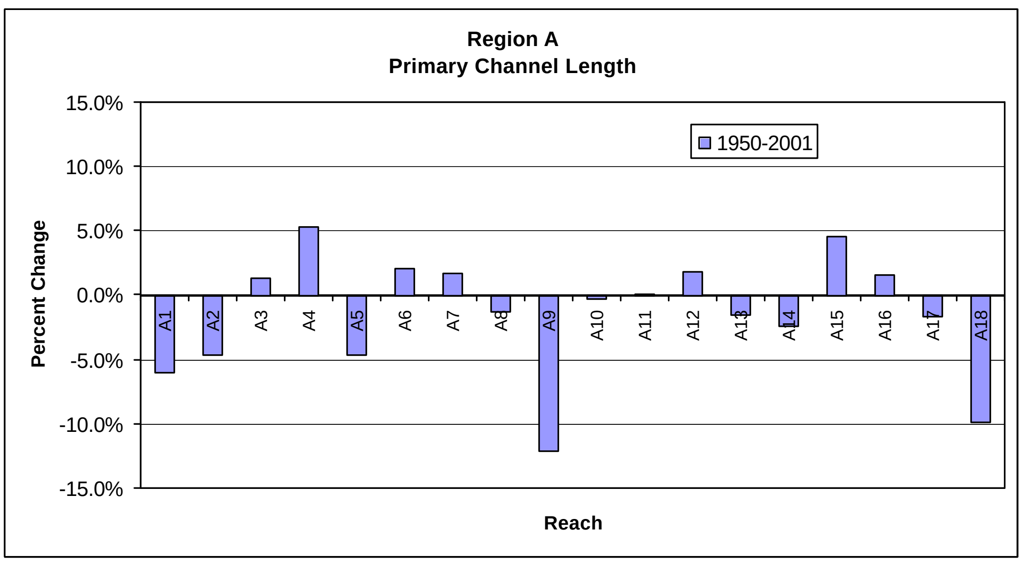


Figure 4-2. Percent change in primary channel length through time, Region A.

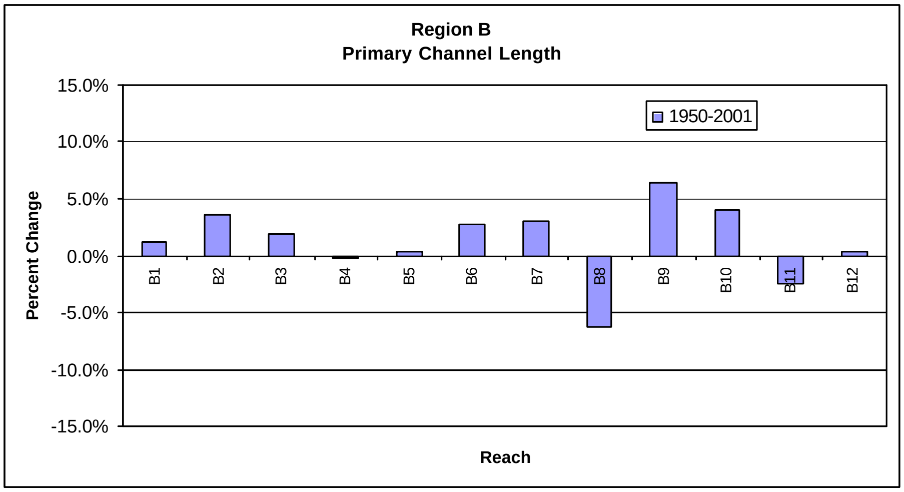


Figure 4-3. Percent change in primary channel length through time, Region B.

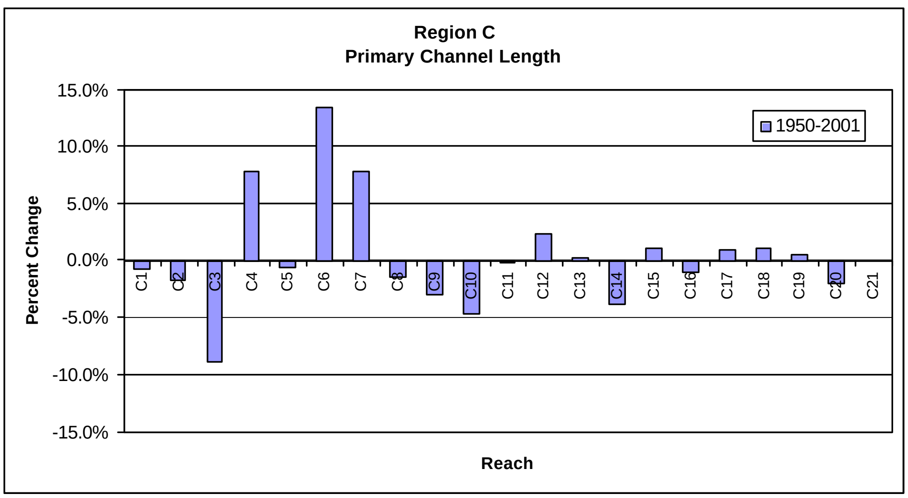


Figure 4-4. Percent change in primary channel length through time, Region C.

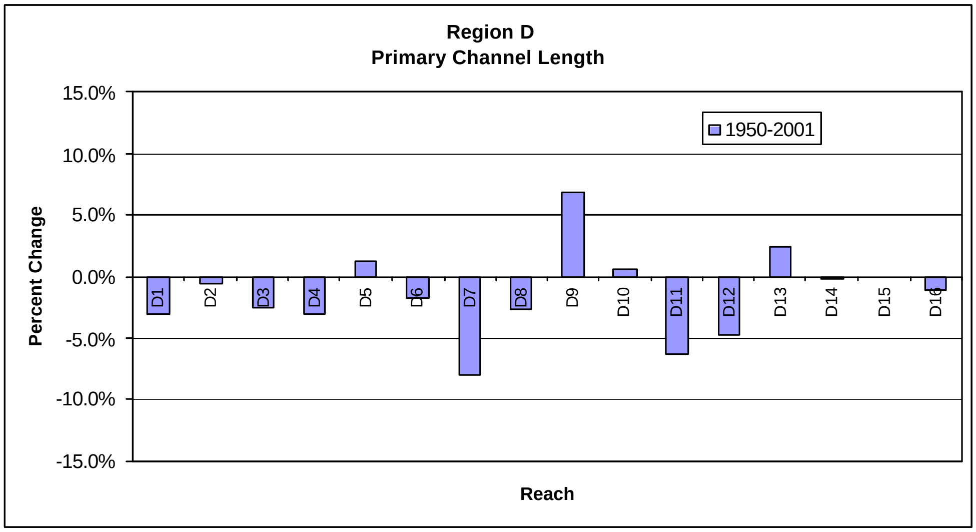


Figure 4-5. Percent change in primary channel length through time, Region D.

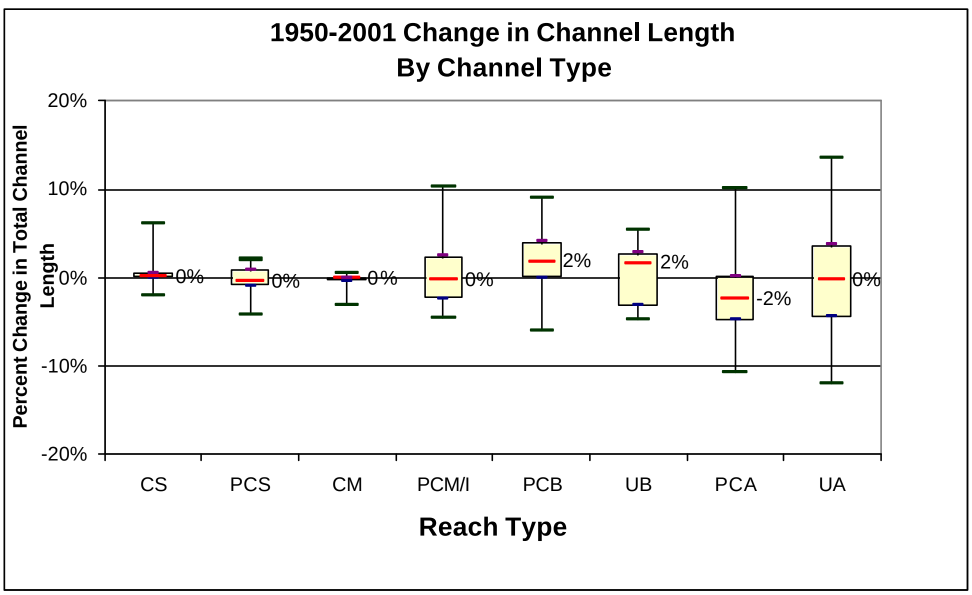


Figure 4-6. Summary of percent change in channel length for each reach type.

4.2 Sinuosity

Sinuosity, which is defined as the ratio of channel length to valley length, depicts how tortuous a stream channel is for a given valley distance. Calculated sinuosity values derived from the 2001 color infra red imagery show that the majority of the river has a sinuosity of less than 1.2 (Figure 4-7). The most striking exception to that value is in the upper portions of Region C, where sinuosity exceeds 1.4 in five reaches between C3 and C9. These reaches are located just below Myers Bridge, as well as in the Mission and Hammond Valleys near Hysham and Forsyth, respectively.

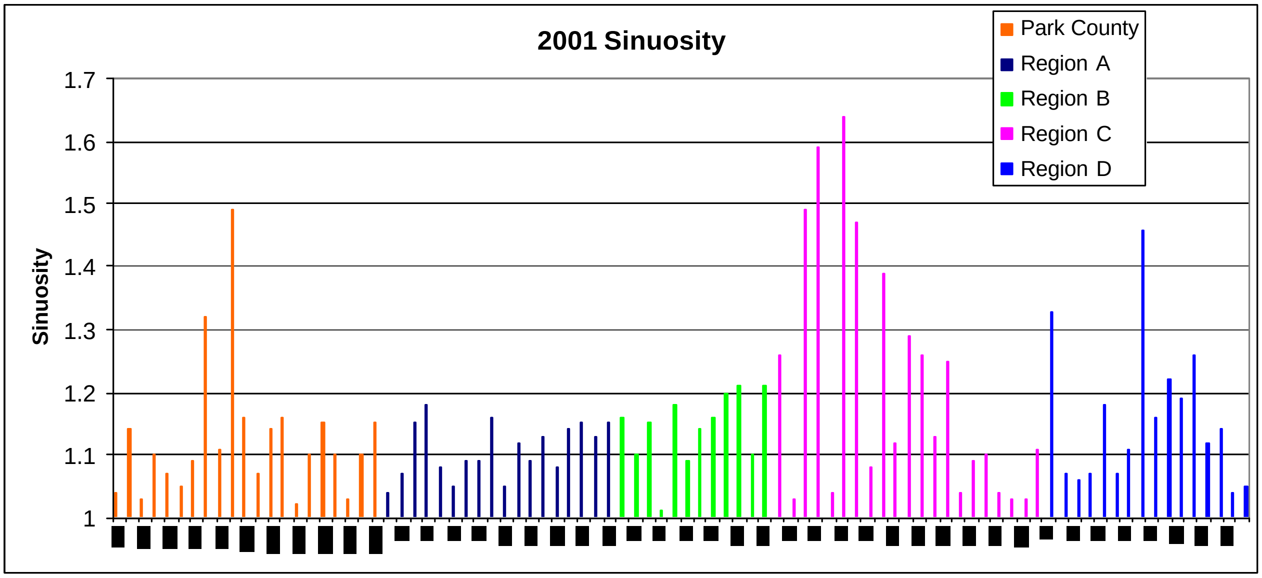


Figure 4-7. Channel sinuosity for each reach (2001), Yellowstone River

When grouped by reach classifications, 2001 sinuosity values show some stratification within relatively broad ranges of values (Figure 4-8). The channels classified as straight have low sinuosities, and a narrow range of values. Most reaches classified as meandering, braided, or partially confined anabranching have sinuosities between approximately 1.1 and 1.2. The highest sinuosity values are in the unconfined anabranching reach type, which snows a median sinuosity value of 1.2, and a 75th percentile value of over 1.4.

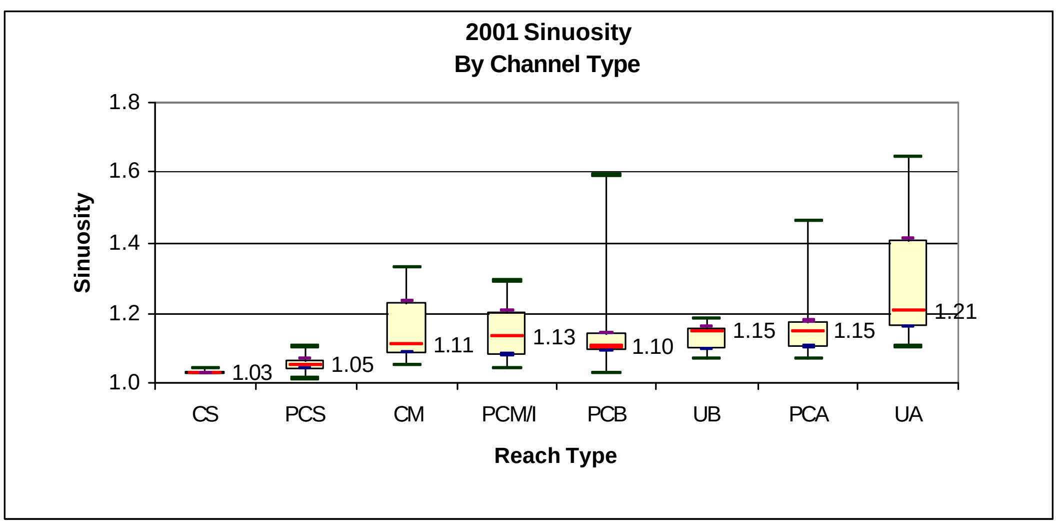


Figure 4-8. Summary of 2001 channel sinuosity for each reach type

A comparison of changes in sinuosity through time is not presented here, as these changes are the same as those identified by comparison of total channel length (Section 4.1).

4.3 Braiding Parameter

Braiding parameter is a measure of the cumulative length of side channels relative to that of the main channel. A high braiding parameter reflects the presence of extensive side channels. A braiding parameter of 4, for example, indicates that the total channel length is 4 times the main channel length, such that three quarters of the entire channel length is made up of side channel. In contrast, a braiding parameter of 1 indicates no side channels.

The extent to which side channels are evident on air photos within a coarse grained, complex river like the Yellowstone changes with differing amounts of flow. At low flow conditions, braiding parameters tend to be high due to flow splits around gravel bars. As flows increase, those bars are submerged and the braiding parameter (as visible on air photos) drops. Therefore, it is important to consider the effects of flows when compiling braiding parameter data collected under different flow conditions.

4.3.1 Bank Full Braiding Parameter

The bank full braiding parameter is intended to define the extent of side channel length when side channels are actively flowing during a bank full event. On many river systems, this bank full flow typically occurs on an average of every 1.6 years. During typical snowmelt runoff, this bank full event probably lasts on the order of a few days to a couple of weeks. Bank full braiding parameter reflects the following ratio:

$$\frac{(\text{Primary channel length} + \text{Anabranching channel length})}{\text{Primary channel length}}$$

The information below contains graphical summaries of measured change through time, as well as plotted statistical summaries of these changes with respect to reach type. In support of this analysis, the individual braiding parameter values measured for each reach are tabulated in Appendix C. The table in Appendix C lists the changes in braiding parameter through time for each reach, and bar charts showing the measured values for each reach are compiled in Appendix D.

Plotted changes in braiding parameter through time are shown in Figure 4-9 through Figure 4-13. The data summary suggests that there has been a general reduction in braiding parameter (side channel length) in Park County (Figure 4-9), especially between Deep Creek (PC10) and Mission Creek (PC18). A significant increase in braiding parameter was measured in PC9, which is located between Mallard's Rest and Pine Creek.

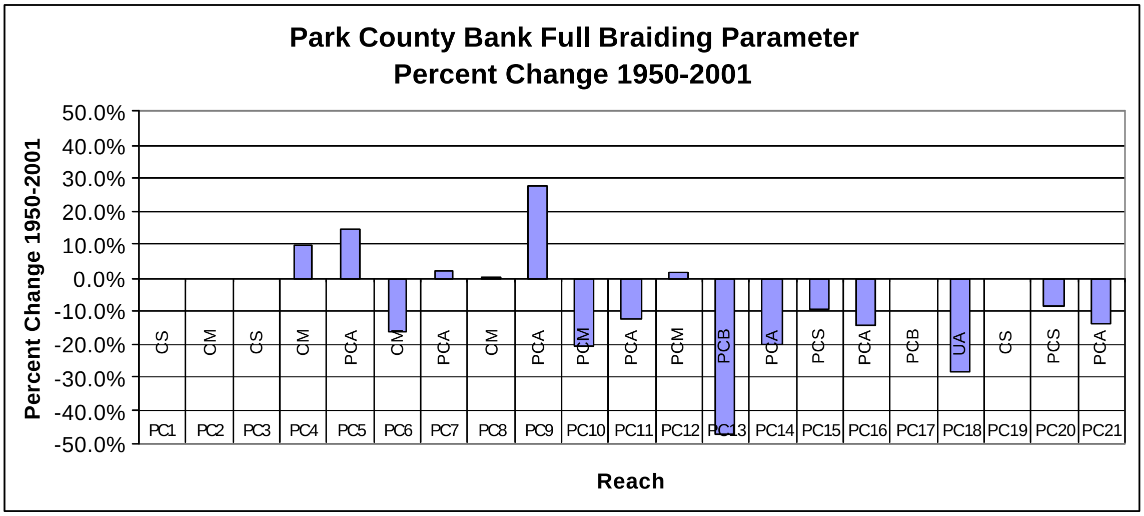


Figure 4-9. Percent change in braiding parameter through time, Park County.

Downstream of Park County, in Region A (Springdale to Clarks Fork), a few reaches had notable increases in braiding parameter between 1950 and 1976, although most reaches show an overall decline between 1950 and 2001 (Figure 4-10). It appears that 1976 to 2001 was characterized by systemic loss of side channels in Region A.

In Region B (Clarks Fork to Bighorn River; Figure 4-11), there are no evident systemic shifts in braiding parameter through time. Braiding parameter decreased in approximately half of the reaches within Region B, with notable increases measured in Reaches B4, B5, and B6, which are located just below Billings near Huntley.

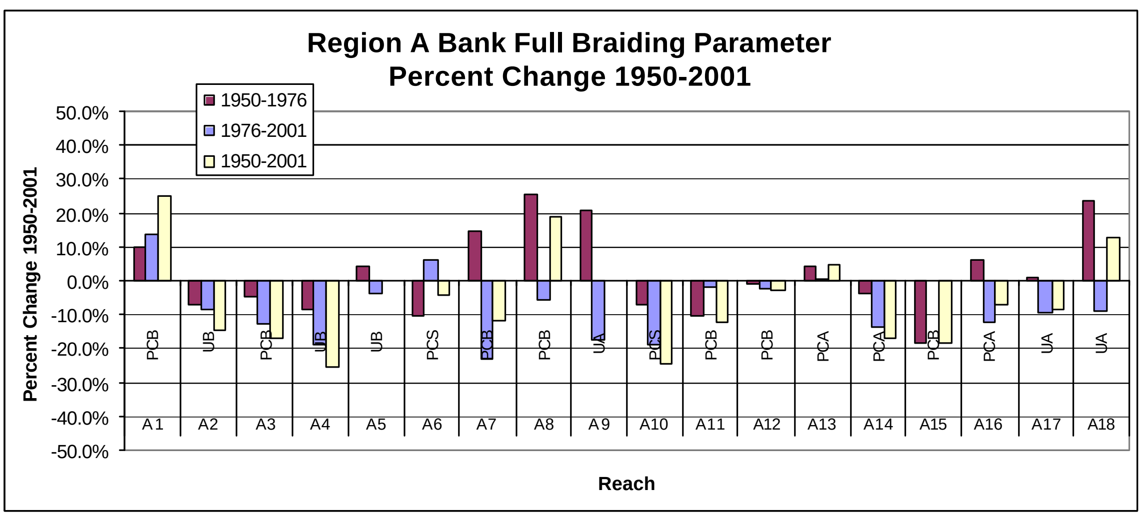


Figure 4-10. Percent change in braiding parameter through time, Region A.

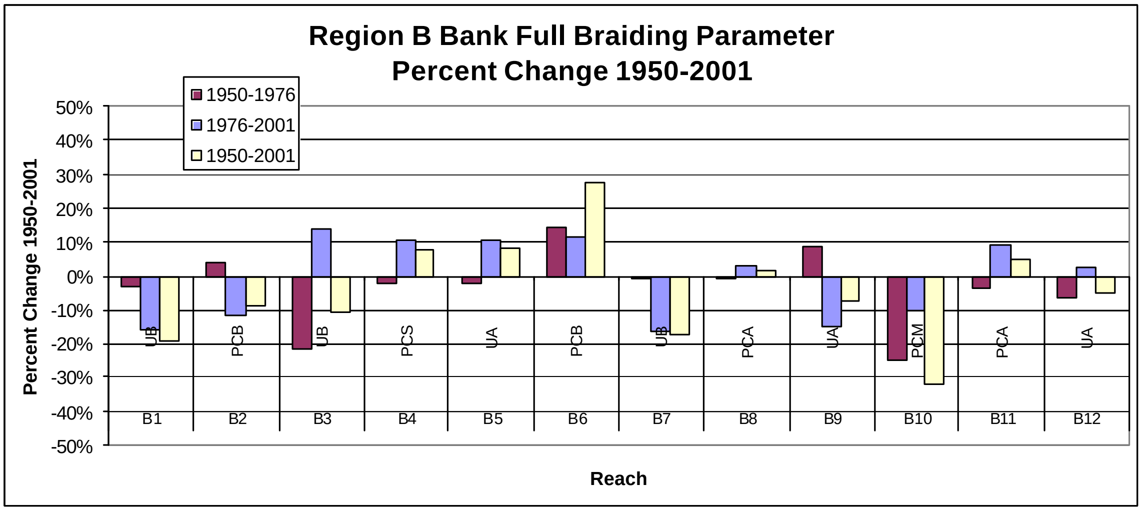


Figure 4-11. Percent change in braiding parameter through time, Region B.

Similar to Region A, the braiding Parameter in Region C (Bighorn to Powder) shows overall reductions since 1950 (Figure 4-12). The greatest losses appear to have occurred between 1976 and 2001. Between the Powder River and the mouth of the Yellowstone River, most reaches within Region D experienced less than a 15% change in overall braiding parameter between 1950 and 2001 (Figure 4-12). Notable exceptions are in Reach D6 at Glendive, where braiding parameter was significantly reduced, and the lowermost reaches at the mouth of the river, which show consistent increases in overall braiding parameter. A review of the aerial photography for reaches D14-D16 near the mouth of the Yellowstone indicates that the calculated increase in bank full braiding parameter correlates to a conversion of secondary channels in 1950 (open bars) to anabranching channels in 2001 (densely vegetated).

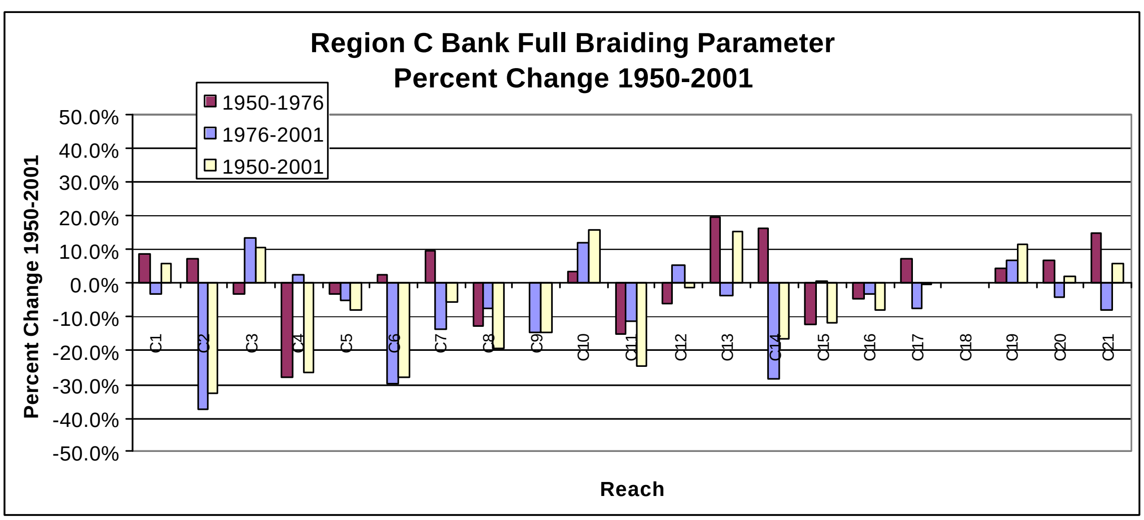


Figure 4-12. Percent change in braiding parameter through time, Region C.

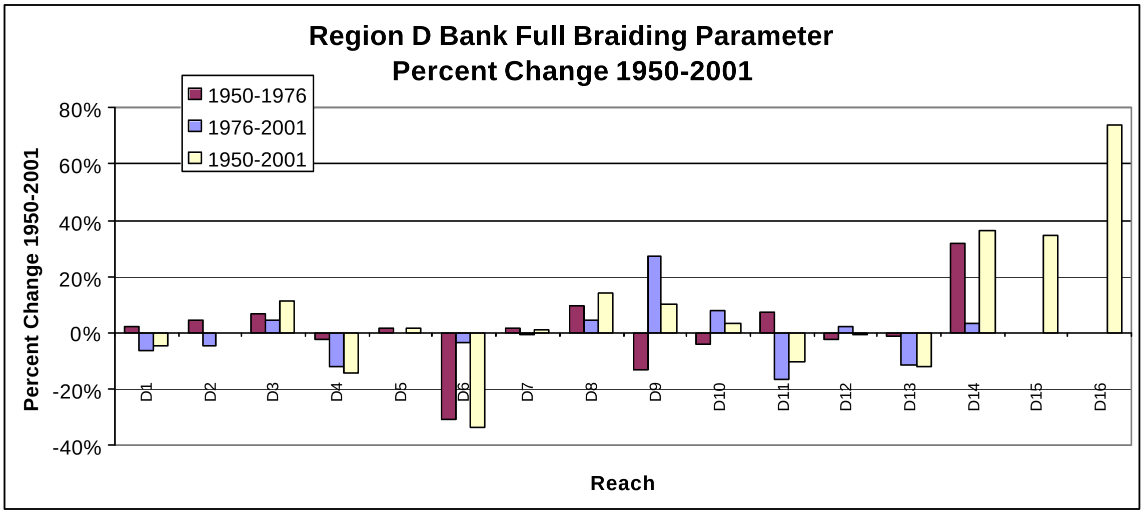


Figure 4-13. Percent change in braiding parameter through time, Region D.

A plot of measured braiding parameters from the 2001 color infra red imagery shows that the reach types show a consistent trend of increasing braiding parameter from the straight and confined channel types to anabranching channel types (Figure 4-14). The confined reaches, in which bedrock is a major component on both channel banks (CS and CM), show the lowest braiding parameters, hence the lowest extent of side channels. Where straight or meandering channels are only partially confined (PCS and PCM/I), meaning bedrock plays a limited role, braiding parameters are significantly higher. Whereas the meandering and braided channels that are partially confined by bedrock (PCB and PCM) have similar braiding parameter values, the braided reaches that are unaffected by bedrock (UB) show moderately higher braiding parameters. Similarly, anabranching channels that are affected by the valley wall geology (PCA) have slightly lower braiding parameter values than unconfined anabranching (UA) channel types.

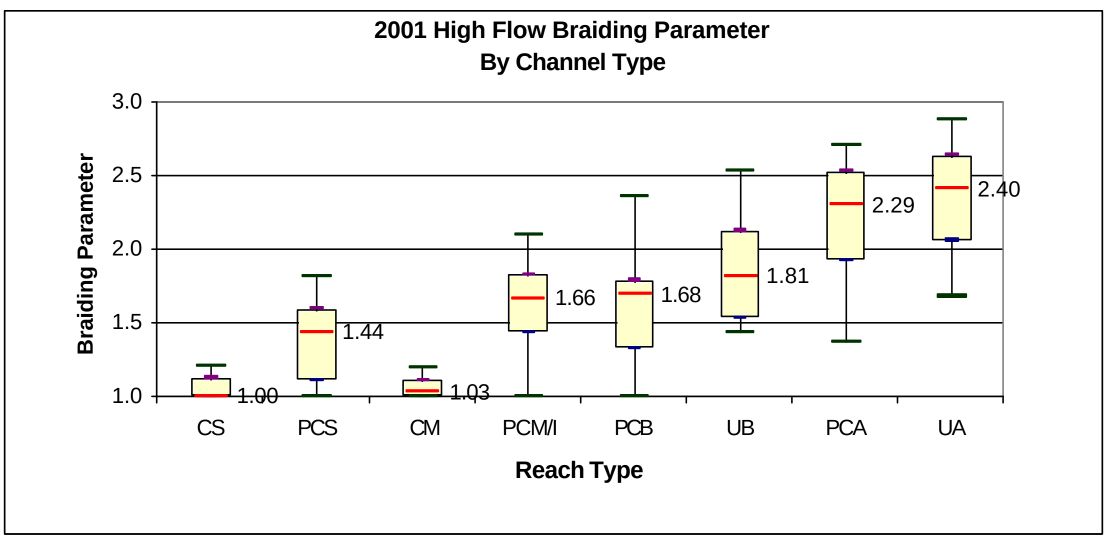


Figure 4-14. Statistical summary of 2001 braiding parameter by reach type.

When the braiding parameters for each channel type are plotted through time, the straight, meandering, and anabranching channels show no trend in terms of overall increasing or decreasing values through time. However, braided channels, both confined and unconfined, show a distinct reduction in their range and median values between 1950 and 2001. The unconfined braided channels show this trend most clearly (Figure 4-15).

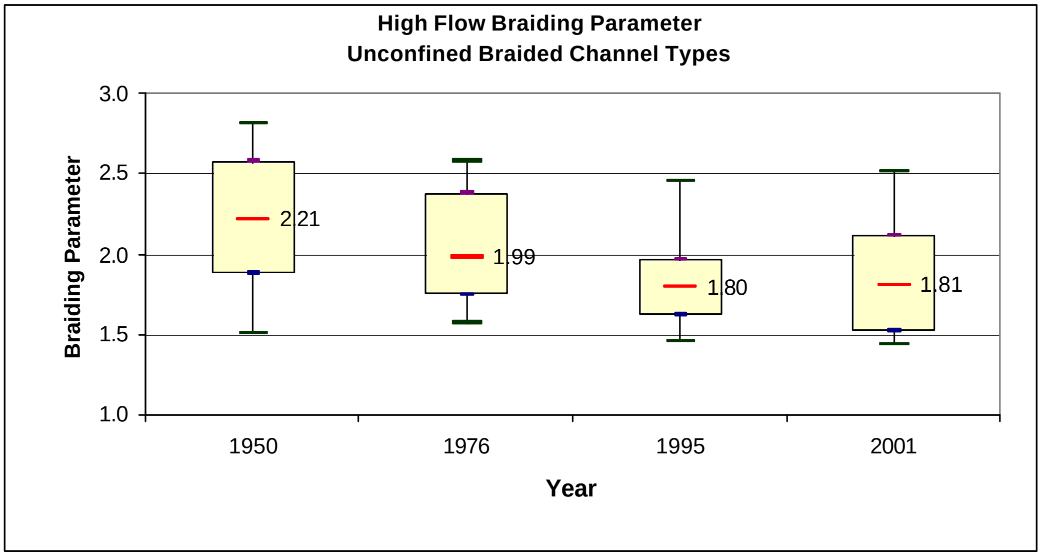


Figure 4-15. Statistical summary of braiding parameter through time, all channel types.

In order to better depict the changes in braiding parameter through time, each anabranching or braided reach was assessed in terms of its percent increase or decrease in braiding parameter value between 1950 and 2001. Figure 4-16 shows that in Park County, the median value for braiding parameter change between 1950 and 2001 is -12% for anabranching/braided reaches and 0% for all other reach types. For Park County, data are only available for 1950 and 2001, hence intermittent time frames have not been considered.

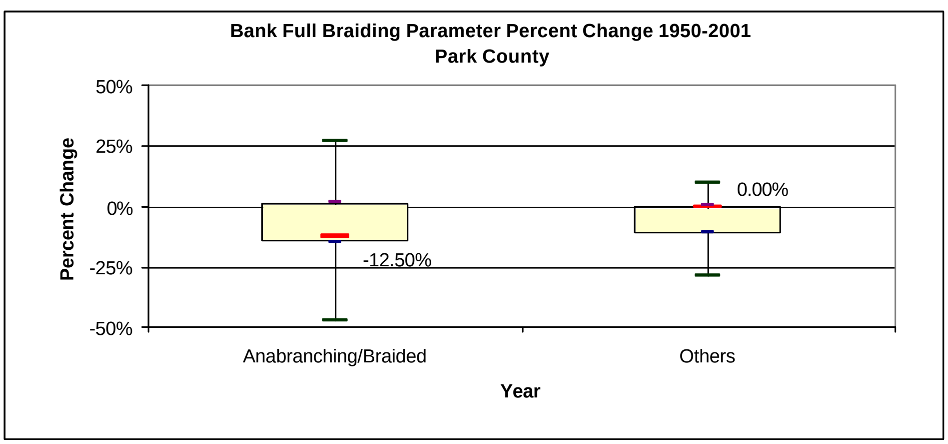


Figure 4-16. Percent change in braiding parameter for anabranching/braided and all other channel types, Park County for 1950-2001 time frame.

In region A, the median change in braiding parameter for the anabranching/braided channel types consists of a 2.8% increase between 1950 and 1976, followed by a 13% decrease between 1976 and 1995 (Figure 4-17). The 1995-2001 time frame was characterized by a slightly negative median value for change in braiding parameter. Thus the data indicate that the 1976 to 1995 time frame was characterized by a significant reduction in braiding parameter for most reaches. For the entire time frame (1950-2001), the median change in braiding parameter is -7.5%.

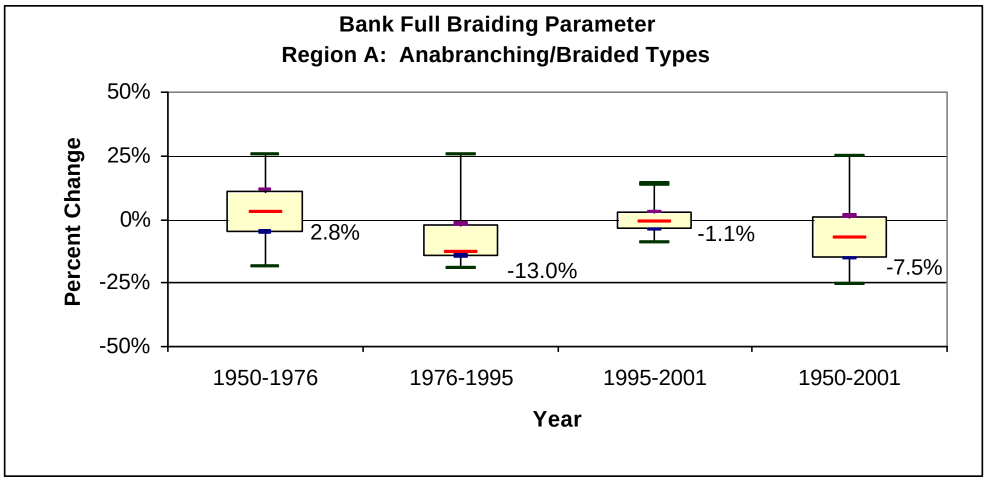


Figure 4-17. Statistical summary of braiding parameter changes through time, Region A.

In region B, most reaches show reductions in braiding parameter values during all time frames with the exception of 1995-2001 (Figure 4-18). The most significant losses were from 1976 to 1995. Most anabranching/braided reaches in Region C also showed significant loss in braiding parameter between 1976 and 1995. The median change in parameter value during that time frame was -16.4% (Figure 4-19). Hence one half of the reaches showed losses greater than that value. Over the combined time period, from 1950 to 2001, approximately three fourths of the reaches experienced a reduction in braiding parameter (the 75th percentile is 0% change; Figure 4-19), and for one half of the reaches, that change exceeded -14.7%. Measured changes in braiding parameter in Region D are relatively small and show no overall trend (Figure 4-20).

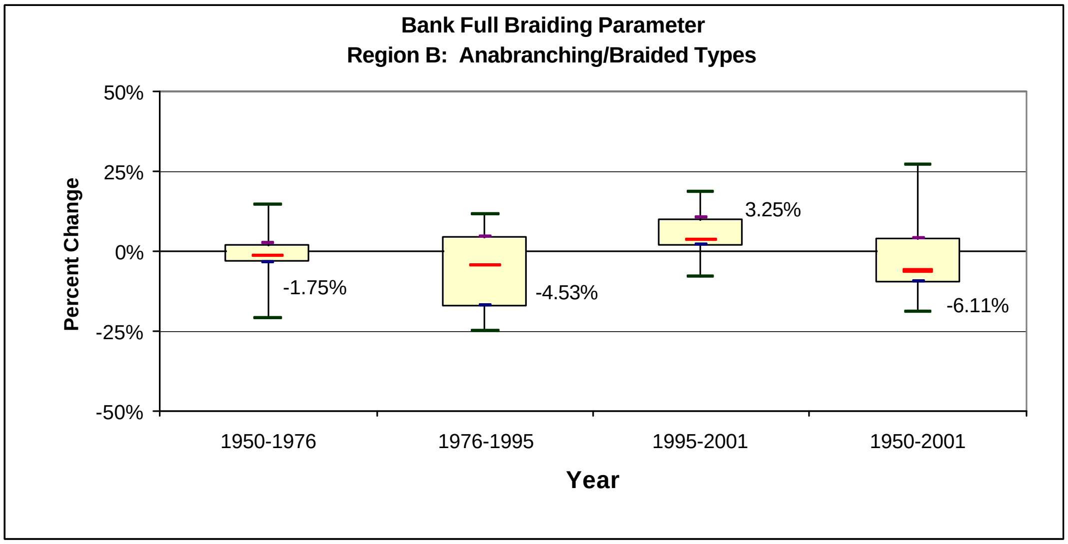


Figure 4-18. Statistical summary of braiding parameter changes through time, Region B.

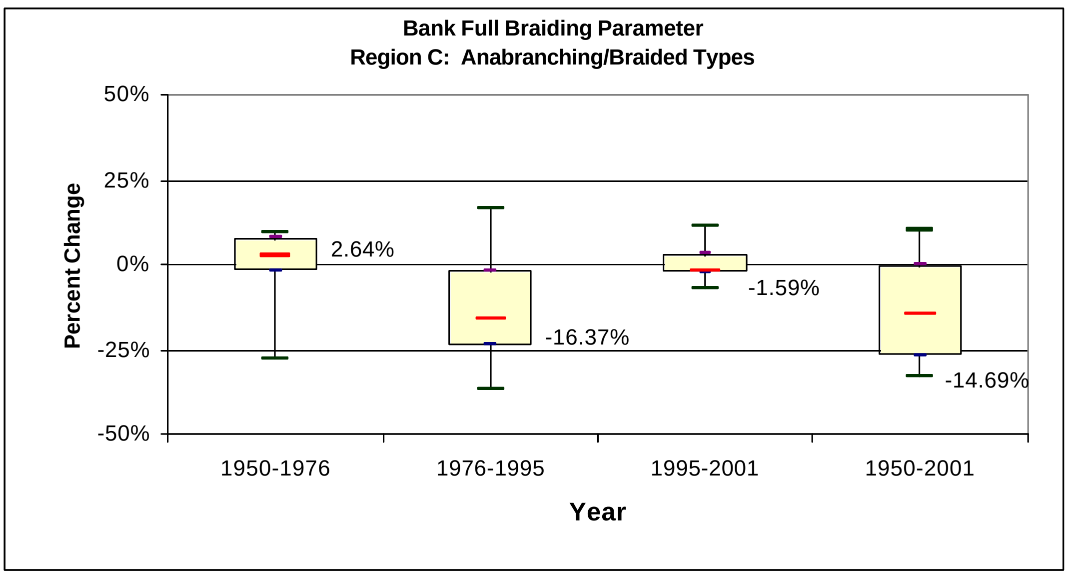


Figure 4-19. Statistical summary of braiding parameter changes through time, Region C.

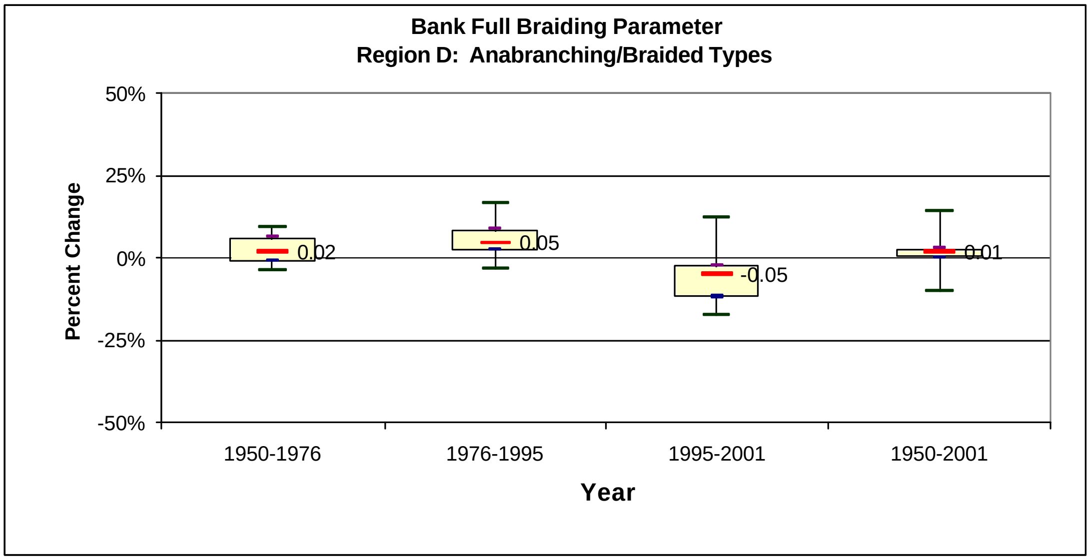


Figure 4-20. Statistical summary of braiding parameter changes through time, Region D.

4.3.2 Low Flow Braiding Parameter

As described in Section 4.3, the low flow braiding parameter reflects the extent of both anabranching and secondary channels that are visible on each suite of air photos. Because the parameter includes low flow secondary channels, the low flow braiding parameter is either equal to or higher than the high flow braiding parameter. The low flow braiding parameter values can be used to assess the extent of side channels that are active for a given suite of air photos.

The low flow braiding parameter is calculated as the following ratio:

$$\frac{\text{(Primary channel length + Anabranching channel length + Secondary channel length)}}{\text{Primary channel length}}$$

Figure 4-21 shows the measured 2001 low flow braiding parameter for all reaches. The plot shows a basic trend of increasing low flow complexity from approximately reach A4 (Big Timber) downstream to Reach B12 (Bighorn River). Below the Bighorn River confluence, the low flow braiding parameter drops until Reach D4 (just upstream of Glendive), where it increases through Reach D12 below Intake. Bar charts showing measured values for each reach for each suite of photos are compiled in Appendix D.

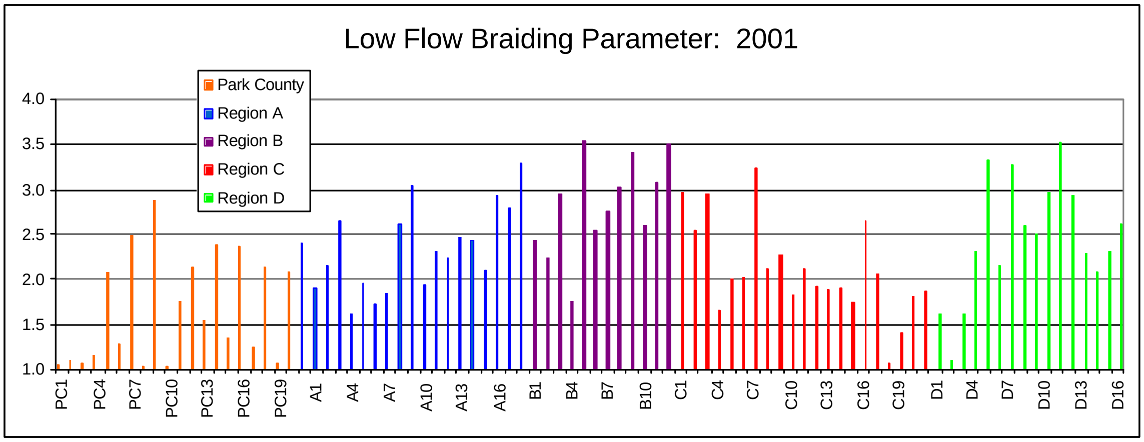


Figure 4-21. Low flow braiding parameter for 2001, all reaches.

4.4 River Complexity Index (RCI)

River complexity index is a measure of both channel sinuosity and the number of channel intersections within a given reach. A high RCI value reflects either a high sinuosity, and/or a high number of channel intersections. Since the channel intersection density is related to flow condition (similar to braiding parameter) the RCI values presented below have been calculated to reflect bankfull conditions, using the nodes that define intersections between anabranching and primary channels (Figure 2-1; green symbology). The low flow nodes (Figure 2-1; yellow symbology) can also be used to assess low flow complexity; calculated values for low flow RCI are contained in Appendix B and Appendix C.

RCI values are shown as RCI/km to normalize the numbers to channel length. The plots below show some trends of RCI both spatially and temporally. In Appendix B, the calculated bankfull RCI values for each reach are tabulated, and calculated changes through time are listed in Appendix C. Appendix D contains supplemental bar charts showing values for each reach.

A plot of bankfull RCI values for the entire project reach (Figure 4-22) shows that the complexity index is highest in PC9 (Mallard's Rest to Pine Creek), B9 (below Pompey's Pillar), B12 (just above the Bighorn confluence), and C7 (Mission Valley). RCI values show an increasing trend in the downstream direction between the Clark's Fork and the Bighorn River (Region B), and a distinct declining trend from the Bighorn confluence to the Powder River (Region C).

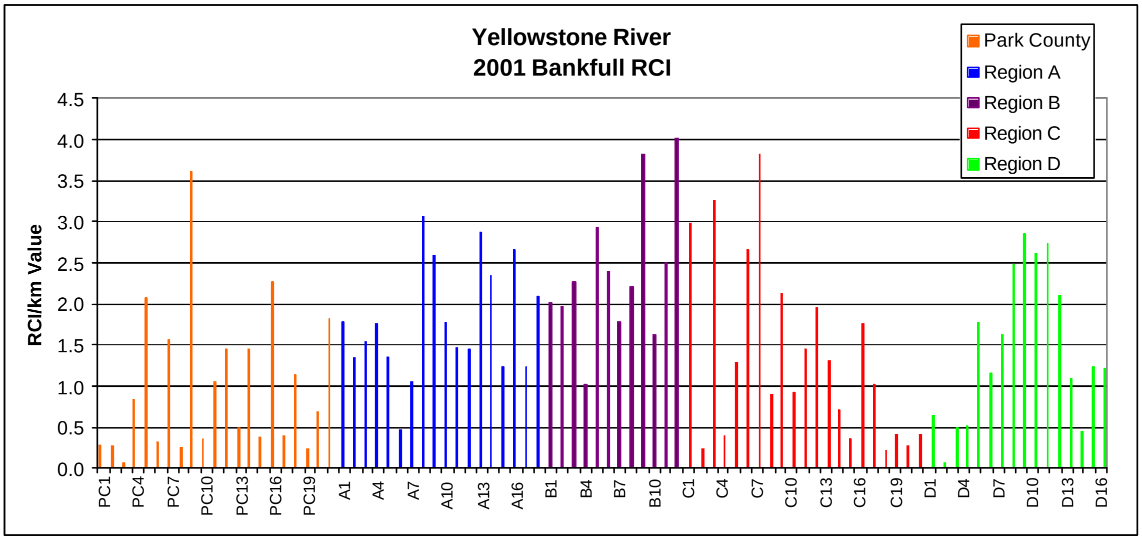


Figure 4-22. 2001 bankfull RCI values for all reaches.

Plots of changes in RCI values between the 1950's and 2001 show that in Park County, RCI values have decreased through time (Figure 4-23). On the Yellowstone River, RCI/km values typically range from 0 to 3. Hence a reduction of over 2 RCI units in several reaches of Park County is substantial. In Region A, the RCI/km values have dropped in 16 out of 18 reaches between 1950 and 2001 (Figure 4-24). Region B shows no distinct trend in RCI; however the most significant changes since 1950 have all been reductions in RCI value (Figure 4-25).

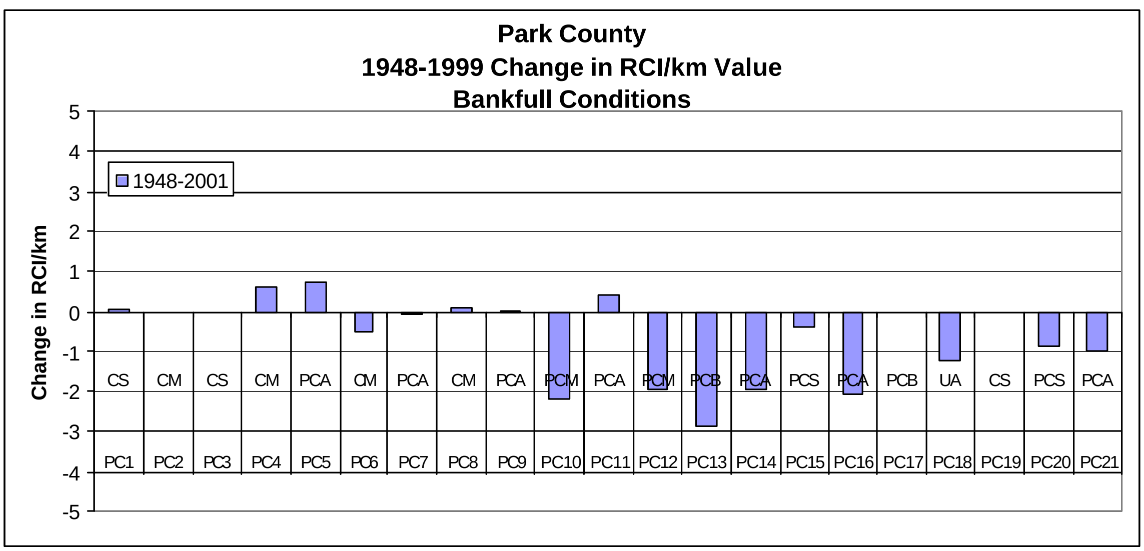


Figure 4-23. Change in River Complexity Index from 1948-2000, Park County.

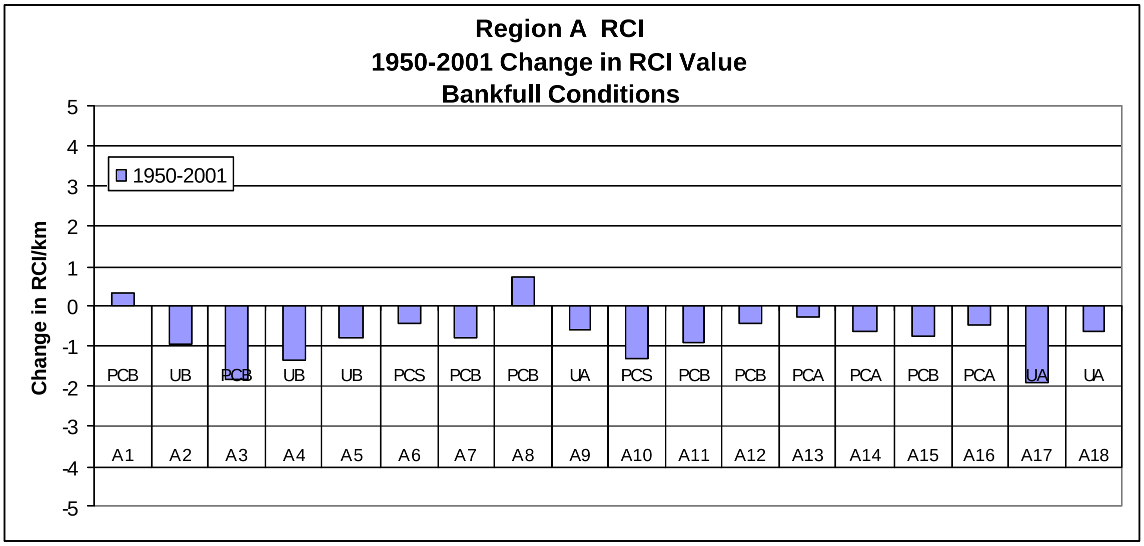


Figure 4-24. Change in River Complexity Index from 1950's-2000, Region A.

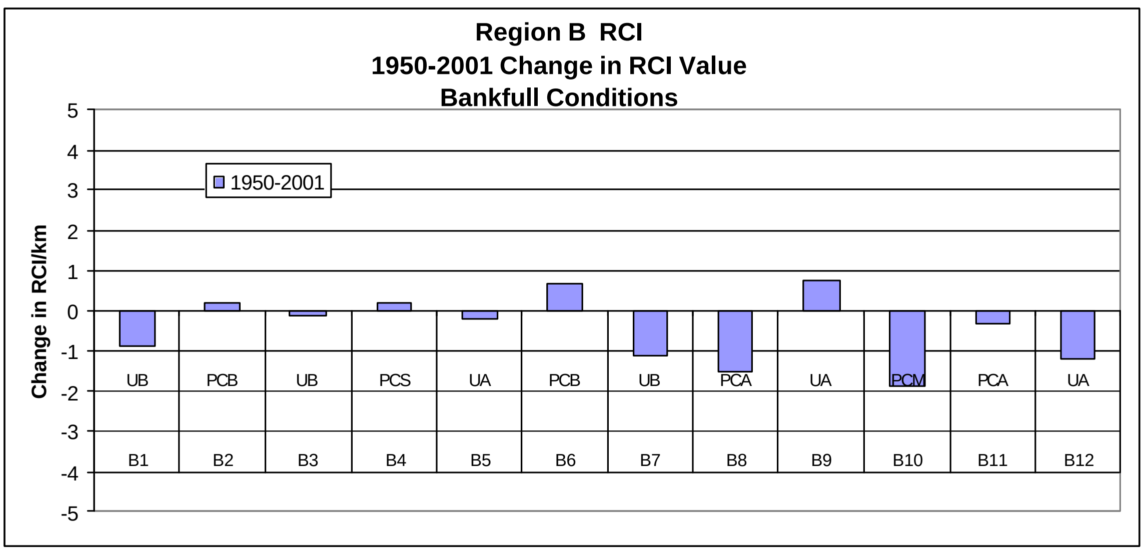


Figure 4-25. Change in River Complexity Index from 1950's-2000, Region B.

Below the Bighorn River, RCI values have commonly decreased over the last 50 years (Figure 4-26). Three reaches that show reduced RCI values are classified as Partially Confined Meandering/Islands reach types located between Forsyth and Miles City. In Region D, changes have been relatively minor (Figure 4-27).

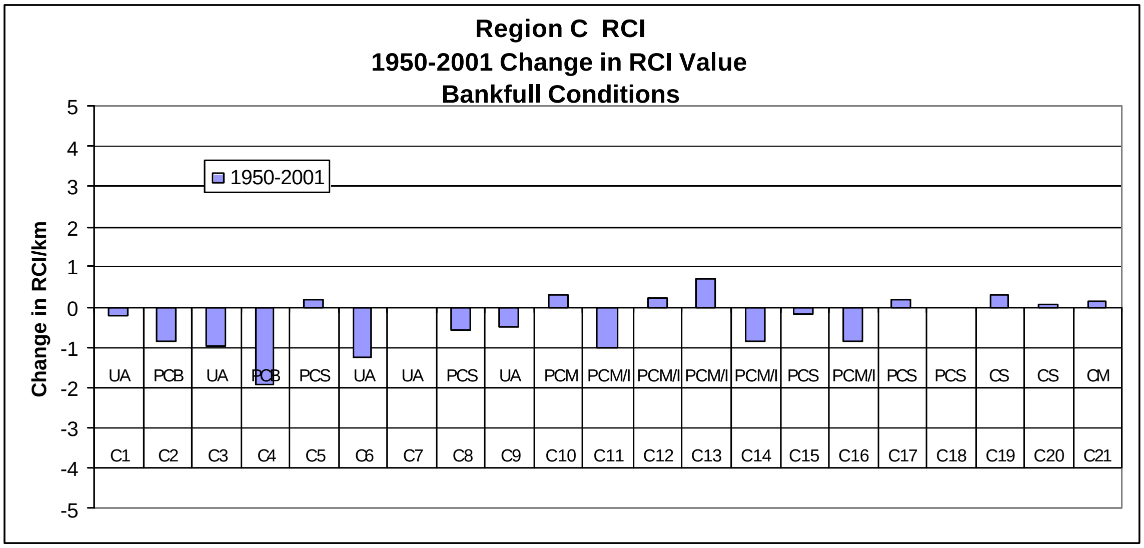


Figure 4-26. Percent change in River Complexity Index from 1950's-2000, Region C.

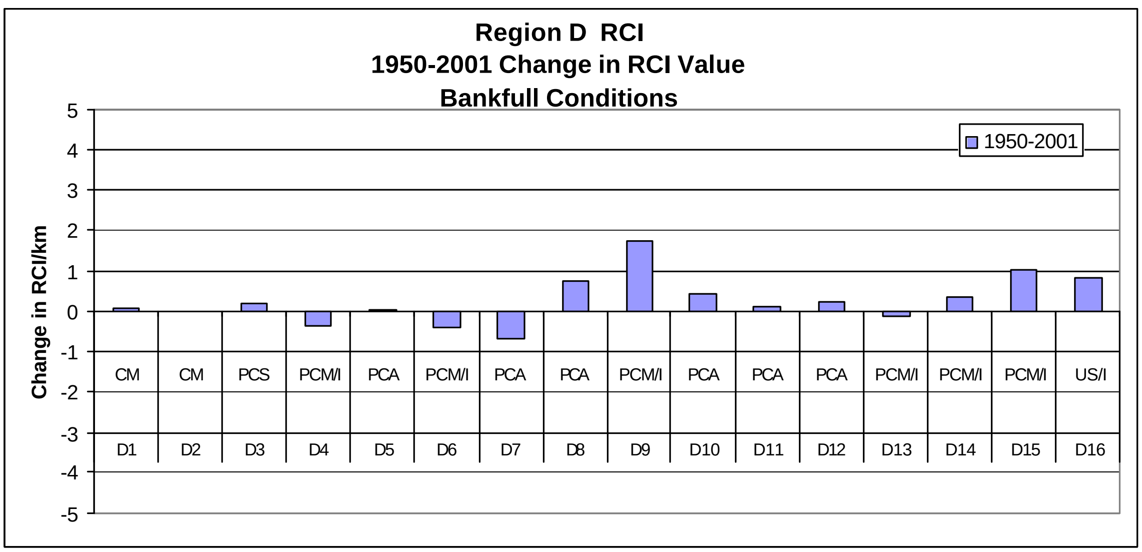


Figure 4-27. Change in River Complexity Index from 1950's-2000, Region D.

A summary of the complexity index measurements in terms of reach type shows increasing values from confined straight to meandering to braided to anabranching channels. Unconfined braided (UB) and unconfined anabranching (UB) channels are both associated with higher RCI values than their partially confined counterparts (PCB and PCA). Reaches with extensive bedrock influence (CS and CM) are associated with the lowest calculated RCI values.

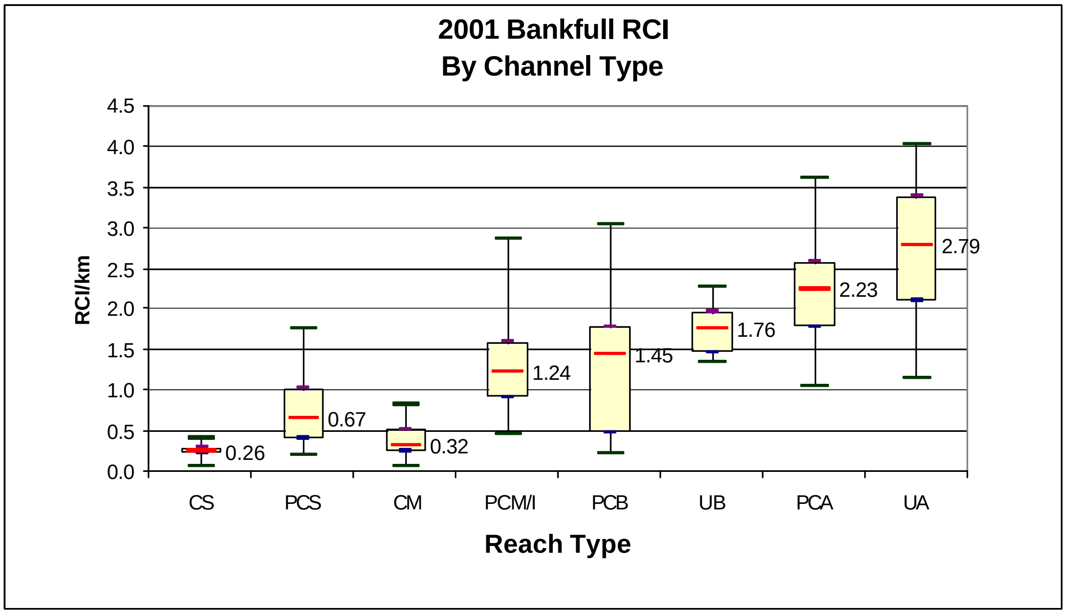


Figure 4-28. Statistical summary of bankfull 2001 RCI values for each channel type

A comparison of bankfull RCI values through time reflects combined changes in sinuosity and number of channel intersections. A reduction in RCI value through time reflects a channel straightening, and/or a reduced number of channel intersections. Results from Park County indicate that for braided and anabranching channel types, the median RCI value has dropped from 2.6 in 1948 to 1.5 in 1998. The “box” portion of the plot, which identifies the range between the 25th and 75th percentile values, is markedly smaller in 1998, reflecting a narrowing in the range of RCI values through time.

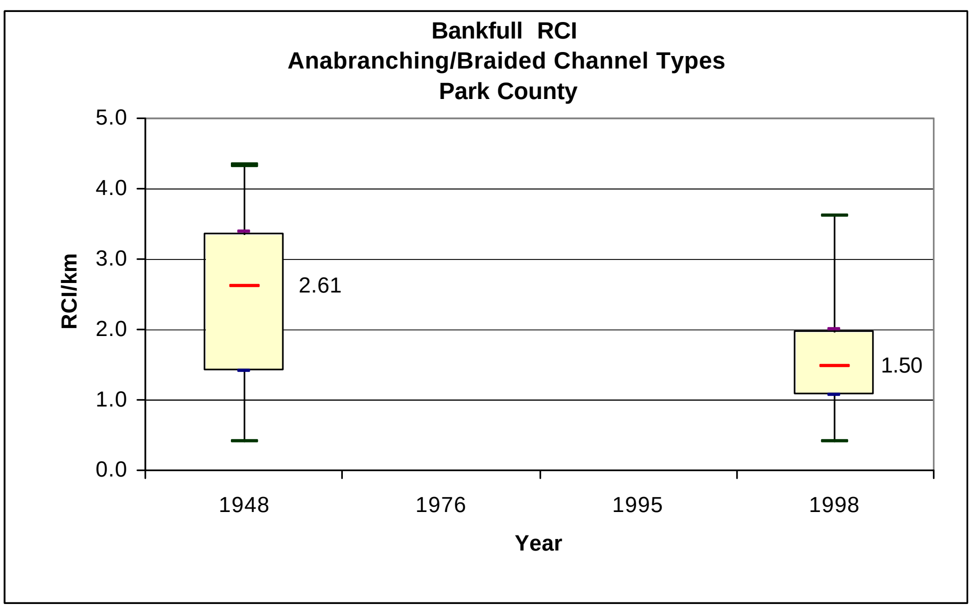


Figure 4-29. RCI through time for anabranching/braided channel types, Park County

Downstream of Park County, data are also available from 1976 and 1995. A summary of RCI values for Unconfined Anabranching (UA) channel types between Springdale and the mouth show a distinct increase in values between 1950 and 1976 followed by a marked drop between 1976 and 1995 (Figure 4-30).

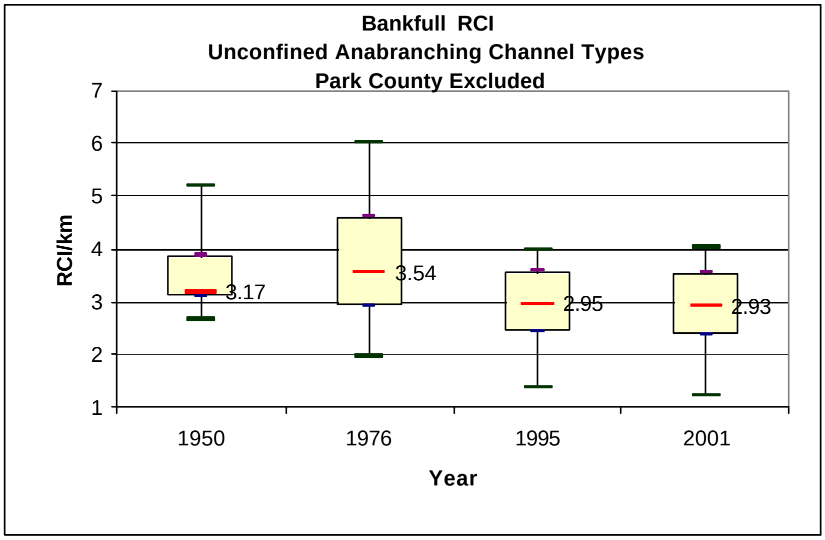


Figure 4-30. RCI through time for Unconfined Anabranching channel type.

It is interesting to note that anabranching channels that abut the valley wall over a significant length and thus are partially confined (PCA) collectively show little change through time (Figure 4-31). Partially confined meandering and braided channels, on the other hand, do show reductions in RCI values through time (Figure 4-32 and Figure 4-33).

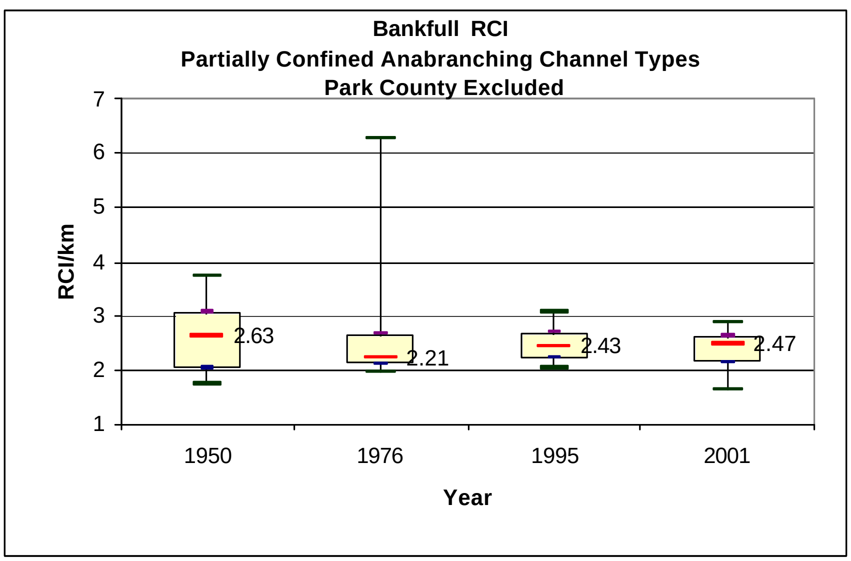


Figure 4-31. RCI through time for Partially Confined Anabranching channel type.

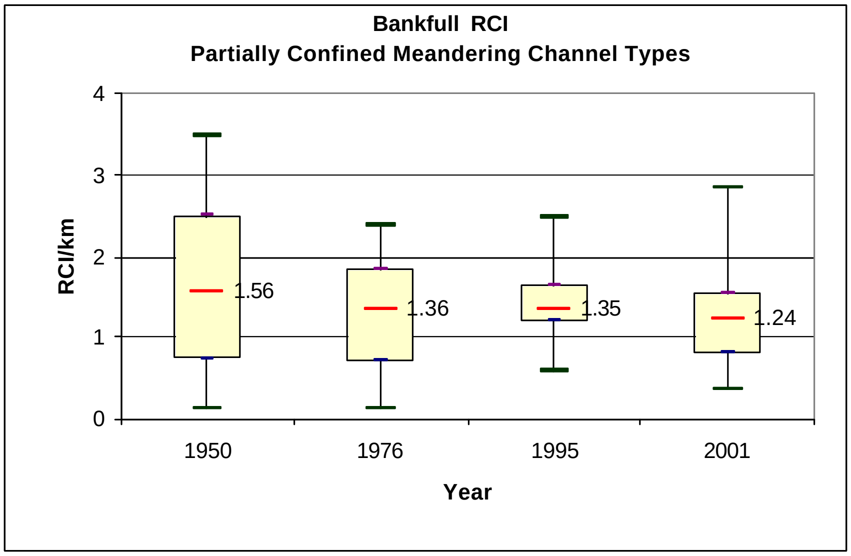


Figure 4-32. RCI through time for Partially Confined Meandering channel type.

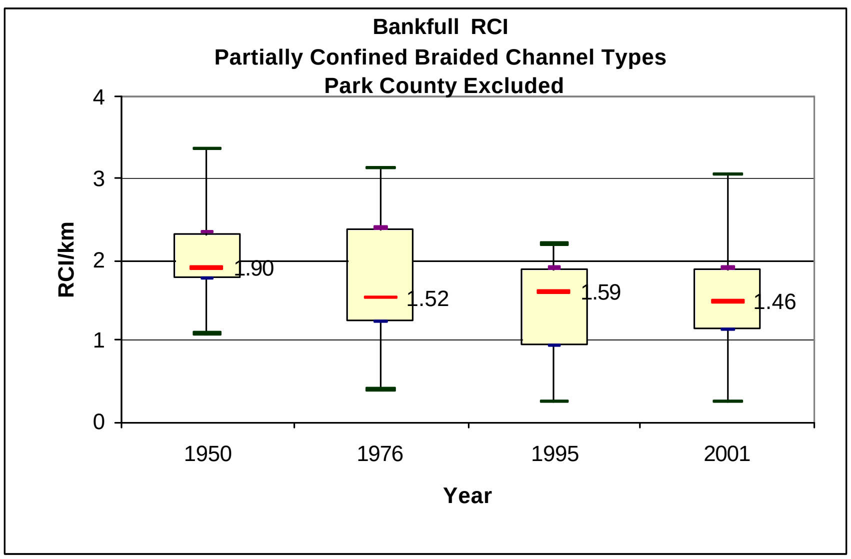


Figure 4-33. RCI Summary for Partially Confined Braided channel type.

The unconfined braided channel type shows a significant collective loss of RCI values through time (Figure 4-34). The changes depict significant reductions in RCI values between 1950 and 1976, with the median RCI dropping from 2.7 to 1.6 during that time frame. Since 1976, values appear to have rebounded slightly.

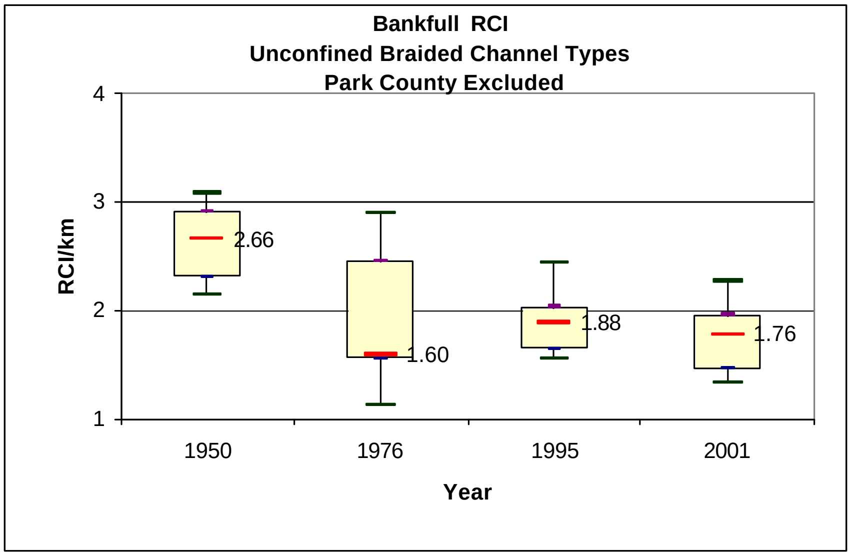


Figure 4-34. RCI through time for Unconfined Braided channel type.

When the river segment from Springdale to the mouth is broken into Regions, spatial trends emerge regarding shifts in complexity index through time for anabranching/braided reach types. The results show reductions in RCI values through time for all Regions with the exception of Region D, which extends from the mouth of the Powder River to the Missouri River Figure 4-35 through Figure 4-38.

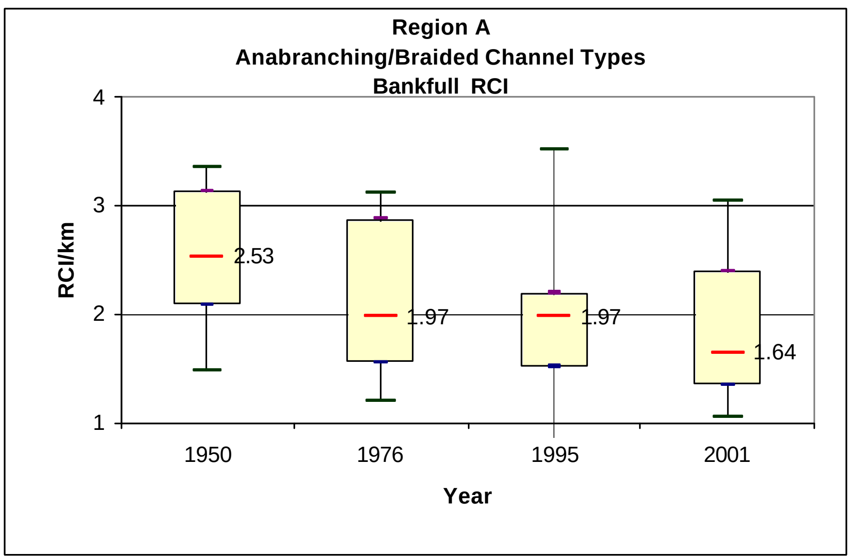


Figure 4-35. RCI through time for anabranching/braided channel types, Region A

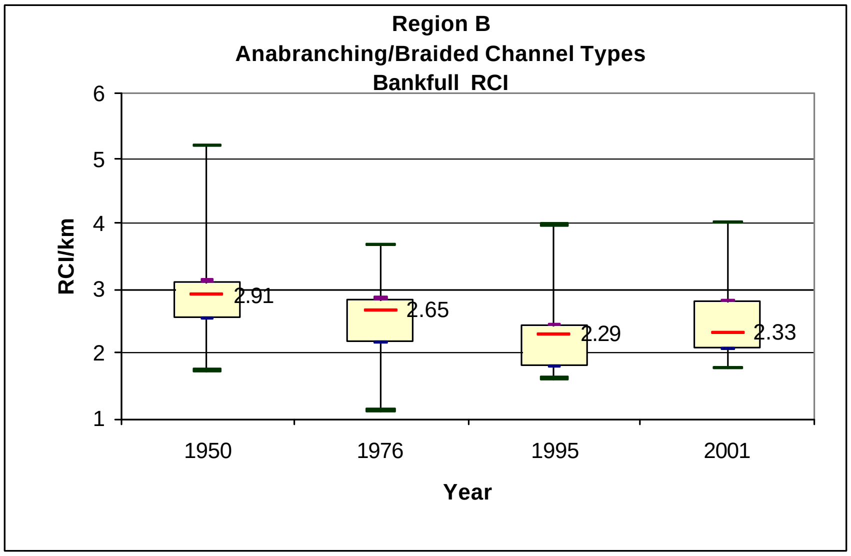


Figure 4-36. RCI through time for anabranching/brai ded channel types, Region B

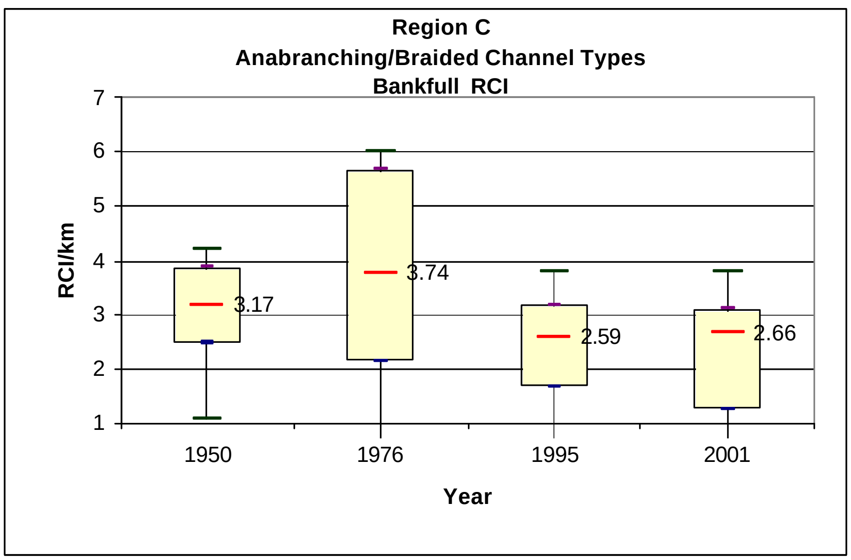


Figure 4-37. RCI through time for anabranching/braided channel types, Region C

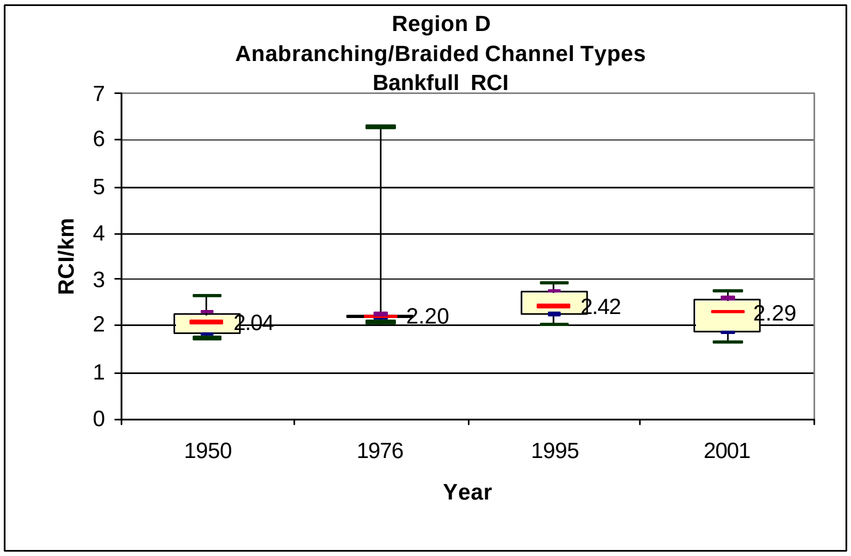


Figure 4-38. RCI through time for anabranching/braided channel types, Region D

4.5 Channel Displacement

Channel displacement ratios, which reflect square meters of channel migration per meter of channel length, are shown in Figure 4-39 for the all reaches. This parameter reflects rates of channel change during the 1950-2001 time frame. Results show a clustering of high displacement ratios between Reach A16 and Reach B1, which is in the vicinity of Laurel. With respect to reach type, channel displacement ratios are highest in anabranching and braided channel types, and partially confined channel types (PCA, PCB) tend to have lower displacement ratios than their unconfined counterparts (UA, UB; Figure 4-40).

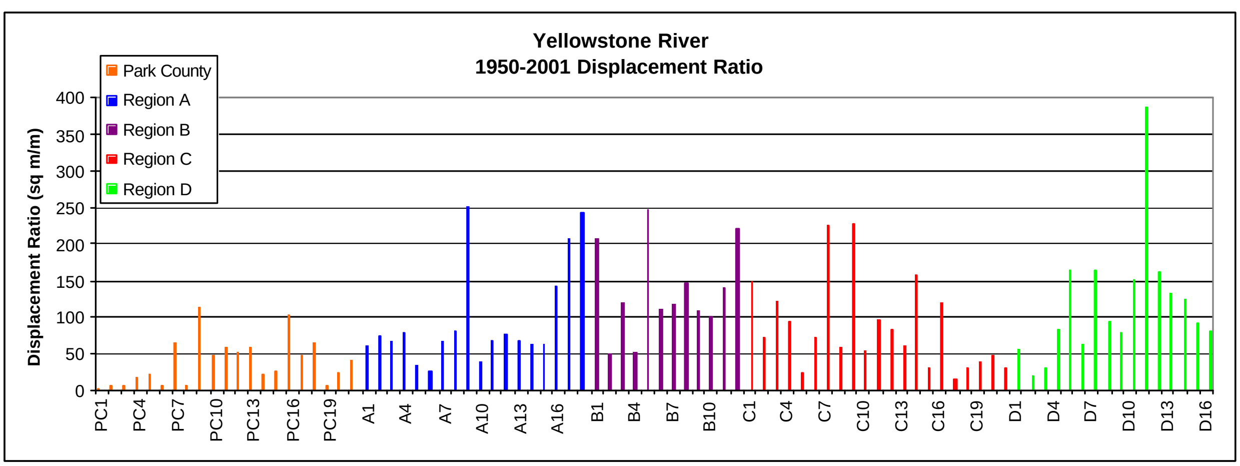


Figure 4-39. 1950-2001 Channel Displacement Ratio Yellowstone River.

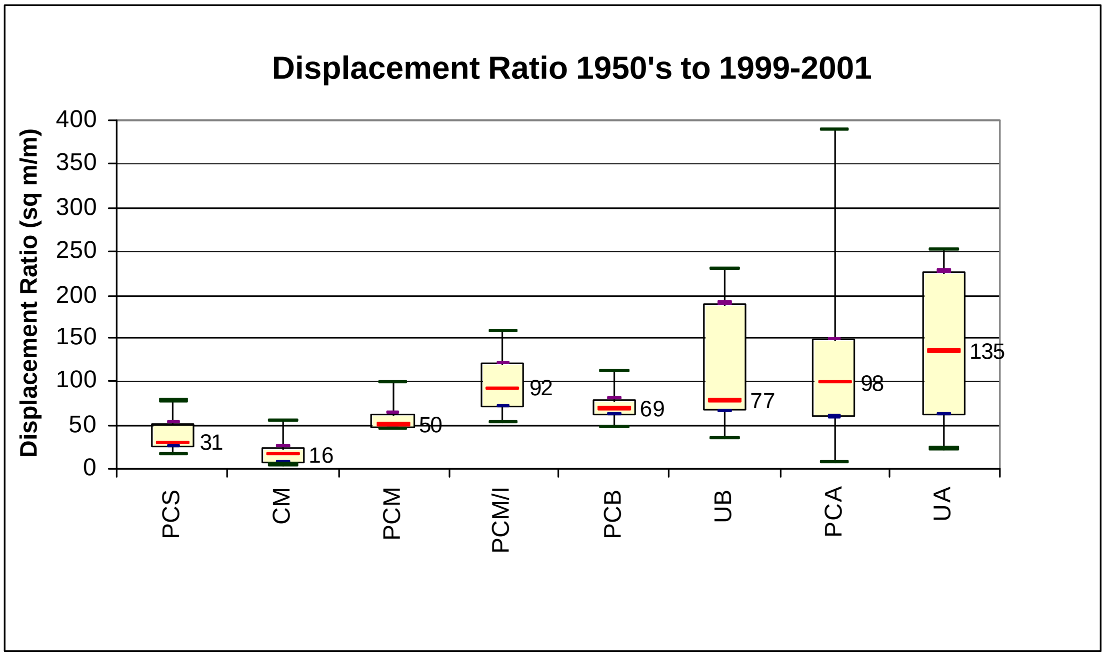


Figure 4-40. Channel Displacement Ratios summarized by channel type.

5 References

Applied Geomorphology, Inc (AGI) and DTM Consulting, Inc. (DTM), 2004. Geomorphic Reconnaissance and GIS Development, Yellowstone River, Montana- Springdale to the Missouri River Confluence: Report prepared for Custer County Conservation District, Miles City, MT, 108p.

Brown, A.G. 2002. Learning from the past: Palaeohydrology and palaeoecology. Freshwater Biology 47 (4): 817-829.

DTM Consulting, Inc. (DTM), and Applied Geomorphology, Inc. (AGI), 2006. Work Order 1: Geomorphic Parameters and GIS Development, Yellowstone River: Report prepared for Yellowstone River Conservation Districts Council, Billings, MT, June 30, 2006, 47p.

Appendix A: Reach Lengths, Classification, and General Location

Table A-1. Summary of reach types and geographic location.

Reach Identification	Length (km)	County	Classification	Comments
PC1	7.6	Park	CS: Confined straight	*Gardiner* to *Little Trail Cr.*
PC2	5.0	Park	CM: Confined meandering	*Devil's Slide* area
PC3	16.6	Park	CS: Confined straight	*Corwin Springs* to *Carbella*; *Yankee Jim Canyon*
PC4	5.8	Park	CM: Confined meandering	*Carbella* to *Hwy 89 Br.*
PC5	6.2	Park	PCA: Partially confined anabranching	*Hwy 89 Br.* to *Big Creek*
PC6	6.9	Park	CM: Confined meandering	*Big Creek* to *Six Mile Cr*
PC7	9.9	Park	PCA: Partially confined anabranching	*Six Mile Cr* to *Grey Owl*
PC8	20.3	Park	CM: Confined meandering	*Grey Owl* to just below *Mallard's Rest*; very sinuous, confined
PC9	3.1	Park	PCA: Partially confined anabranching	To *Pine Creek*
PC10	5.6	Park	PCM: Partially confined meandering	To downstream of *Deep Creek*; *Weeping wall, Jumping Rainbow*, onset of *spring creeks*
PC11	3.8	Park	PCA: Partially confined anabranching	To near *Suce Cr*, Wineglass Mtn to west
PC12	3.2	Park	PCM: Partially confined meandering	To *Carters Bridge*
PC13	2.5	Park	PCB: Partially confined braided	Through canyon upstream of Livingston
PC14	5.6	Park	PCA: Partially confined anabranching	Through Interstate bridge crossing to *Livingston*; multiple threads
PC15	2.9	Park	PCS: Partially confined straight	To *Mayors Landing*; moderate south valley wall control
PC16	6.9	Park	PCA: Partially confined anabranching	To just upstream of *Hwy 89 bridge*
PC17	3.2	Park	PCB: Partially confined braided	Through Hwy 89 bridge crossing to *Shields River*
PC18	8.5	Park	UA: Unconfined anabranching	To below *Mission Creek*; multiple channels
PC19	4.4	Park	CS: Confined straight	To near *Locke Cr*; railroad closely borders to south
PC20	7.2	Park	PCS: Partially confined straight	Moderately confined canyon section; railroad closely borders to south

Reach Identification	***Length (km)***	***County***	***Classification***	***Comments***
PC21	3.7	Park	PCA: Partially confined anabranching	To *Springdale*; multiple threads
A1	5.4	Sweetgrass	PCB: Partially confined braided	*Springdale*: Low primary sinuosity; large open bar area; extensive armoring
A2	11.1	Sweetgrass	UB: Unconfined braided	*Grey Bear* fishing access
A3	8.6	Sweetgrass	PCB: Partially confined braided	Upstream of *Big Timber*; Hell Creek Formation valley wall
A4	5.6	Sweetgrass	UB: Unconfined braided	To *Boulder River* confluence; encroachment at Big Timber; extensive armor
A5	5.2	Sweetgrass	UB: Unconfined braided	Low Qat1 terrace on right bank
A6	4.8	Sweetgrass	PCS: Partially confined straight	Channel closely follows left valley wall
A7	15.9	Sweetgrass	PCB: Partially confined braided	*Greycliff*: Narrow valley bottom with alluvial fan margins
A8	8.2	Sweetgrass	PCB: Partially confined braided	Floodplain isolation behind interstate and R/R
A9	6.2	Sweetgrass Stillwater	UA: Unconfined anabranching	To *Reed Pt*; extensive secondary channels in corridor
A10	6.9	Stillwater	PCS: Partially confined straight	Channel closely follows left valley wall
A11	11.2	Stillwater	PCB: Partially confined braided	High right bank terrace with bedrock toe; *I-90 bridge* crossing
A12	9.8	Stillwater	PCB: Partially confined braided	To *Stillwater* confluence
A13	5.8	Stillwater	PCA: Partially confined anabranching	*Columbus*; extensive armoring, broad islands
A14	12.5	Stillwater	PCA: Partially confined anabranching	Valley bottom crossover
A15	9.5	Stillwater, Carbon	PCB: Partially confined braided	Follows Stillwater/Carbon County line
A16	12.4	Stillwater, Carbon	PCA: Partially confined anabranching	*Park City*: Major shift in land use, and increase in valley bottom width
A17	10.4	Yellowstone Carbon	UA: Unconfined anabranching	To *Laurel;* WAI Reach A
A18	3.8	Yellowstone	UA: Unconfined anabranching	To Clark Fork; land use change to row crops; WAI Reach A
B1	24.6	Yellowstone	UB: Unconfined braided	Extensive armoring *u/s Billings*; WAI Reaches B,C,D
B2	9.8	Yellowstone	PCB: Partially confined braided	*Billings*; WAI Reach E
B3	7.0	Yellowstone	UB: Unconfined braided	Wide corridor d/s *Billings*; WAI Reach F
B4	6.1	Yellowstone	PCS: Partially confined straight	Channel closely follows right valley wall; extensive bank armor
B5	12.0	Yellowstone	UA: Unconfined anabranching	*Huntley:* includes *Spraklin Island*
B6	9.9	Yellowstone	PCB: Partially confined braided	Channel closely follows left valley wall

Reach Identification	***Length (km)***	***County***	***Classification***	***Comments***
B7	13.9	Yellowstone	UB: Unconfined braided	Unconfined reach
B8	14.7	Yellowstone	PCA: Partially confined anabranching	*Pompey's Pillar*
B9	7.5	Yellowstone	UA: Unconfined anabranching	Meander cutoff isolated by railroad
B10	11.6	Yellowstone	PCM: Partially confined meandering	Encroached
B11	13.1	Yellowstone	PCA: Partially confined anabranching	To *Custer Bridge*
B12	7.3	Yellowstone	UA: Unconfined anabranching	To *Bighorn River* confluence
C1	9.5	Treasure	UA: Unconfined anabranching	From *Bighorn* confluence: Includes 1 mile of left bank valley wall control; Extensive bank protection.
C2	8.9	Treasure	PCB: Partially confined braided	To *Myers Br* (RM 285.5); Railroad adjacent to channel on valley wall; low sinuosity
C3	7.6	Treasure	UA: Unconfined anabranching	To *Yellowstone Diversion*: very sinuous; large meanders, extensive bars; historic avulsion
C4	6.1	Treasure	PCB: Partially confined braided	Below *Yellowstone Diversion*
C5	5.1	Treasure	PCS: Partially confined straight	*Hysham*
C6	9.1	Treasure	UA: Unconfined anabranching	*Mission Valley*
C7	14.7	Treasure	UA: Unconfined anabranching	*Mission Valley*
C8	10.4	Treasure Rosebud	PCS: Partially confined straight	Rosebud/Treasure County Line
C9	17.2	Rosebud	UA: Unconfined anabranching	*Hammond Valley*
C10	11.0	Rosebud	PCM: Partially confined meandering	*Forsyth*
C11	18.3	Rosebud	PCM/I: Partially confined meandering/islands	To *Cartersville Bridge*
C12	16.2	Rosebud	PCM/I: Partially confined meandering/islands	*Rosebud*; numerous meander cutoffs
C13	10.8	Rosebud	PCM/I: Partially confined meandering/islands	Valley bottom crossover
C14	19.6	Rosebud Custer	PCM/I: Partially confined meandering/islands	Series of meander bends
C15	6.0	Custer	PCS: Partially confined straight	Very low riparian vegetation
C16	11.6	Custer	PCM/I: Partially confined meandering/islands	to *Miles City*
C17	7.2	Custer	PCS: Partially confined straight	*Miles City; Tongue River*
C18	5.2	Custer	PCS: Partially confined straight	Channel follows left valley wall
C19	17.9	Custer	CS: Confined straight	Confined
C20	12.2	Custer Prairie	CS: Confined straight	Confined
C21	15.2	Custer Prairie	CM: Confined meandering	To *Powder River;* confined

Reach Identification	*Length (km)*	*County*	*Classification*	*Comments*
D1	19.5	Prairie	CM: Confined meandering	To *Terry Bridge*; confined
D2	17.0	Prairie	CM: Confined meandering	To *Fallon, I-90 Bridge*; confined
D3	13.4	Prairie Dawson	PCS: Partially confined straight	Hugs right bank wall; into Dawson County
D4	17.7	Dawson	PCM/I: Partially confined meandering/islands	
D5	20.3	Dawson	PCA: Partially confined anabranching	Long secondary channels; to *Glendive*
D6	8.9	Dawson	PCM/I: Partially confined meandering/islands	*Glendive*
D7	12.3	Dawson	PCA: Partially confined anabranching	
D8	16.4	Dawson	PCA: Partially confined anabranching	To *Intake*
D9	5.6	Dawson	PCM/I: Partially confined meandering/islands	Downstream of *Intake*
D10	18.3	Dawson Wibaux Richland	PCA: Partially confined anabranching	Vegetated islands
D11	10.3	Richland	PCA: Partially confined anabranching	*Elk Island:* Very wide riparian; marked change in channel course since 1981 geologic map base
D12	21.9	Richland	PCA: Partially confined anabranching	Secondary channel on valley wall; Sinuous; long abandoned secondary channel
D13	13.8	Richland	PCM/I: Partially confined meandering/islands	
D14	23.1	Richland, McKenzie	PCM/I: Partially confined meandering/islands	Into *McKenzie County, North Dakota*: High sinuosity
D15	9.6	McKenzie	PCM/I: Partially confined meandering/islands	
D16	11.9	McKenzie	US/I: Unconfined straight/islands	*To mouth*: low sinuosity; alternate bars; vegetated islands

Appendix B: Tabulated Summary of Geomorphic Parameters

Table B-1. Geomorphic parameter values calculated for each reach, 1948-1950 and 1976 data.

			1948-1950									1976							
					Low Flow			Bankfull					Low Flow			Bankfull		
Reach	Class	2001 Valley Distance (km)	Length (km)	Sinuosity	Braiding Parameter	Node Count	RCI/km	Bankfull Braiding Parameter	Node Count	RCI/km	Length (km)	Sinuosity	Braiding Parameter	Node Count	RCI/km	Bankfull Braiding Parameter	Node Count	RCI/km
PC1	CS	7.3	7.1	0.98	1.1	3	0.5	1.0	1	0.3	-----	-----	----	-----	----	--	----	-----
PC2	CM	4.4	5.0	1.14	1.1	2	0.8	1.0		0.3	-----	-----	----	-----	----	--	----	-----
PC3	CS	16.1	16.6	1.03	1.0	4	0.3	1.0		0.1	-----	-----	----	-----	----	--	----	-----
PC4	CM	5.3	5.8	1.10	1.2	4	1.0	1.0		0.2	-----	-----	----	-----	----	--	----	-----
PC5	PCA	5.7	6.2	1.09	1.8	22	4.4	1.4	6	1.3	-----	-----	----	-----	----	--	----	-----
PC6	CM	6.6	6.9	1.05	1.4	12	2.1	1.2	4	0.8	-----	-----	----	-----	----	--	----	-----
PC7	PCA	9.1	10.4	1.14	2.3	39	5.0	1.8	12	1.6	-----	-----	----	-----	----	--	----	-----
PC8	CM	15.4	20.2	1.31	1.1	6	0.6	1.0	1	0.2	-----	-----	----	-----	----	--	----	-----
PC9	PCA	2.8	3.4	1.24	2.1	13	6.3	1.9	7	3.6	-----	-----	----	-----	----	--	----	-----
PC10	PCM	3.7	5.1	1.35	1.3	8	3.3	1.3	6	2.5	-----	-----	----	-----	----	--	----	-----
PC11	PCA	3.3	3.4	1.05	2.4	20	6.7	1.6	1	0.6	-----	-----	----	-----	----	--	----	-----
PC12	PCM	2.9	3.3	1.12	2.1	17	6.8	1.8	8	3.4	-----	-----	----	-----	----	--	----	-----
PC13	PCB	2.2	2.3	1.04	2.0	7	3.8	1.9	6	3.3	-----	-----	----	-----	----	--	----	-----
PC14	PCA	4.8	5.6	1.17	2.7	23	5.8	2.4	13	3.4	-----	-----	----	-----	----	--	----	-----
PC15	PCS	2.8	3.0	1.06	1.4	7	3.0	1.1	1	0.8	-----	-----	----	-----	----	--	----	-----
PC16	PCA	6.3	7.2	1.14	2.4	38	7.1	2.1	23	4.3	-----	-----	----	-----	----	--	----	-----
PC17	PCB	2.8	3.1	1.10	1.3	3	1.6	1.0		0.4	-----	-----	----	-----	----	--	----	-----
PC18	UA	7.7	8.3	1.08	2.8	40	5.7	2.3	16	2.4	-----	-----	----	-----	----	--	----	-----
PC19	CS	4.3	4.4	1.03	1.1	2	0.7	1.0		0.2	-----	-----	----	-----	----	--	----	-----
PC20	PCS	6.6	7.2	1.10	1.7	16	2.9	1.5	8	1.5	-----	-----	----	-----	----	--	----	-----

			1948-1950								1976							
					Low Flow			Bankfull					Low Flow			Bankfull		
Reach	**Class**	**2001 Valley Distance (km)**	***Length (km)***	***Sinuosity***	***Braiding Parameter***	***Node Count***	***RCI/km***	***Bankfull Braiding Parameter***	***Node Count***	***RCI/km***	***Length (km)***	***Sinuosity***	***Braiding Parameter***	***Node Count***	***RCI/km***	***Bankfull Braiding Parameter***	***Node Count***	***RCI/km***
PC21	PCA	3.2	3.6	1.12	2.8	17	6.4	2.2	7	2.8	-----	-----	----	-----	----	--	----	-----
A1	PCB	5.2	5.8	1.11	1.6	13	3.0	1.3	6	1.5	5.7	1.10	1.6	9	2.1	1.5	5	1.3
A2	UB	10.4	11.7	1.12	2.2	39	4.3	1.9	20	2.3	11.2	1.08	2.3	43	4.6	1.7	14	1.6
A3	PCB	7.5	8.5	1.14	2.4	30	4.7	2.3	21	3.4	8.6	1.15	2.6	35	5.6	2.2	19	3.1
A4	UB	4.7	5.3	1.12	2.0	15	3.8	1.9	12	3.1	5.2	1.10	2.2	15	3.7	1.8	6	1.6
A5	UB	4.8	5.4	1.14	1.6	9	2.4	1.5	8	2.1	5.1	1.07	2.1	17	4.0	1.6	6	1.6
A6	PCS	4.5	4.7	1.03	1.7	12	3.0	1.1	3	0.9	4.7	1.03	1.7	11	2.7	1.0		0.2
A7	PCB	14.6	15.7	1.07	1.9	43	3.2	1.6	24	1.8	15.8	1.08	2.1	50	3.8	1.8	29	2.2
A8	PCB	7.5	8.3	1.10	2.4	27	4.1	1.9	15	2.4	8.4	1.11	3.2	49	7.4	2.4	20	3.1
A9	UA	5.4	7.1	1.32	2.4	14	3.7	2.3	12	3.2	6.2	1.15	3.6	33	7.2	2.8	13	3.0
A10	PCS	6.5	6.9	1.05	2.1	23	3.9	1.9	18	3.1	6.8	1.04	2.4	28	4.6	1.8	13	2.2
A11	PCB	10.0	11.2	1.12	2.2	33	3.8	1.8	20	2.4	11.1	1.11	2.2	35	4.0	1.7	12	1.4
A12	PCB	9.0	9.6	1.07	2.3	33	4.0	1.8	15	1.9	9.5	1.05	2.2	33	4.0	1.8	12	1.5
A13	PCA	5.1	5.9	1.15	2.2	19	4.5	1.9	13	3.1	5.7	1.12	2.5	24	5.5	2.0	8	2.0
A14	PCA	11.6	12.8	1.11	2.6	42	4.1	2.3	30	3.0	12.2	1.05	2.7	43	4.0	2.2	28	2.6
A15	PCB	8.3	9.1	1.09	2.2	18	2.5	2.1	14	2.0	9.3	1.11	2.6	29	4.0	1.7	8	1.2
A16	PCA	10.8	12.2	1.13	3.0	52	5.6	2.5	29	3.1	12.0	1.12	3.6	71	7.5	2.6	28	3.0
A17	UA	9.2	10.6	1.15	2.5	36	4.6	2.1	24	3.1	10.4	1.13	2.9	43	5.4	2.1	15	2.0
A18	UA	3.3	4.2	1.27	2.1	7	3.1	1.9	6	2.7	3.9	1.17	2.9	12	4.6	2.4	7	2.8
B1	UB	21.2	24.3	1.14	3.1	98	5.3	2.5	53	2.9	23.6	1.11	3.4	139	7.4	2.4	54	2.9
B2	PCB	8.9	9.5	1.06	2.3	27	3.3	1.9	14	1.8	9.6	1.08	2.6	40	4.9	2.0	16	2.0
B3	UB	6.1	6.9	1.13	3.3	24	4.6	2.8	12	2.4	7.1	1.16	3.9	32	6.2	2.2	5	1.1
B4	PCS	6.0	6.1	1.02	2.1	14	2.6	1.5	4	0.9	6.1	1.03	2.0	11	2.1	1.4	2	0.5
B5	UA	10.1	11.9	1.18	3.1	49	5.8	2.5	26	3.1	12.1	1.19	3.6	71	8.5	2.4	21	2.6

Reach	Class	2001 Valley Distance (km)	1948-1950								1976							
					Low Flow			Bankfull					Low Flow			Bankfull		
			Length (km)	Sinuosity	Braiding Parameter	Node Count	RCI/km	Bankfull Braiding Parameter	Node Count	RCI/km	Length (km)	Sinuosity	Braiding Parameter	Node Count	RCI/km	Bankfull Braiding Parameter	Node Count	RCI/km
B6	PCB	9.1	9.6	1.06	2.5	34	4.1	1.9	14	1.7	10.1	1.11	2.8	45	5.6	2.1	20	2.6
B7	UB	12.2	13.5	1.11	3.3	61	5.6	2.6	31	2.9	13.1	1.07	3.4	68	6.1	2.6	30	2.7
B8	PCA	12.6	15.7	1.24	2.9	56	5.6	2.5	37	3.7	14.3	1.13	3.5	72	6.5	2.5	22	2.1
B9	UA	6.2	7.0	1.12	3.6	35	6.5	2.8	16	3.1	6.8	1.09	4.2	46	8.2	3.0	20	3.7
B10	PCM	9.6	11.2	1.16	2.9	42	5.2	2.5	28	3.5	12.1	1.25	3.0	56	7.4	1.9	16	2.2
B11	PCA	11.9	13.4	1.13	3.2	60	5.8	2.5	29	2.9	13.6	1.15	3.2	65	6.4	2.4	27	2.7
B12	UA	6.0	7.3	1.21	3.3	33	6.8	3.0	25	5.2	7.2	1.19	3.8	42	8.5	2.8	17	3.5
C1	UA	7.6	9.6	1.27	3.1	38	6.5	2.4	18	3.2	9.4	1.24	3.3	40	6.7	2.6	22	3.7
C2	PCB	8.6	9.0	1.05	2.5	17	2.2	2.0	8	1.1	9.1	1.06	2.7	23	2.9	2.1	8	1.1
C3	UA	5.1	8.3	1.64	2.9	24	8.1	2.4	12	4.2	8.9	1.76	3.0	35	12.5	2.3	16	5.9
C4	PCB	3.8	5.6	1.48	2.2	10	4.2	1.8	5	2.3	5.9	1.54	2.2	11	4.8	1.3		0.4
C5	PCS	4.9	5.1	1.05	2.4	11	2.6	2.0	4	1.1	5.0	1.03	2.3	13	3.0	1.9	5	1.3
C6	UA	5.6	8.0	1.45	2.9	22	6.0	2.6	14	3.9	8.8	1.59	3.0	29	8.6	2.7	20	6.0
C7	UA	10.0	13.6	1.36	3.8	54	7.5	3.1	27	3.8	14.3	1.43	4.3	76	11.0	3.3	37	5.5
C8	PCS	9.7	10.6	1.10	2.5	28	3.3	2.0	12	1.5	10.4	1.07	2.5	25	2.9	1.7	8	1.0
C9	UA	12.4	17.7	1.43	3.1	49	5.8	2.5	22	2.6	18.0	1.45	2.9	47	5.6	2.4	26	3.2
C10	PCM	9.8	11.5	1.18	1.5	11	1.4	1.2	4	0.6	10.8	1.11	1.9	19	2.3	1.3	4	0.6
C11	PCM/I	14.2	18.3	1.29	2.6	45	4.2	2.2	26	2.4	18.5	1.30	2.4	48	4.5	1.9	14	1.4
C12	PCM/I	12.9	15.8	1.23	2.0	28	2.8	1.8	17	1.7	16.0	1.25	2.2	29	2.9	1.7	13	1.4
C13	PCM/I	9.6	10.8	1.13	2.2	21	2.6	1.4	4	0.6	10.9	1.13	2.2	23	2.8	1.7	11	1.4
C14	PCM/I	15.7	20.4	1.30	2.0	37	3.1	1.7	18	1.6	18.9	1.20	2.6	55	4.3	1.9	26	2.1
C15	PCS	5.8	5.9	1.03	1.5	4	0.9	1.3	2	0.5	5.9	1.03	1.6	5	1.1	1.1	1	0.4
C16	PCM/I	10.6	11.8	1.11	2.7	33	3.5	2.3	24	2.6	11.7	1.10	2.7	38	4.0	2.2	22	2.4
C17	PCS	6.5	7.1	1.09	1.8	6	1.2	1.7	4	0.8	7.1	1.09	2.2	15	2.7	1.8	8	1.5

Reach	Class	2001 Valley Distance (km)	1948-1950								1976							
					Low Flow			Bankfull					Low Flow			Bankfull		
			Length (km)	Sinuosity	Braiding Parameter	Node Count	RCI/km	Bankfull Braiding Parameter	Node Count	RCI/km	Length (km)	Sinuosity	Braiding Parameter	Node Count	RCI/km	Bankfull Braiding Parameter	Node Count	RCI/km
C18	PCS	5.0	5.2	1.03	1.6	8	1.8	1.0		0.2	5.2	1.04	1.7	5	1.2	1.0		0.2
C19	CS	17.3	17.8	1.03	1.5	15	1.0	1.1	1	0.1	17.8	1.03	1.4	15	1.0	1.1	4	0.3
C20	CS	11.8	12.4	1.05	1.6	12	1.2	1.1	1	0.2	12.2	1.03	1.7	17	1.6	1.2	2	0.3
C21	CM	13.8	15.3	1.11	1.8	19	1.6	1.1	2	0.2	15.3	1.11	1.9	27	2.3	1.2	6	0.6
D1	CM	14.6	20.1	1.37	1.7	25	2.4	1.3	5	0.6	19.4	1.33	1.6	21	2.0	1.3	7	0.7
D2	CM	15.9	17.2	1.08	1.0	2	0.2	1.0		0.1	17.0	1.07	1.0	2	0.2	1.0	2	0.2
D3	PCS	12.7	13.8	1.09	1.5	9	0.9	1.3	3	0.3	13.3	1.05	1.5	9	0.8	1.4	5	0.5
D4	PCM/I	16.5	18.2	1.11	2.1	30	2.1	1.6	12	0.9	17.7	1.08	2.4	34	2.3	1.6	10	0.7
D5	PCA	17.2	20.1	1.16	3.2	61	4.2	2.5	25	1.8	20.4	1.18	3.4	78	5.4	2.5	30	2.1
D6	PCM/I	8.4	9.1	1.09	2.7	19	2.6	2.2	11	1.6	9.0	1.08	2.2	19	2.6	1.5	5	0.8
D7	PCA	11.0	13.4	1.21	3.0	43	4.8	2.4	20	2.3	12.1	1.10	3.0	41	4.2	2.4	21	2.2
D8	PCA	11.2	16.8	1.50	2.7	34	4.7	2.0	12	1.7	16.7	1.49	2.4	25	3.5	2.2	16	2.3
D9	PCM/I	4.9	5.3	1.08	2.9	19	4.4	1.8	4	1.1	5.4	1.11	2.0	11	2.7	1.6	7	1.8
D10	PCA	15.0	18.1	1.21	3.3	56	4.6	2.6	26	2.2	18.4	1.23	3.2	65	5.4	2.5	26	2.2
D11	PCA	8.7	11.0	1.27	4.2	48	7.2	3.0	17	2.6	12.4	1.43	3.7	57	9.6	3.2	37	6.3
D12	PCA	17.4	23.0	1.32	3.0	47	3.7	2.5	24	1.9	22.2	1.28	2.8	51	3.8	2.5	27	2.1
D13	PCM/I	12.3	13.4	1.09	2.7	32	2.9	2.1	13	1.2	13.3	1.09	2.6	31	2.8	2.1	14	1.3
D14	PCM/I	20.3	23.2	1.14	2.3	47	2.7	1.0	1	0.1	22.9	1.13	2.3	50	2.8	1.4	8	0.5
D15	PCM/I	9.2	9.6	1.04	2.6	21	2.5	1.5	1	0.2	-----	-----	----	-----	----	--	-----	0.1
D16	US/I	11.3	12.1	1.06	2.9	38	3.7	1.2	3	0.4	-----	-----	----	-----	----	--	-----	0.1

Table B-2. Geomorphic parameter values calculated for each reach, 1948-1950 and 1976 data.

		1995								*2001*							
				Low Flow			*Bankfull*					*Low Flow*			*Bankfull*		
Reach	*Class*	*Length (km)*	*Sinuosity*	*Braiding Parameter*	*Node Count*	*RCI/km*	*Bankfull Braiding Parameter*	*Node Count*	*RCI/km*	*Length (km)*	*Sinuosity*	*Braiding Parameter*	*Node Count*	*RCI/km*	*Bankfull Braiding Parameter*	*Node Count*	*RCI/km*
PC1	CS	-----	-----	----	-----	----	-----	-----	-----	7.6	1.04	1.0	3	0.6	1.0	1	0.3
PC2	CM	-----	-----	----	-----	----	-----	-----	-----	5.0	1.14	1.1	2	0.8	1.0		0.3
PC3	CS	-----	-----	----	-----	----	-----	-----	-----	16.6	1.03	1.1	8	0.6	1.0		0.1
PC4	CM	-----	-----	----	-----	----	-----	-----	-----	5.8	1.10	1.1	5	1.3	1.1	3	0.8
PC5	PCA	-----	-----	----	-----	----	-----	-----	-----	6.2	1.07	2.1	29	5.6	1.6	10	2.1
PC6	CM	-----	-----	----	-----	----	-----	-----	-----	6.9	1.05	1.3	12	2.1	1.0	1	0.3
PC7	PCA	-----	-----	----	-----	----	-----	-----	-----	9.9	1.09	2.5	44	5.4	1.8	12	1.6
PC8	CM	-----	-----	----	-----	----	-----	-----	-----	20.3	1.32	1.0	2	0.3	1.0	2	0.3
PC9	PCA	-----	-----	----	-----	----	-----	-----	-----	3.1	1.11	2.9	22	9.2	2.5	8	3.6
PC10	PCM	-----	-----	----	-----	----	-----	-----	-----	5.6	1.49	1.0	2	1.2	1.0		0.4
PC11	PCA	-----	-----	----	-----	----	-----	-----	-----	3.8	1.16	1.8	11	4.2	1.4	2	1.1
PC12	PCM	-----	-----	----	-----	----	-----	-----	-----	3.2	1.07	2.1	9	3.6	1.8	3	1.4
PC13	PCB	-----	-----	----	-----	----	-----	-----	-----	2.5	1.14	1.5	5	3.1	1.0		0.5
PC14	PCA	-----	-----	----	-----	----	-----	-----	-----	5.6	1.16	2.4	29	7.2	1.9	5	1.4
PC15	PCS	-----	-----	----	-----	----	-----	-----	-----	2.9	1.02	1.3	7	2.9	1.0		0.4
PC16	PCA	-----	-----	----	-----	----	-----	-----	-----	6.9	1.10	2.4	36	6.4	1.8	12	2.3
PC17	PCB	-----	-----	----	-----	----	-----	-----	-----	3.2	1.15	1.3	4	2.1	1.0		0.4
PC18	UA	-----	-----	----	-----	----	-----	-----	-----	8.5	1.10	2.1	30	4.5	1.7	7	1.1
PC19	CS	-----	-----	----	-----	----	-----	-----	-----	4.4	1.03	1.1	2	0.7	1.0		0.2
PC20	PCS	-----	-----	----	-----	----	-----	-----	-----	7.2	1.10	2.1	24	4.2	1.3	3	0.7
PC21	PCA	-----	-----	----	-----	----	-----	-----	-----	3.7	1.15	2.4	15	5.8	1.9	4	1.8

Reach	Class	1995								2001							
				Low Flow			Bankfull					Low Flow			Bankfull		
		Length (km)	Sinuosity	Braiding Parameter	Node Count	RCI/km	Bankfull Braiding Parameter	Node Count	RCI/km	Length (km)	Sinuosity	Braiding Parameter	Node Count	RCI/km	Bankfull Braiding Parameter	Node Count	RCI/km
A1	PCB	5.3	1.02	2.5	21	4.3	1.9	9	2.0	5.4	1.04	1.9	14	3.0	1.7	8	1.8
A2	UB	11.2	1.07	2.6	57	6.0	1.7	14	1.5	11.1	1.07	2.2	41	4.3	1.6	12	1.3
A3	PCB	8.6	1.15	2.5	39	6.2	1.8	9	1.5	8.6	1.15	2.7	41	6.5	1.9	9	1.5
A4	UB	5.6	1.18	1.7	14	3.7	1.5	7	2.0	5.6	1.18	1.6	12	3.2	1.4	6	1.7
A5	UB	5.2	1.08	2.1	21	5.0	1.6	8	2.0	5.2	1.08	2.0	17	4.1	1.5	5	1.4
A6	PCS	4.7	1.04	1.8	13	3.2	1.1	2	0.7	4.8	1.05	1.7	12	3.0	1.1	1	0.5
A7	PCB	16.0	1.09	1.8	43	3.3	1.5	13	1.0	15.9	1.09	1.8	41	3.1	1.4	13	1.0
A8	PCB	8.2	1.09	2.5	27	4.1	2.1	14	2.2	8.2	1.09	2.6	31	4.6	2.3	20	3.0
A9	UA	6.4	1.18	2.7	25	5.7	2.4	15	3.5	6.2	1.16	3.0	33	7.3	2.3	11	2.6
A10	PCS	6.9	1.05	1.6	14	2.4	1.3	6	1.1	6.9	1.05	1.9	21	3.5	1.5	10	1.8
A11	PCB	11.3	1.13	2.2	38	4.4	1.6	13	1.6	11.2	1.12	2.3	40	4.6	1.6	12	1.5
A12	PCB	9.7	1.08	2.1	27	3.4	1.6	6	0.8	9.8	1.09	2.2	25	3.1	1.8	11	1.4
A13	PCA	5.8	1.12	2.5	22	5.0	2.1	13	3.1	5.8	1.13	2.5	22	5.1	2.0	12	2.9
A14	PCA	12.6	1.09	2.2	37	3.6	1.9	23	2.3	12.5	1.08	2.4	51	4.9	1.9	24	2.3
A15	PCB	9.3	1.12	2.2	24	3.4	1.9	14	2.0	9.5	1.14	2.1	23	3.3	1.7	8	1.2
A16	PCA	12.5	1.16	3.0	62	6.8	2.3	22	2.5	12.4	1.15	2.9	53	5.7	2.3	24	2.7
A17	UA	10.5	1.14	2.1	23	3.0	1.8	10	1.4	10.4	1.13	2.8	44	5.5	1.9	9	1.2
A18	UA	3.8	1.16	2.8	16	6.0	2.1	3	1.4	3.8	1.15	3.3	22	8.0	2.2	5	2.1
B1	UB	25.0	1.18	2.5	83	4.7	2.0	31	1.8	24.6	1.16	2.4	67	3.7	2.0	36	2.0
B2	PCB	9.9	1.11	2.0	28	3.6	1.8	12	1.6	9.8	1.10	2.2	31	3.9	1.8	15	2.0
B3	UB	7.0	1.15	2.5	14	2.8	2.5	12	2.4	7.0	1.15	2.9	20	4.0	2.5	11	2.3
B4	PCS	6.1	1.03	1.6	7	1.4	1.4	4	0.9	6.1	1.01	1.8	9	1.7	1.6	5	1.0
B5	UA	12.1	1.20	3.0	53	6.4	2.4	19	2.4	12.0	1.18	3.5	70	8.3	2.7	24	2.9
B6	PCB	10.0	1.10	2.4	33	4.1	2.0	14	1.8	9.9	1.09	2.5	28	3.5	2.4	19	2.4
B7	UB	14.0	1.15	2.2	27	2.6	1.9	16	1.6	13.9	1.14	2.8	45	4.3	2.1	18	1.8

Reach	Class	1995								2001							
				Low Flow			Bankfull					Low Flow			Bankfull		
		Length (km)	Sinuosity	Braiding Parameter	Node Count	RCI/km	Bankfull Braiding Parameter	Node Count	RCI/km	Length (km)	Sinuosity	Braiding Parameter	Node Count	RCI/km	Bankfull Braiding Parameter	Node Count	RCI/km
B8	PCA	14.4	1.14	2.9	42	3.9	2.7	26	2.4	14.7	1.16	3.0	46	4.3	2.5	23	2.2
B9	UA	7.5	1.20	3.1	37	7.3	2.4	18	3.6	7.5	1.20	3.4	38	7.5	2.6	19	3.8
B10	PCM	11.5	1.19	2.7	42	5.3	2.1	19	2.5	11.6	1.21	2.6	42	5.4	1.7	12	1.6
B11	PCA	12.9	1.09	3.2	66	6.2	2.5	23	2.2	13.1	1.10	3.1	52	4.9	2.6	26	2.5
B12	UA	7.2	1.20	3.6	41	8.3	2.8	19	4.0	7.3	1.21	3.5	32	6.6	2.9	19	4.0
C1	UA	9.5	1.26	2.9	32	5.5	2.4	14	2.5	9.5	1.26	3.0	32	5.5	2.5	17	3.0
C2	PCB	8.9	1.03	2.5	27	3.3	1.3	1	0.2	8.9	1.03	2.6	28	3.4	1.3	1	0.2
C3	UA	7.5	1.49	2.8	15	4.7	2.7	12	3.8	7.6	1.49	2.9	18	5.6	2.6	10	3.2
C4	PCB	5.9	1.54	1.9	7	3.2	1.3	1	0.8	6.1	1.59	1.7	5	2.5	1.3		0.4
C5	PCS	5.1	1.04	1.9	9	2.1	1.8	6	1.5	5.1	1.04	2.0	10	2.4	1.8	5	1.3
C6	UA	9.1	1.64	2.1	11	3.5	2.0	9	3.0	9.1	1.64	2.0	11	3.5	1.9	8	2.7
C7	UA	15.3	1.53	3.0	40	6.3	2.6	21	3.4	14.7	1.47	3.2	51	7.6	2.9	25	3.8
C8	PCS	10.5	1.09	1.9	14	1.7	1.7	10	1.2	10.4	1.08	2.1	25	2.9	1.6	7	0.9
C9	UA	19.1	1.53	2.1	24	3.1	2.0	20	2.6	17.2	1.39	2.3	28	3.2	2.1	18	2.1
C10	PCM	11.0	1.12	1.7	12	1.5	1.4	6	0.8	11.0	1.12	1.8	16	2.0	1.4	7	0.9
C11	PCM/I	18.8	1.32	1.8	25	2.4	1.6	12	1.2	18.3	1.29	2.1	39	3.6	1.7	15	1.4
C12	PCM/I	16.1	1.25	1.7	21	2.1	1.6	14	1.5	16.2	1.26	1.9	28	2.8	1.8	19	2.0
C13	PCM/I	10.8	1.13	1.8	13	1.6	1.7	10	1.3	10.8	1.13	1.9	18	2.2	1.6	10	1.3
C14	PCM/I	19.6	1.25	2.0	26	2.1	1.8	16	1.4	19.6	1.25	1.9	37	3.0	1.4	8	0.7
C15	PCS	6.0	1.04	1.7	5	1.1	1.2	1	0.4	6.0	1.04	1.7	7	1.4	1.1	1	0.4
C16	PCM/I	11.6	1.09	2.5	29	3.1	2.1	15	1.6	11.6	1.09	2.6	35	3.7	2.1	16	1.7
C17	PCS	7.1	1.10	1.8	7	1.4	1.7	6	1.2	7.2	1.10	2.1	12	2.2	1.7	5	1.0
C18	PCS	5.2	1.04	1.3	3	0.8	1.3	2	0.6	5.2	1.04	1.1	2	0.6	1.0		0.2
C19	CS	17.9	1.03	1.4	13	0.8	1.1	4	0.3	17.9	1.03	1.4	13	0.8	1.2	6	0.4
C20	CS	12.2	1.03	1.7	16	1.5	1.1	2	0.3	12.2	1.03	1.8	22	2.0	1.1	2	0.3

Reach	Class	1995								2001							
				Low Flow			Bankfull					Low Flow			Bankfull		
		Length (km)	Sinuosity	Braiding Parameter	Node Count	RCI/km	Bankfull Braiding Parameter	Node Count	RCI/km	Length (km)	Sinuosity	Braiding Parameter	Node Count	RCI/km	Bankfull Braiding Parameter	Node Count	RCI/km
C21	CM	15.3	1.11	1.8	24	2.0	1.2	8	0.7	15.2	1.11	1.9	26	2.2	1.1	4	0.4
D1	CM	19.5	1.33	1.3	12	1.2	1.2	6	0.6	19.5	1.33	1.6	25	2.4	1.2	6	0.6
D2	CM	17.0	1.07	1.1	4	0.3	1.0		0.1	17.0	1.07	1.1	4	0.3	1.0		0.1
D3	PCS	13.3	1.05	1.7	11	1.0	1.4	5	0.5	13.4	1.06	1.6	11	1.0	1.4	5	0.5
D4	PCM/I	17.7	1.08	2.3	37	2.5	1.5	8	0.6	17.7	1.07	2.3	43	2.9	1.4	7	0.5
D5	PCA	18.2	1.06	3.2	45	2.8	2.9	35	2.2	20.3	1.18	3.3	76	5.3	2.5	25	1.8
D6	PCM/I	9.0	1.08	1.9	13	1.8	1.4	4	0.6	8.9	1.07	2.2	20	2.7	1.5	8	1.2
D7	PCA	12.2	1.11	3.3	43	4.4	2.5	19	2.0	12.3	1.11	3.3	49	5.1	2.4	15	1.6
D8	PCA	16.4	1.46	2.4	29	3.9	2.3	19	2.6	16.3	1.46	2.6	33	4.4	2.3	18	2.5
D9	PCM/I	5.6	1.16	2.1	10	2.6	2.0	9	2.4	5.6	1.16	2.5	15	3.8	2.0	11	2.9
D10	PCA	18.6	1.24	2.6	37	3.2	2.4	26	2.2	18.3	1.22	3.0	52	4.3	2.6	31	2.6
D11	PCA	10.4	1.21	3.7	31	4.5	3.3	20	2.9	10.3	1.19	3.5	48	6.7	2.7	19	2.7
D12	PCA	21.6	1.24	3.1	62	4.5	2.7	38	2.8	21.9	1.26	2.9	54	4.0	2.5	28	2.1
D13	PCM/I	13.5	1.10	2.3	24	2.2	2.1	18	1.7	13.8	1.12	2.3	27	2.6	1.9	11	1.1
D14	PCM/I	23.1	1.14	1.8	27	1.6	1.7	23	1.4	23.1	1.14	2.1	39	2.3	1.4	7	0.5
D15	PCM/I	9.5	1.02	2.1	13	1.5	2.1	10	1.2	9.6	1.04	2.3	18	2.1	2.0	10	1.2
D16	US/I	12.0	1.06	2.4	20	2.0	2.3	18	1.8	11.9	1.05	2.6	29	2.8	2.1	12	1.2

Appendix C Tabulated Summary of Geomorphic Parameters

Table C-1. Calculated changes in geomorphic parameters through time.

Reach	Class	1950-2001 Displacement Ratio (sq m per m)	Change in Bankfull RCI/km value	Pct Change in Channel Length	Pct Change in Bankfull Braiding Parameter			
			1950-2001	1950-2001	1950-1976	1976-1995	1995-2001	1950-2001
PC1	CS	2.9	0.1	6.1%	-----	-----	-----	0.0%
PC2	CM	6.7	0.0	-0.1%	-----	-----	-----	0.0%
PC3	CS	6.2	0.0	0.0%	-----	-----	-----	0.0%
PC4	CM	16.2	0.6	0.2%	-----	-----	-----	9.7%
PC5	PCA	21.7	0.7	-1.5%	-----	-----	-----	14.6%
PC6	CM	6.5	-0.5	0.0%	-----	-----	-----	-16.5%
PC7	PCA	63.0	-0.1	-4.6%	-----	-----	-----	2.1%
PC8	CM	5.7	0.1	0.5%	-----	-----	-----	0.1%
PC9	PCA	112.9	0.0	-10.8%	-----	-----	-----	27.6%
PC10	PCM	47.1	-2.2	10.3%	-----	-----	-----	-20.7%
PC11	PCA	58.0	0.4	10.1%	-----	-----	-----	-12.5%
PC12	PCM	51.8	-2.0	-4.3%	-----	-----	-----	1.8%
PC13	PCB	56.5	-2.9	9.1%	-----	-----	-----	-47.0%
PC14	PCA	20.8	-2.0	-1.1%	-----	-----	-----	-20.1%
PC15	PCS	25.9	-0.4	-4.2%	-----	-----	-----	-9.5%
PC16	PCA	101.6	-2.1	-3.7%	-----	-----	-----	-14.9%
PC17	PCB	45.9	0.0	4.0%	-----	-----	-----	0.0%
PC18	UA	64.4	-1.2	2.7%	-----	-----	-----	-28.6%
PC19	CS	5.4	0.0	0.2%	-----	-----	-----	0.0%
PC20	PCS	22.9	-0.8	-0.4%	-----	-----	-----	-8.8%
PC21	PCA	40.2	-1.0	2.8%	-----	-----	-----	-14.1%
A1	PCB	59.2	0.3	-6.0%	9.8%	25.6%	-9.4%	25.0%
A2	UB	75.2	-0.9	-4.7%	-7.1%	-4.0%	-4.3%	-14.7%
A3	PCB	66.3	-1.8	1.3%	-4.8%	-14.4%	2.0%	-16.9%
A4	UB	78.6	-1.3	5.3%	-8.2%	-17.1%	-2.2%	-25.6%
A5	UB	34.6	-0.8	-4.7%	4.1%	2.0%	-5.9%	-0.1%
A6	PCS	25.8	-0.4	2.1%	-10.2%	9.1%	-2.3%	-4.3%
A7	PCB	65.2	-0.8	1.6%	14.6%	-19.1%	-4.5%	-11.5%
A8	PCB	80.7	0.7	-1.4%	25.9%	-13.9%	9.8%	19.0%
A9	UA	251.2	-0.6	-12.1%	20.8%	-13.1%	-4.6%	0.1%
A10	PCS	37.2	-1.3	-0.3%	-6.9%	-27.0%	10.9%	-24.6%
A11	PCB	68.9	-0.9	0.1%	-10.5%	-2.8%	1.2%	-12.0%
A12	PCB	77.5	-0.4	1.8%	-0.6%	-14.2%	14.1%	-2.7%
A13	PCA	68.7	-0.3	-1.6%	4.3%	3.7%	-3.2%	4.7%
A14	PCA	61.7	-0.6	-2.4%	-3.6%	-15.0%	1.5%	-16.8%
A15	PCB	61.9	-0.7	4.5%	-18.3%	10.0%	-9.2%	-18.4%
A16	PCA	143.2	-0.5	1.5%	6.3%	-12.3%	0.1%	-6.7%
A17	UA	207.2	-1.9	-1.7%	1.4%	-12.9%	3.8%	-8.4%

Reach	Class	1950-2001 Displacement Ratio (sq m per m)	Change in Bankfull RCI/km value	Pct Change in Channel Length	Pct Change in Bankfull Braiding Parameter			
			1950-2001	1950-2001	1950-1976	1976-1995	1995-2001	1950-2001
A18	UA	241.7	-0.6	-9.9%	23.5%	-13.2%	5.2%	12.8%
B1	UB	205.3	-0.9	1.2%	-3.2%	-18.6%	2.9%	-18.9%
B2	PCB	48.2	0.2	3.6%	3.5%	-12.9%	1.2%	-8.8%
B3	UB	119.0	-0.1	2.0%	-21.5%	11.2%	2.6%	-10.4%
B4	PCS	51.9	0.2	-0.3%	-2.6%	-3.4%	14.3%	7.6%
B5	UA	246.3	-0.2	0.4%	-2.4%	-3.1%	13.9%	7.7%
B6	PCB	111.5	0.6	2.7%	14.5%	-5.9%	18.2%	27.2%
B7	UB	117.5	-1.1	3.2%	-1.1%	-25.2%	11.3%	-17.6%
B8	PCA	147.6	-1.5	-6.2%	-1.0%	11.4%	-7.9%	1.6%
B9	UA	108.2	0.8	6.4%	8.5%	-20.7%	7.6%	-7.4%
B10	PCM	98.9	-1.9	4.1%	-24.6%	12.3%	-19.8%	-32.2%
B11	PCA	140.8	-0.3	-2.5%	-3.8%	5.5%	3.6%	5.1%
B12	UA	221.5	-1.2	0.3%	-6.8%	1.4%	0.8%	-4.8%
C1	UA	148.7	-0.2	-0.9%	8.8%	-6.9%	4.3%	5.6%
C2	PCB	72.0	-0.9	-1.8%	7.5%	-36.4%	-1.8%	-32.8%
C3	UA	120.8	-1.0	-8.9%	-2.9%	16.6%	-2.7%	10.2%
C4	PCB	94.2	-1.9	7.8%	-28.2%	4.1%	-1.6%	-26.4%
C5	PCS	22.6	0.2	-0.5%	-3.0%	-3.4%	-1.7%	-7.9%
C6	UA	71.8	-1.2	13.4%	2.6%	-24.3%	-7.1%	-27.8%
C7	UA	226.2	0.0	7.8%	9.5%	-22.7%	11.5%	-5.6%
C8	PCS	56.7	-0.6	-1.4%	-12.9%	-2.0%	-5.5%	-19.4%
C9	UA	228.1	-0.5	-3.0%	-0.2%	-16.4%	2.2%	-14.7%
C10	PCM	53.8	0.3	-4.6%	3.3%	6.5%	5.4%	15.9%
C11	PCM/I	95.4	-1.0	-0.2%	-14.9%	-15.7%	5.2%	-24.6%
C12	PCM/I	82.2	0.2	2.2%	-5.9%	-6.0%	11.7%	-1.2%
C13	PCM/I	59.8	0.7	0.2%	19.5%	0.7%	-4.4%	15.1%
C14	PCM/I	158.2	-0.9	-3.8%	16.6%	-7.3%	-22.8%	-16.6%
C15	PCS	30.6	-0.2	1.1%	-12.1%	0.9%	-0.6%	-11.8%
C16	PCM/I	120.2	-0.9	-1.0%	-5.0%	-4.2%	0.9%	-8.1%
C17	PCS	15.9	0.2	0.9%	7.5%	-4.9%	-2.6%	-0.5%
C18	PCS	29.8	0.0	1.0%	0.0%	27.6%	-21.7%	0.0%
C19	CS	37.6	0.3	0.5%	4.4%	1.0%	5.8%	11.5%
C20	CS	45.8	0.1	-2.0%	6.8%	-4.3%	0.0%	2.2%
C21	CM	29.3	0.2	0.0%	14.6%	2.5%	-9.9%	5.8%
D1	CM	55.7	0.1	-3.1%	2.3%	-6.7%	0.0%	-4.5%
D2	CM	18.9	0.0	-0.6%	4.5%	-4.3%	0.0%	0.0%
D3	PCS	28.8	0.2	-2.5%	7.0%	2.3%	1.7%	11.4%
D4	PCM/I	82.5	-0.4	-3.1%	-2.6%	-5.5%	-6.9%	-14.2%
D5	PCA	163.7	0.0	1.2%	1.8%	16.3%	-13.8%	1.9%
D6	PCM/I	61.7	-0.4	-1.7%	-30.9%	-8.1%	5.1%	-33.3%
D7	PCA	164.5	-0.7	-8.0%	1.8%	3.5%	-4.1%	1.0%
D8	PCA	94.0	0.7	-2.7%	9.2%	6.0%	-1.3%	14.2%
D9	PCM/I	78.6	1.7	6.9%	-13.0%	23.7%	2.6%	10.4%

Reach	Class	1950-2001 Displacement Ratio (sq m per m)	Change in Bankfull RCI/km value	Pct Change in Channel Length	Pct Change in Bankfull Braiding Parameter			
			1950-2001	1950-2001	1950-1976	1976-1995	1995-2001	1950-2001
D10	PCA	150.0	0.4	0.6%	-4.2%	-3.6%	11.9%	3.3%
D11	PCA	387.6	0.1	-6.2%	7.6%	1.6%	-17.7%	-10.1%
D12	PCA	160.8	0.2	-4.8%	-2.4%	9.4%	-6.5%	-0.1%
D13	PCM/I	132.2	-0.2	2.5%	-1.4%	1.6%	-12.4%	-12.2%
D14	PCM/I	124.1	0.3	-0.2%	31.6%	24.2%	-16.7%	36.2%
D15	PCM/I	91.6	1.0	0.0%	-----	-----	-5.2%	34.7%
D16	US/I	80.8	0.8	-1.1%	-----	-----	-8.6%	73.8%

Appendix D: Plotted Results

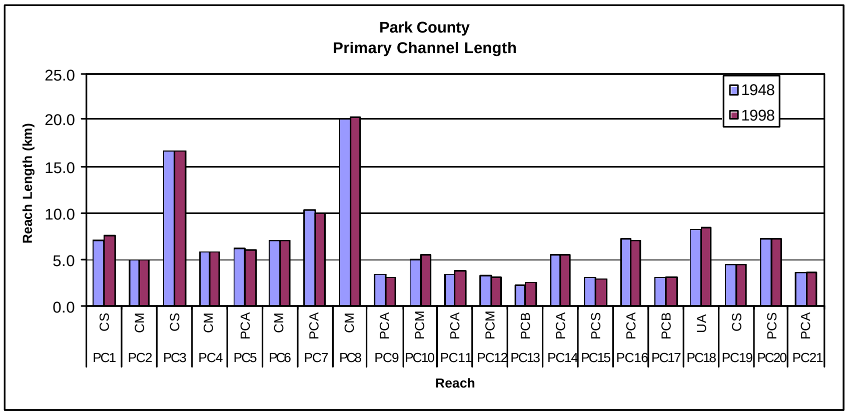


Figure D-1. Primary channel lengths, Park County

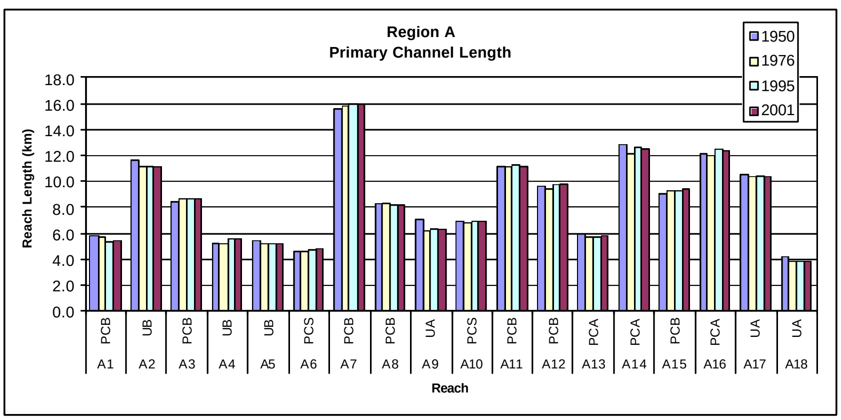


Figure D-2. Primary channel lengths, Region A

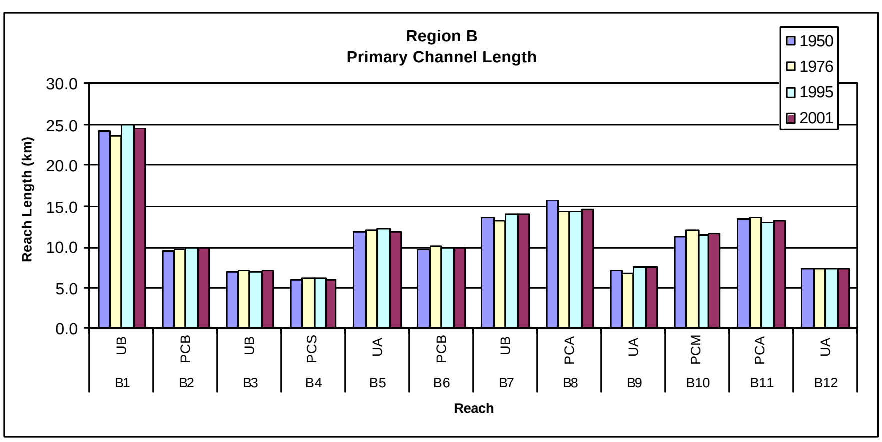


Figure D-3. Primary Channel lengths, Region B

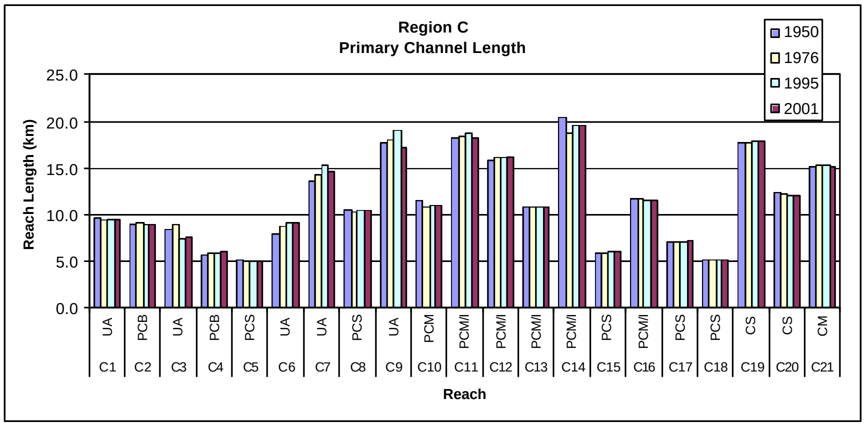


Figure D-4. Primary Channel lengths, Region C.

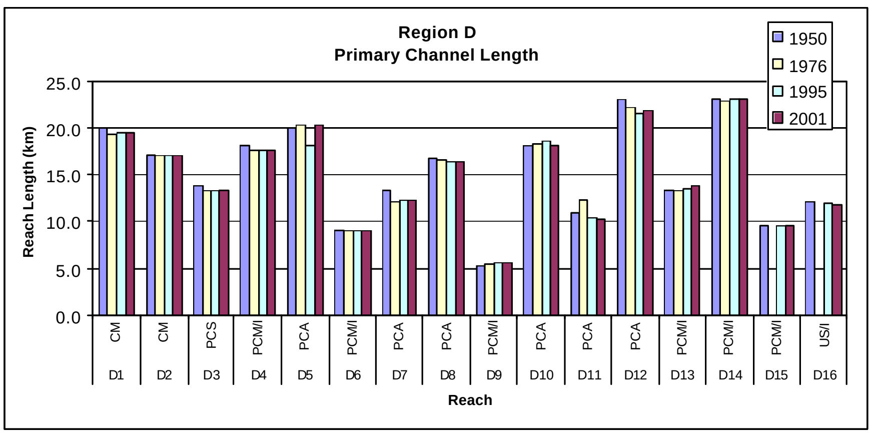


Figure D-5. Primary Channel lengths, Region D.

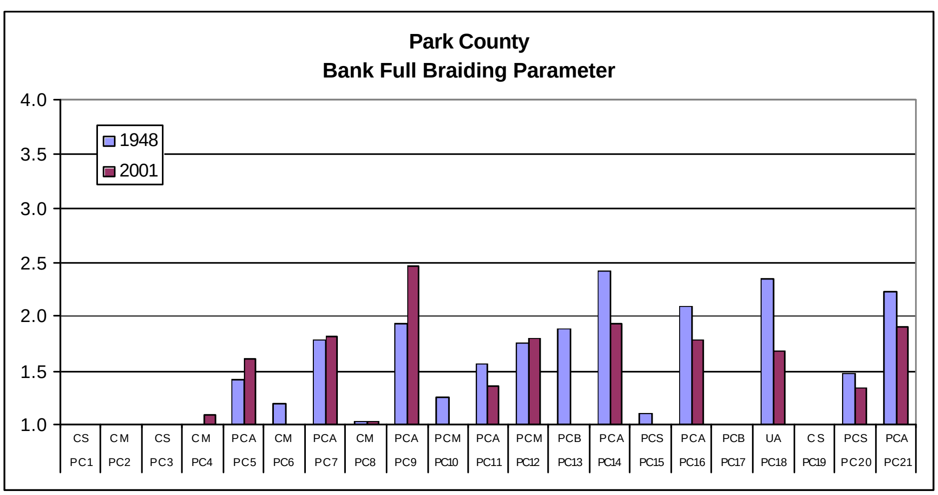


Figure D-6. Braiding Parameter, Park County

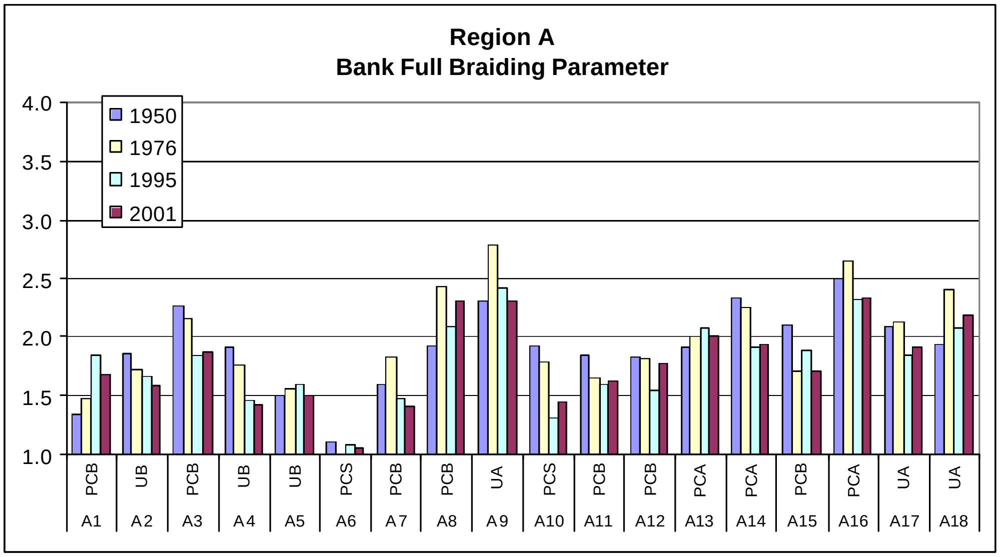


Figure D-7. Braiding parameter, Region A.

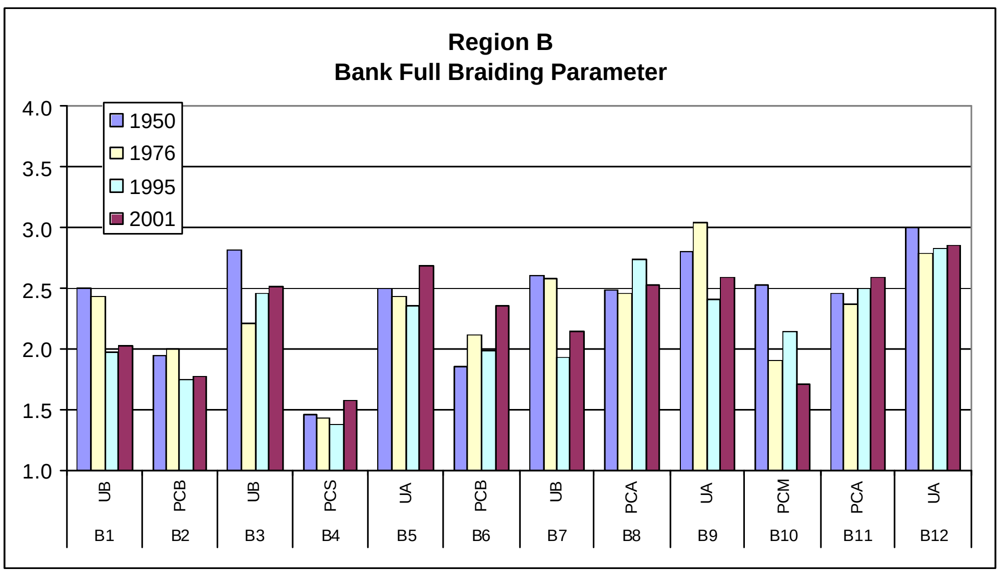


Figure D-8. Braiding parameter, Region B.

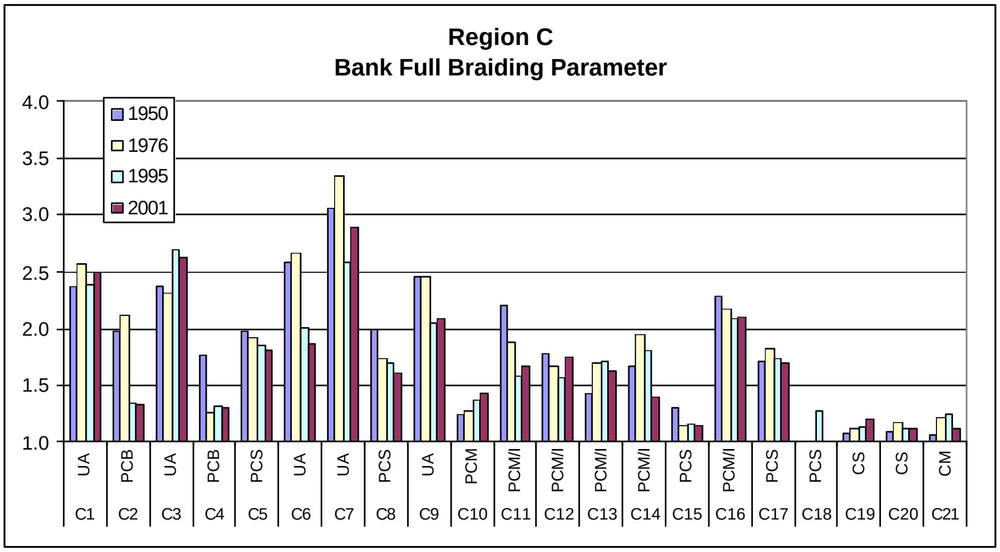


Figure D-9. Braiding parameter, Region C.

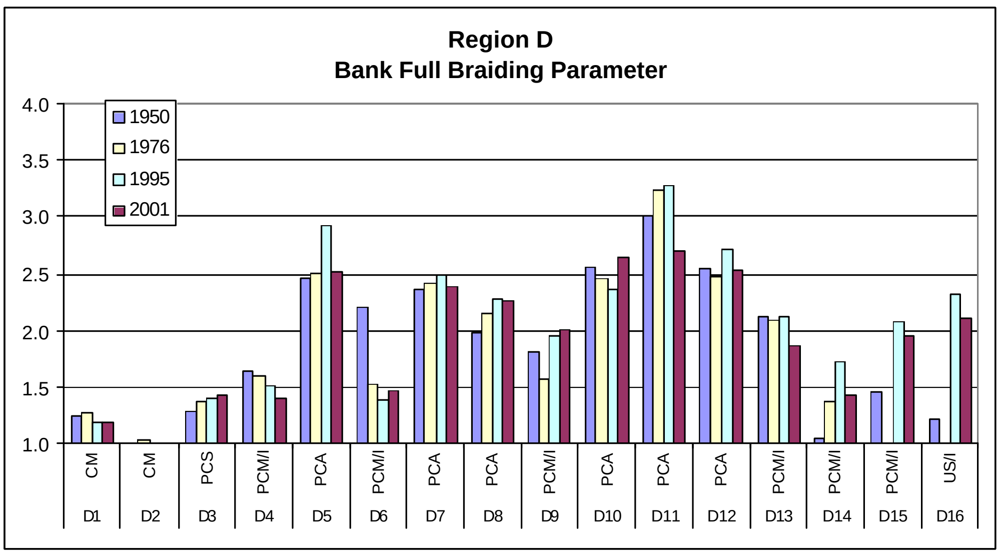


Figure D-10. Braiding parameter, Region D.

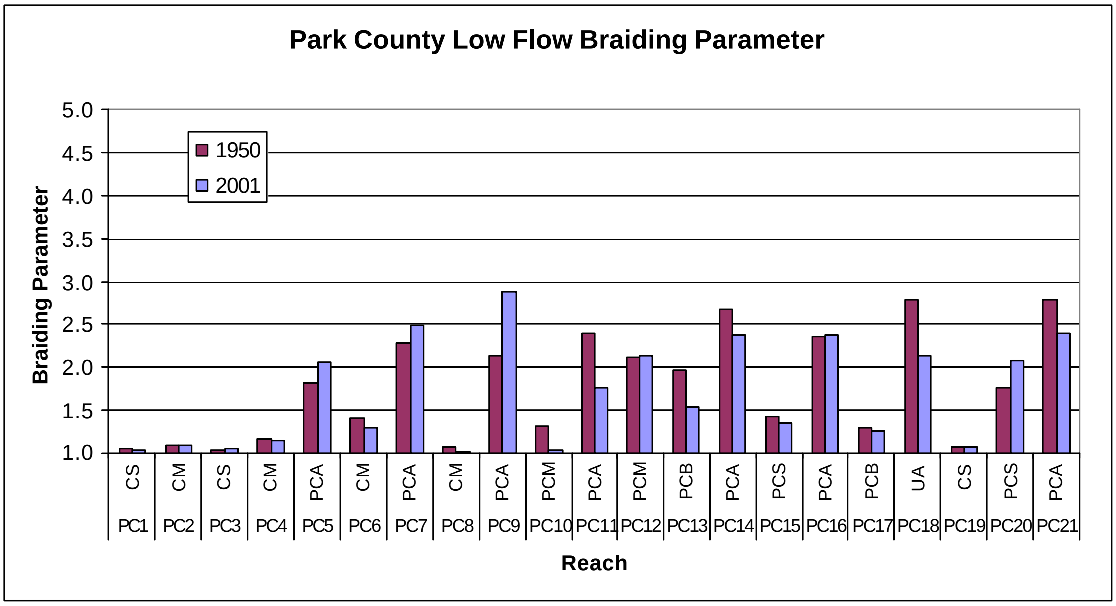


Figure D-11. Low flow braiding parameter Park County.

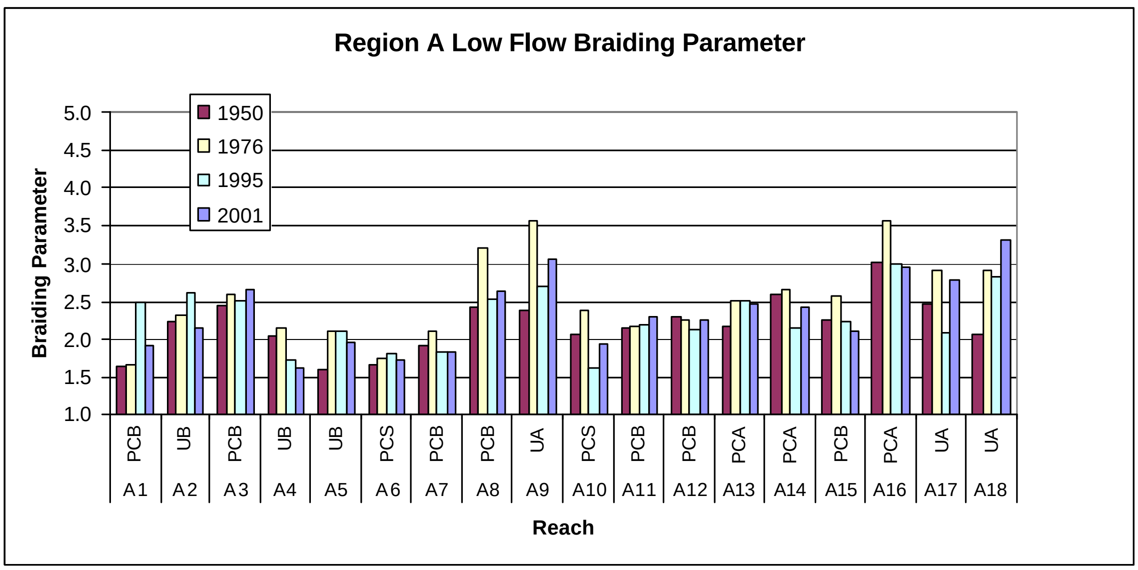


Figure D-12. Low flow braiding parameter Region A.

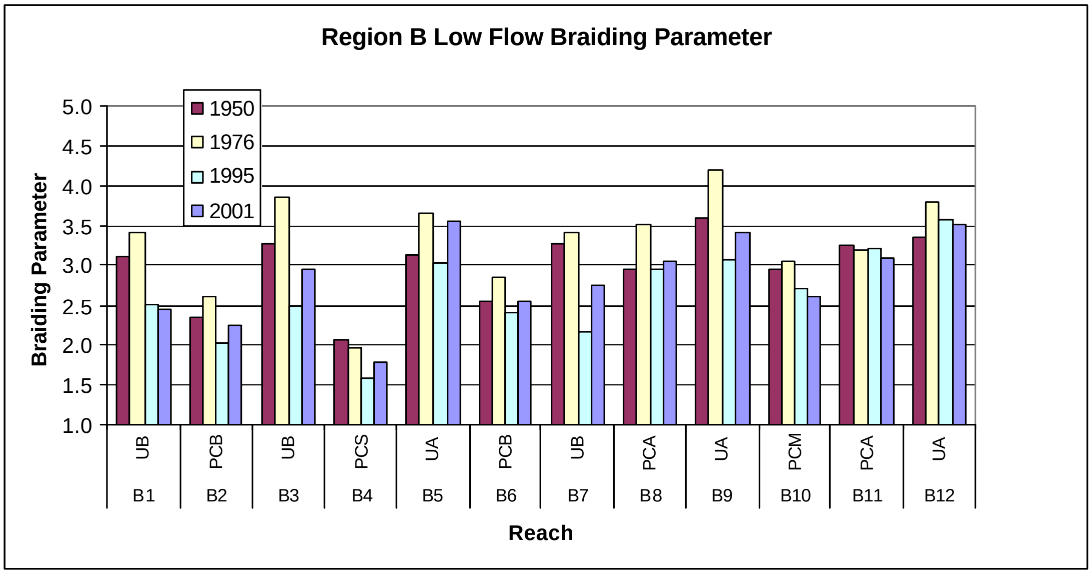


Figure D-13. Low flow braiding parameter Region B.

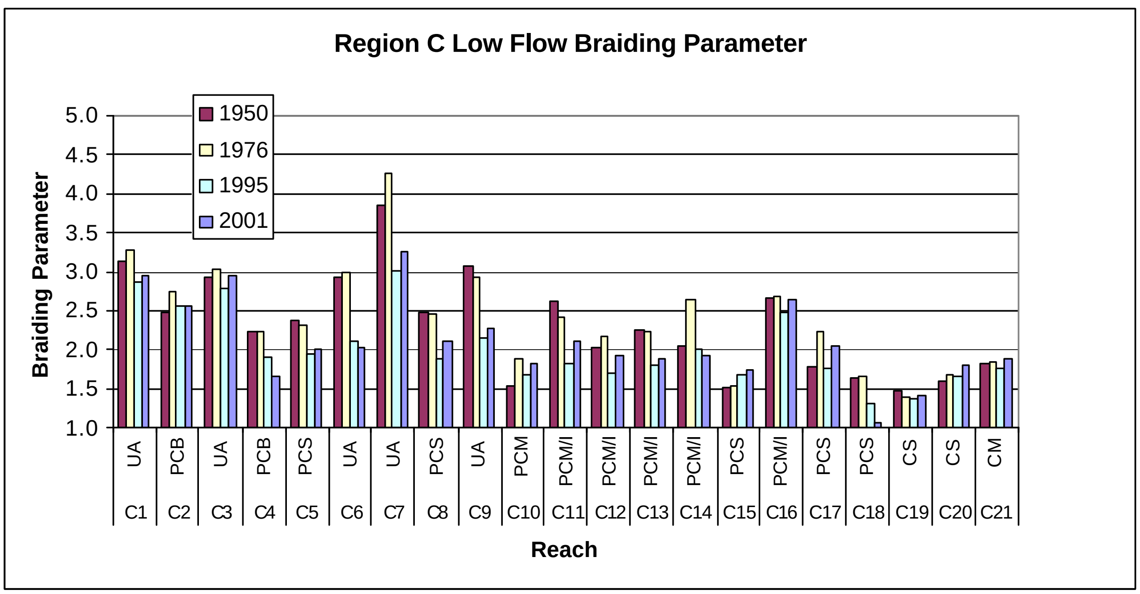


Figure D-14. Low flow braiding parameter Region C.

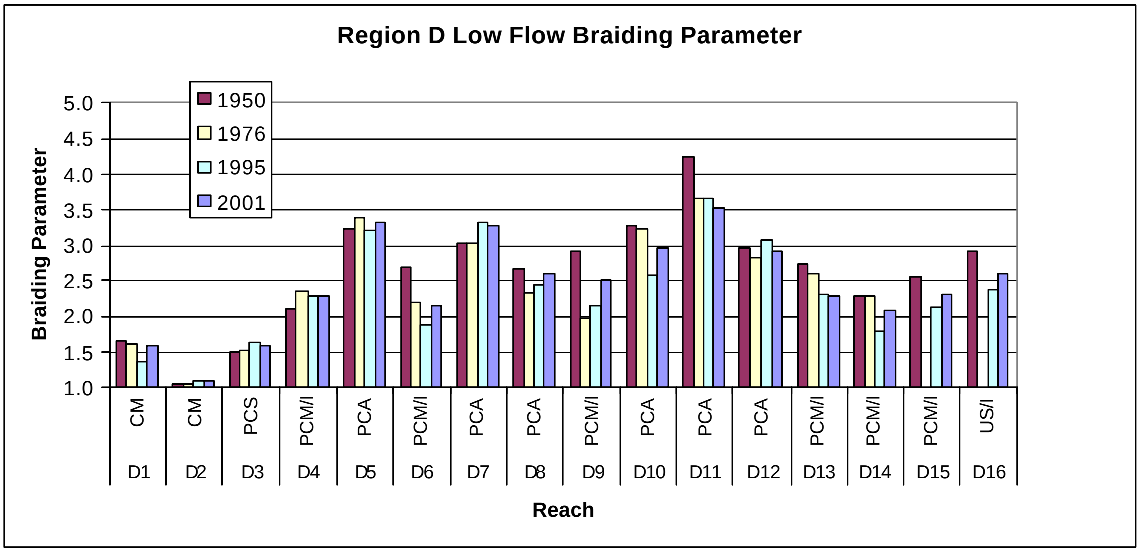


Figure D-15. Low flow braiding parameter Region D.

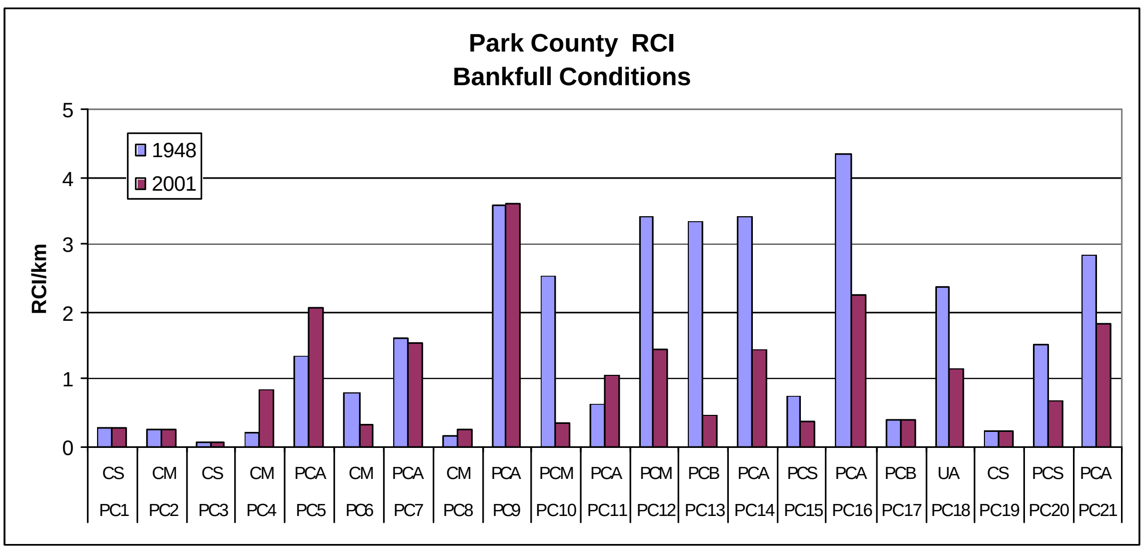


Figure D-16. River complexity index, Park County.

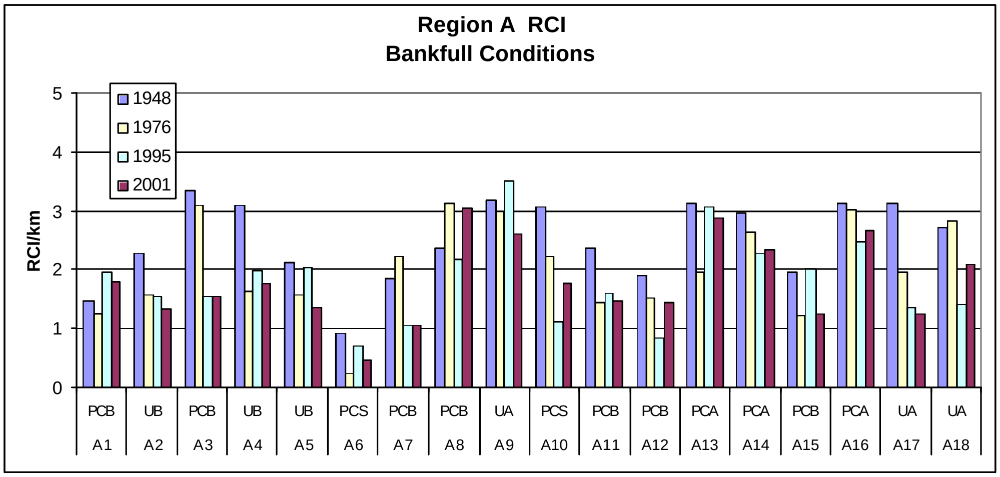


Figure D-17. River complexity index, Region A.

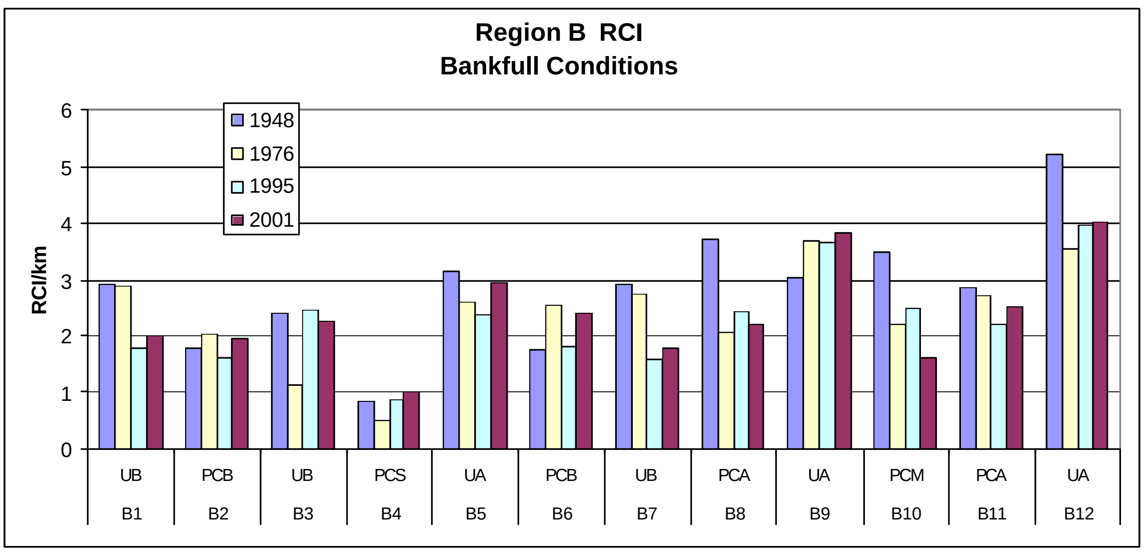


Figure D-18. River complexity index, Region B.

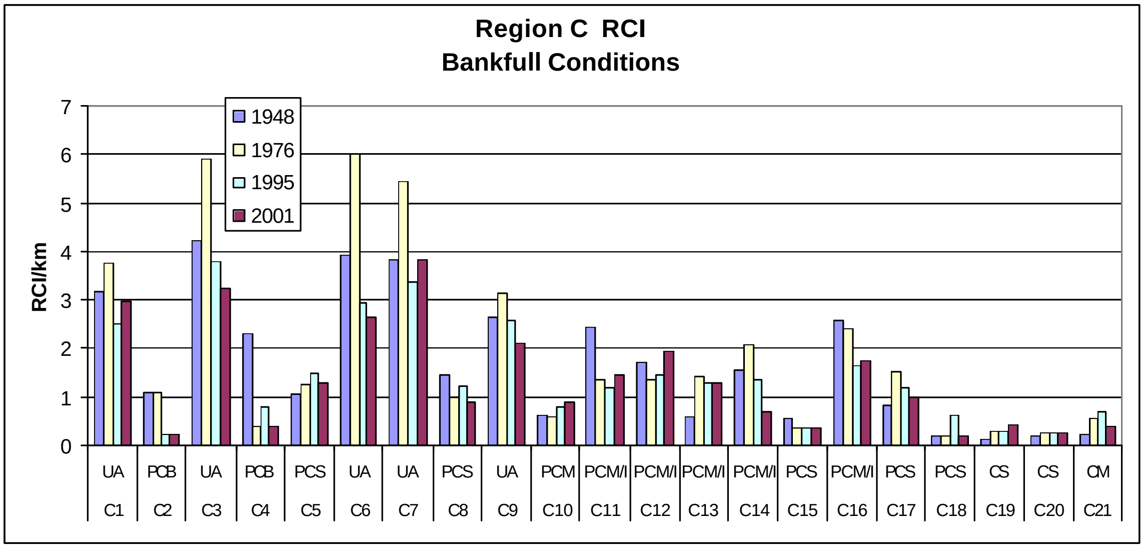


Figure D-19. River complexity index, Region C.

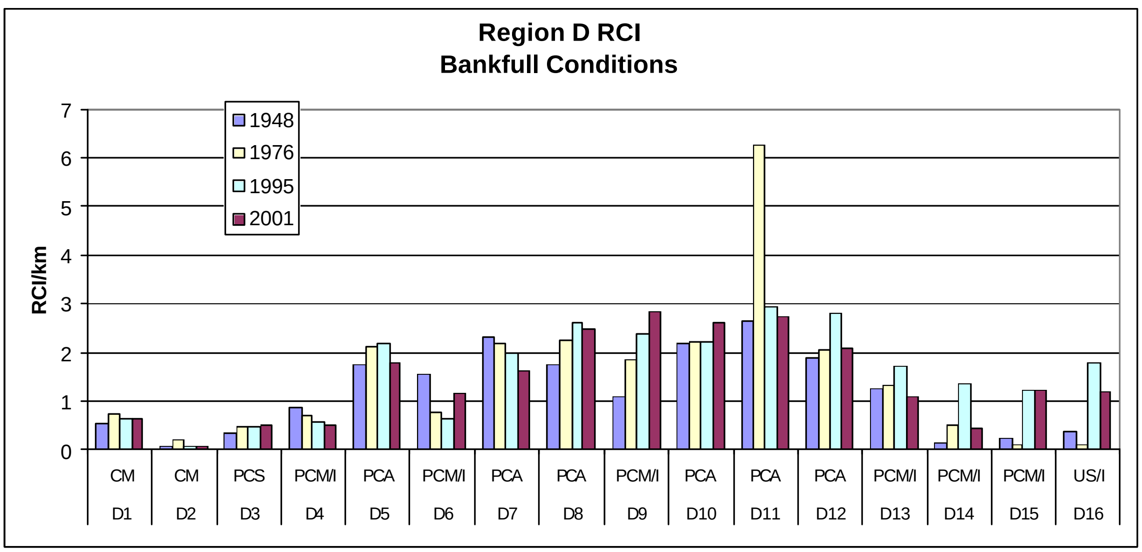


Figure D-20. River complexity index, Region D.

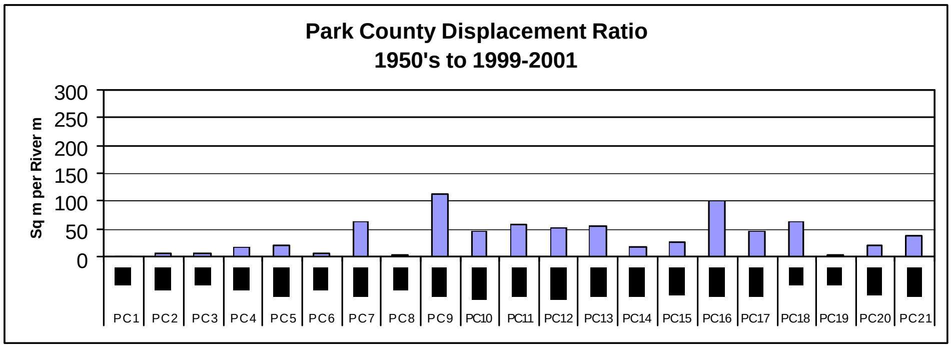


Figure D-21. Channel Displacement Ratio, Park County.

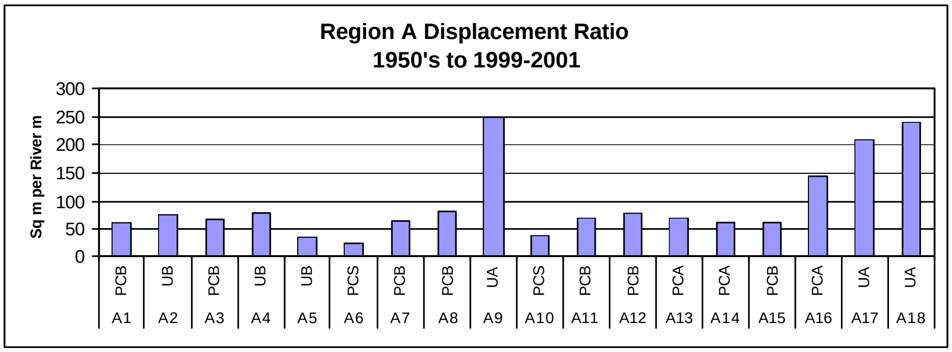


Figure D-22. Channel Displacement Ratio, Region A.

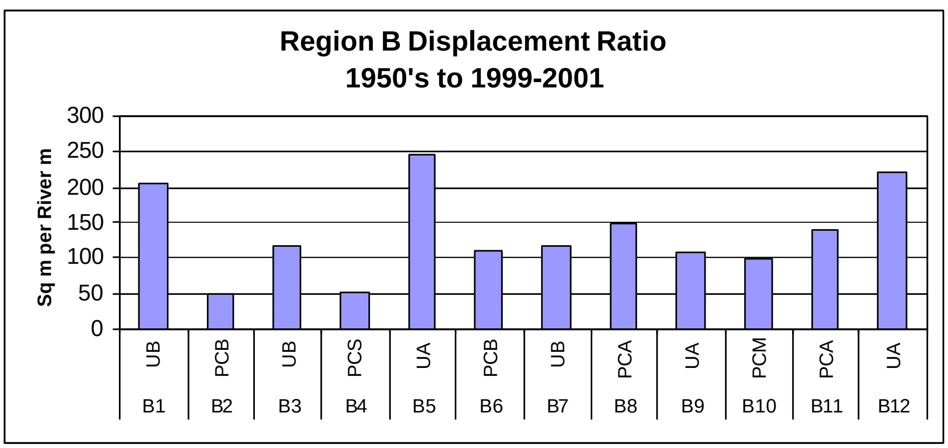


Figure D-23. Channel Displacement Ratio, Region B.

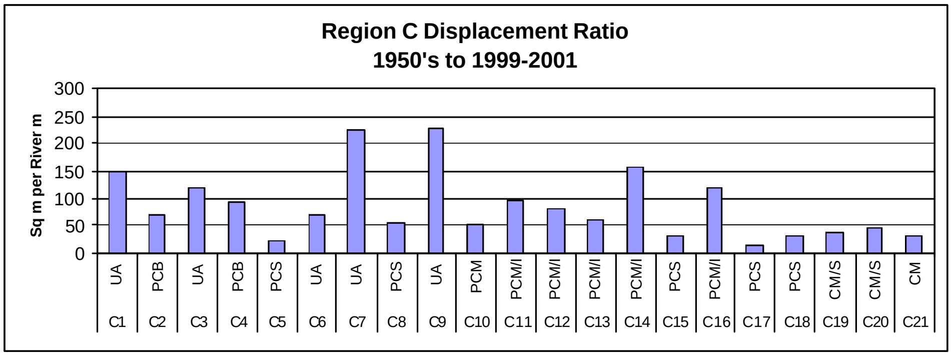


Figure D-24. Channel Displacement Ratio, Region C.

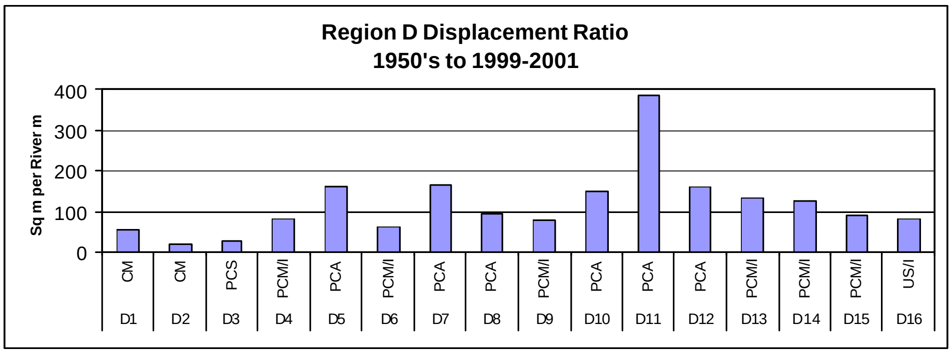


Figure D-25. Channel Displacement Ratio, Region D