Reply to Parsons' Report "Investigations of the Platte River Channel Dynamics and Comparison with Foundational Assumptions and Hypothesis of the EIS Team's 'White Paper'"

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Introduction

The Bureau of Reclamation (Reclamation)[1] welcomes a critical review of the work by Murphy and Randle (2003)[2] (entitled "Platte River Channel: History And Restoration") in the interest of increasing understanding of the Platte River system for better management of the system. Unfortunately, the review by Parsons (*Results of Parsons' Investigations of Platte River Channel Dynamics and Comparison with Foundational Assumptions and Hypotheses of the EIS Team's "White Paper"*) is a flawed critical review of Reclamation's work and it does not increase our knowledge of the river system. The technical evaluation provided by Parsons has several serious shortcomings. The Parsons report misunderstands and misrepresents Reclamation's position, contains ambiguous, contradictory, and misleading statements, uses non-standard definitions of key terms, offers explanations that do not demonstrate a clear understanding of the issues, and generally lacks references in support of substantive statements.

In this reply, Reclamation first counters the central position taken by Parsons that climate change has caused the morphological changes in the Platte River over the past 100 years, and that humans have had no impact on the system. This is followed by some specific examples of Parsons questionable and unsubstantiated argumentation. This includes a discussion of Parsons claim that vegetation has no effect on the morphology of the Platte River, their claim that aerial photographs are not a valid method of assessing changes in river morphology, their claim that the effective discharge of the Platte River has remained substantially unchanged over the entire period of record, followed by a brief discussion of the SEDVEG model. Finally, some general comments on Parsons' attempts to discredit and refute Reclamation's position are provided. Numerous points of disagreement were not discussed due to a lack of time and space, but omitted issues are not considered any less important than those discussed herein.

Causes of Changes to the Platte River Over the Past 100 Years

The principal claim by Parsons is that the morphological changes in the Platte River over the past 100 years are a direct result of climate change. Parsons has provided an unsubstantiated case in

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[1] Parsons refers to Reclamation as the EIS team.
[2] Parsons critique is of an earlier draft of this paper (2001) often referred to as the "white paper".

an attempt to prove that water resources development has had little or no impact on the morphology of the Platte River, despite the fact that the Platte River is one of the most regulated rivers in the United States, with basin reservoir storage significantly greater than the annual river flow. Parsons position is contrary to a preponderance of evidence that indicates that changes in flow and sediment supply as a result of water resources development have caused the morphological and ecological changes to the Platte River over the past 100 years. Murphy and Randle (2003) have summarized a large body of literature that substantiates this view and have provided detailed evidence and arguments based on proven theory in river morphology that illuminate the processes by which these changes have occurred. The following discussion provides some details of the arguments used by Parsons in order to show the weakness of their position.

The core of Parsons' argument is founded on the equivocal use of the term "climate change." Parsons states that "[a]s shown in the A1 technical report, climate driven changes in plan form and vegetation expansion offer a more scientific explanation of the far-reaching changes observed in the last 100 years" (p. ES-3). However, Parsons' discussion in the A1 technical report does not apply to the time scale of the past 100 years. The discussion in technical report A1 is primarily of long term climatic effects on river morphology on the scale of thousands of years. Additionally, there is an extensive discussion in the D1/D2 report—entitled *Results of Investigations D1 and D2—Macro-Historical Evaluation of Surficial Processes and Macro-Historical Evaluation of Climate Change*—on long term climate changes and the effects of such changes of climate on the morphology of the Platte River. Clearly, Parsons is referring to long term patterns and processes, and it is not appropriate to use long term climate change to explain river morphologic changes over the past 100 years.

Given this ambiguity in the use of the term "climate change" by Parsons, in this reply Reclamation uses the term "climatic events" to refer to periods of drought or wet periods that could have some impact on river morphology in the short term (10 to 100 years). The term "climate change" will be used when discussing larger time scales, i.e., thousands of years, as it is used by Parsons.

With this clarification of terms, Parsons argument can be summarized as follows. The morphology of the Platte River has changed in the past, on the time scale of thousands of years, in response to climate change. There are "geomorphic thresholds" that, if passed, can lead to significant morphological changes even given small extrinsic or intrinsic changes to the system. The Platte River is unstable, or was until recently according to Parsons, and on the edge of a threshold so that any relatively small change can cause a significant morphological response. Parsons further claims that some extrinsic geomorphically significant factor has caused the Platte River to pass a threshold value, though they have not provided an indication of what type of threshold was passed. Parsons goes on to state that

> the magnitude of the change in extrinsic conditions required to cross a threshold may be sufficiently small that it may not be possible to distinguish the proximate cause of the change in morphology from among all possible causes (p. A1-12).

Parsons then concludes that

> [a] threshold between the pre- and post-development river has not been identified, nor have drivers other than climate been identified as instrumental in causing these types of changes in this region, but it is reasonably concluded that the river is in a greater state of dynamic equilibrium than it was in its pre-development form (p. A1-13).

In other words, it is concluded by Parsons that since no other causes can be identified by them, climate change caused the geomorphic changes that have occurred in the Platte River in the past 100 years.

The reason that Parsons has not been able to identify drivers other than climate change is because the focus of their review and the body of literature cited in the A1 technical report is concerned with natural long term climate change and not on the impacts of human development. There is an extensive body of literature documenting the effects of dams and other human activities on the morphology of rivers (Surian and Rinaldi, 2003; Collier et al., 2000; Dominick and O'Neill, 1998; Friedman et al., 1998; Johnson, 1998; Williams and Wolman, 1984; Schumm and Meyer, 1979, amongst others). Parsons does not explore this literature or consider its relevance to the Platte River.

In order to determine what the actual drivers are for changes in the post-development Platte River, we must first understand what factors are important in determining river morphology, specifically channel width. Leopold and Maddock (1953) show that for ranges of discharge up to bank-full discharge channel width is related to discharge through a simple power function:

$$w = aQ^b \qquad (1)$$

where w is channel width measured at the water surface, Q is discharge, and a and b are constants determined empirically. Once bank-full stage is exceeded and a river overflows its banks, the width increases rapidly and a new relation would need to be determined. While the value of the exponent b is variable, a value of 0.5 is often used.

In addition to the importance of discharge on width, Yang (1986) developed a relation from the following simple relation first developed by Lane (1955):

$$Q_s d \propto QS \qquad (2)$$

where Q_s is the sediment discharge, d is the sediment particle diameter, and S is the channel slope. Using the theory of minimum energy dissipation rate (Yang and Song, 1979), the unit stream power equation (Yang, 1973), and equation (2) Yang (1986, 1996) developed the following relation:

$$\frac{Q_s d^{0.5}}{K} = \frac{Q^2 S}{WD} \qquad (3)$$

where W is the channel width, D is the channel depth, and K is a site specific parameter. Rearranging equation (3) to solve for W yields:

$$W = \frac{Q^2 SK}{Q_s d^{0.5} D} \quad (4)$$

Equation (4) shows that 5 factors contribute to the determination of channel width: sediment and water discharge, channel slope, sediment particle size diameter, and channel depth, and these factors interact in complex ways. Murphy and Randle (2003) have shown that the effects of development in the form of flow control and diversions have affected the discharge and sediment supply in the Platte River. Changes in these two factors have caused the morphological changes in the Platte River. The discharge of the Platte River has changed significantly with storage and flow diversion, and reservoirs trap sediment greatly reducing sediment loads in the river. These changes in runoff and sediment supply disturbed the pre-development river balance (see equation 3) and caused the river to adjust to a new equilibrium. There has been, overall, a reduction in channel width, a decrease in sediment discharge, an increase in depth, especially just downstream of clear water flows from dams and diversion returns, and an increase in particle size in many areas. While the slope has adjusted in some reaches, in the large scale it has remained relatively constant. The effects of development greatly outweigh the effects of short term climatic events, which are also masked by nearly complete flow control on the river. Human development in the Platte River basin, including the South and North Platte Rivers, has been the primary driver of the morphological changes in the river over the past 100 years.

Vegetation as a Geomorphic Agent and Indicator

In their Executive Summary, Parsons has stated that

> [t]he use of unvegetated width as a geomorphic indicator [in Murphy and Randle (2003)] is *unprecedented* and misleading. The unvegetated width of a river is not a measure of its equilibrium width, effective discharge width, or 'active' channel, and changes in this width should not be correlated with anything except vegetative expansion. Other far more relevant measures of width are available but were not used (emphasis added, p. ES-5).

The other "far more relevant measures of width" are not specified by Parsons. Parsons also claims to have completely refuted "[t]he foundational assumption that unvegetated portions of the river are morphologically relevant…" (p. ES-4). They make the following related comment from the A3 technical report. "This study shows that previous investigations [i.e., Murphy and Randle (2003)]are lacking in relevant (geomorphologic) definitions of channel width, [and] that the choice of 'unvegetated width' has nothing to do with geomorphology…" (p. A3-44).

The rejection of the concept of unvegetated width by Parsons, and the denial that vegetation can act as a driving force in river morphology, conflicts with accepted science of geomorphology. First, regarding the efficacy of vegetation in geomorphology, Graf (1978), in a study on fluvial adjustments to the expansion of tamarisk on the Colorado Plateau, states that "[b]ecause tamarisk colonizes moist sand, grows rapidly, and stabilizes sediment, it is an effective geomorphic agent" (p. 1491). The growth of cottonwoods and willows along the Platte River has the same effects as does the growth of tamarisk noted in Graf's paper. Alternatively, as Gyssels and Poesen (2003) have stated, "[t]he influence of vegetation characteristics on the rates of geomorphological processes has been the subject of numerous studies" (p. 371). In fact, Viles (1988) has used the term “biogeomorphology”, the title of her book, in reference to the area of geomorphology concerned with the effects of plants and animals on earth surface processes and the development of landforms. It is difficult to understand how Parsons has failed to notice such a significant aspect of geomorphology present in the literature.

Second, regarding the use of vegetation in determining channel boundaries, Osterkamp and Hedman (1982) point out that the use of the term “active channel” as an in-channel reference level was first used by Hedman et al. (1974). They go on to quote a description of active channel from Osterkamp and Hedman (1977) as

> a short term *geomorphic feature* subject to change by prevailing discharges. The upper limit is defined by a break in the relatively steep bank slope of the active channel to a more gently sloping surface beyond the channel edge. *The break in slope normally coincides with the lower limit of permanent vegetation so that the two features, individually or in combination, define the active channel reference level.* The section beneath the reference level is that portion of the stream entrenchment in which the channel is actively, if not totally, sculptured by the normal process of water and sediment discharge (emphasis added, Osterkamp and Hedman, 1982, p. 3).

The primary factors that govern the physical process and morphology of rivers are, according to Church (1992), “the volume and time distribution of water supplied from upstream; the volume, timing and character of sediment delivered to the channel; the nature of the materials through which the river flows; the local geological history of the riverine landscape” (p. 126). The first two factors are significantly affected by water resources development. Church also lists local climate, the nature of riparian vegetation, and land use in the drainage basin as secondary factors that influence river morphology. Note the inclusion of vegetation as morphologically significant. Church (1992) goes on to state that “[c]orrelations have been demonstrated between riparian plant communities and elevation above some reference water level; hence between plant species and duration of inundation…. A significant channel boundary is the ‘lower limit of continuous terrestrial vegetation’—the limit of the ‘active channel’…—which is more or less well defined on most stream banks” (p. 126).

Obviously, the importance of vegetation as a geomorphic agent and the use of the concept of active channel is highly visible in the literature. And, given the presence of this common definition of active channel in a paper heavily used by Parsons, i.e., Osterkamp et al. (1987) (see below), the failure of Parsons to notice this important aspect of geomorphology is hard to understand.

Dismissal of Evidence from Aerial Photographs

Parsons states that it is not possible to

> determine geomorphologically-defined ‘channel width’ from these [aerial] photos [of the Platte River], yet this error has been rampant and has misled the EIS team. The photos only give the amount of open versus vegetated areas. All one can ascertain is the amount of ‘channel’ narrowing in a geomorphologic framework. In fact, even the amount of vegetated expansion is suspect, because all one can see from photos is the canopy width, which depends on season and maturity of the plants (p. ES-4).

It seems that Parsons rejects the accepted practice of using aerial photos as a tool for assessing changes in river morphology. Yet this assertion is confused. Parsons seems to say that channel width cannot be determined from aerial photos yet one *can* determine the amount of channel narrowing. The question for Parsons is "how can one determine channel narrowing without determining channel width?" The fact of the matter is that it is standard practice to use aerial photographs to assess changes in channel width, and the changes in channel width are obvious to anyone who looks at the aerial photos of the Platte River available for the time period.

Effective Discharge and "Effective Channel Width"

Parsons states that

> [t]he USGS established that there is a direct correlation of effective discharge and the associated channel width, yet the White Paper does not rely on this relationship. Instead, the unvegetated width (which in no way reflects a geomorphologic measure) is correlated with annual peak flows. The A3 [actually A4] investigation relied on this relationship and concluded that the effective discharge has not changed substantially, and that the associated effective-discharge channel and river corridor widths closely match 1938 conditions, with some evidence that they are not too different than conditions in the 1860's (p. ES-6).

Parson's conclusion that the effective discharge of the Platte River has not changed substantially in the past 100 years cannot be accepted because their methodology is not valid. Parsons uses the mean monthly flow rate in their determination of effective discharge. It is essential that relatively short duration high magnitude events are represented in the flow duration curve used to estimate effective discharge (Biedenharn and Copeland, 2000; see also Soar and Thorne, 2001). Mean monthly flow data are much too coarse to meet this condition. Randle and Samad (2003) provide an in depth analysis of effective discharge of the Platte River using several accepted methods. Under all methods, they show that the effective discharge has decreased by over 50% from the period of 1895-1909 to 1970-1999 for the Platte River at Overton and at Grand Island, and by over 35% from 1910-1935 to 1970-1999 at Overton. While a slight reduction (under 25%) in effective discharge is shown under most methods from the period 1910-1935 to 1970-1999 at Grand Island.

Additionally, there is no data on Platte River discharge prior to 1895, so it would be difficult to envision just what evidence there could be on so called "effective-discharge channel width" when the effective discharge cannot be determined.

Ultimately, it seems that Parsons wishes to establish that if the effective discharge has not changed, then changes in channel width are not related to changes in flow. Even if Parsons was correct that effective discharge had not changed, the use of channel forming discharge concepts is not directly applicable to braided rivers, such as the Platte River, since they are aggrading (Copeland et al., 2000). The use of and reliance upon the effective discharge as the most significant factor that determines channel width and pattern is not recommended without field confirmation even for stable systems (Biedenharn and Copeland, 2000). This is not to say that an effective discharge, defined as the discharge that carries the greatest sediment load, is not important and cannot be estimated for the Platte River. It only means that this discharge should not be considered as the channel forming discharge. The main point is that in an unstable channel it is very difficult to define a channel forming discharge. The connection between effective discharge and the expected width of the Platte River that Parsons makes is dubious.

SEDVEG Model

Parsons review of the SEDVEG model was of an earlier version and the model has been much revised. Parsons has acknowledged the fact that they were looking at an early version of SEDVEG and that much of their critique would not pertain to an updated version. Therefore, Reclamation will discuss the general approach used in application and calibration of the model to show that the current SEDVEG model is a valid and useful management tool.

Geomorphic investigations of the Platte River relied on three levels of analysis: (1) qualitative analysis, (2) quantitative analysis, and (3) numerical modeling. The basic conclusions were based on the qualitative and quantitative analyses. The numerical model was used to provide additional confirmation of these basic conclusions and to evaluate EIS alternatives. Parsons misunderstands and misrepresents how the model functions, how it is applied, and they incorrectly claim that the model is biased toward degradation.

The numerical model developed by Murphy et al. (2001) was designed to evaluate the linked processes of river hydraulics, sediment transport, erosion, and deposition, vegetation growth and removal, and the resulting loss or gain of fish and wildlife habitat. This model provides a tool for evaluating future habitat conditions without having to assume that the channel geometry remains constant.

The numerical model is largely deterministic, but does require the user to specify some coefficients that require calibration. All of the specified coefficients are within a reasonable range. For example, Manning's n roughness coefficients are based on a FEMA Flood Insurance report and range from 0.035 for the main channel to 0.07 for the forested flood plain. The model adjusts the roughness value between these limits depending on extent of vegetation growth.

In order to avoid bias, one set of user specified model coefficients is calibrated to an equilibrium condition (neither aggrading nor degrading) during the simulation of the 1865 to 1909 period when river flow and sediment loads were much greater and continuous along the river. The same coefficients used for the calibration prior to water resources development are also used in model to simulate river conditions during two later periods:

1. From 1910 to 1969, when river flows and sediment loads are significantly reduced and the channel narrowed substantially; and

2. From 1970 to 1999, when river flows and sediment loads did not significantly change and the rate of channel narrowing significantly decreased.

As an additional calibration step for the simulation of future conditions, the initial river slope from 1989 measured cross sections was locally calibrated to produce an equilibrium condition for a 5,000 ft^3/s steady flow at all cross sections. Therefore, when the model predicts aggradation or degradation, it is due to discontinuities in river flow rather than an inherent bias.

The model represents a set of linked hypotheses that describe the key processes affecting the Platte River channel. The fact that a one set of coefficients can be used by the model to successfully simulate the variable responses that occurred during the period 1865 to 1999, including an equilibrium condition, provides confirmation of the basic understanding of how and why the Platte River has evolved as presented by Murphy and Randle (2003).

General Comments

In this section, some general comments are given regarding Parsons' attempt to discredit Reclamation's work. In large part, the report by Parsons contains strong statements contradicting Reclamation's position that are largely unsubstantiated and often times contrary to the accepted science.

1.) Parsons often misrepresents Reclamation's position in a manner that sets up a "straw man" to be easily knocked down. For example, Parsons repeatedly claims that it is Reclamation's contention that reductions in peak flow are *solely* responsible for channel narrowing and vegetation expansion along the Platte River. This is false. Murphy and Randle (2003) nowhere state that peak flows alone are responsible for the morphological and ecological changes in the Platte River over the past 100 years.

Another example of this occurs in Parsons report A1, which states that "by the absence of discussion of climate affects [*sic*] [Reclamation] apparently regarded the possible hydrologic and geomorphic effects associated with changing climatic conditions as unimportant in the functioning of the Platte River system" (p. A1-3). This criticism is unjustified since hydrologic patterns were considered in Murphy and Randle (2003) for the period of concern, the past 100 years. There is an in depth discussion on the effects of drought on channel morphology and vegetation encroachment and the importance of short term climatic events is presented explicitly in Murphy and Randle (2003).

2.) Parsons exaggerates the importance of minor points. That is, Parsons over stresses differences in interpretation that are minor details compared to the overall big picture. For instance, Reclamation observes that the slope of the Central Platte River is relatively constant over its length. Parsons goes to great lengths to show that the slope of the Platte River is not uniform at small spatial scales in order to dispute Reclamation's point. This is a trivial point since no river has a perfectly uniform slope at small scales. The significant point, that a relatively uniform slope in the large scale has important geomorphic implications, is ignored by Parsons.

3.) Parsons employs an unusual use and definition of key concepts and terms as a rhetorical strategy. That is, Parsons often uses terms or concepts in a sense that depart from standard scientific usage, which are then used in an attempt to refute Reclamation's position. For example, Reclamation focuses on the unvegetated portion of the river channel because this is the area that provides useful habitat for the target endangered species. When permanent vegetation moves into the channel, it eliminates that area as usable habitat. The area of active channel corresponds to the area of usable habitat (see detailed discussion above), because flow limits the growth and establishment of permanent vegetation (Johnson, 1994).

Parsons points out that the presence of vegetation does not render that area "unable to carry water." This is supposed to counter the idea that permanent vegetation (cottonwoods and willow) can be used to establish the active channel boundaries. Parsons argues that, since vegetation can grow in channels and "not render them unable to carry water," vegetation does not mark active channel boundaries, i.e., vegetation (cottonwoods and willows) can be present within the active channel. However, Reclamation does not deny that old vegetated channels may still carry flow, these channels simply do not carry flow a significant amount of time nor in large quantities. Hence they are not part of the active channel. What Parsons defines as active channel is not consistent with Reclamation's definition rendering Parsons argument off the point and irrelevant to the habitat restoration program.

4.) Parsons often dismisses or ignores data or literature that conflicts with their conclusions. For example, the use of aerial photographs to assess changes in river morphology over time has been rejected by Parsons as a valid method in geomorphic analysis (see discussion of this point above). Parsons never addresses any of the historic photographs of the Platte River that support the conclusion of channel narrowing and vegetation expansion into former areas of active channel. Parsons use of the historic flow record is selective, focusing on specific periods of record or locations in the river basin.

Another example is Parsons' reliance on a paper by Osterkamp et al. (1987) (*cf*. D1/D2 technical report) to make the case that the morphology of the Platte River has changed in response to long term climate changes. However, they fail to report information in the same paper that is at odds with their position on use of the term "active channel" (see above) and the cause of the changes in the Platte River over the past 100 years. Osterkamp et al. (1987) state that "[t]he 'active channel' [is] defined at the upper limit as the break in the steep bank slope of the active channel and the lower limit of permanent vegetation" (p. 184). Osterkamp et al. (1987) also state that "[t]he hydrology and morphology of the Platte River have changed considerably since the settlement of the river basin in the mid-nineteenth century. Peak discharges have decreased and the channel has narrowed *because of flow regulation* by both on-stream and off-stream storage" (emphasis added, p. 185). This is a significant oversight by Parsons.

5.) Finally, Parsons often claims that topics are subjective when in fact they are not. It appears that Parsons is attempting to downplay the empirical nature of the issues. This is most apparent when Parsons calls empirically based conclusions, "assumptions." For example, Parsons claims that the conclusion by Reclamation that reductions in peak flows have contributed to the process of channel narrowing is an assumption (see p. ES-6), and that sediment size has not increased to "the extent assumed by the EIS team" (p. ES-7) when this is clearly not an assumption but an observation based on analysis of empirical data.

Conclusion

The central claim of Parsons that climate change has caused the morphological and ecological changes in the Platte River over the last 100 years and water resources development has little or no impact is indefensible. The main body of theory and research in river morphology shows that the substantial, human-induced changes in river flow and sediment transport will induce the types of changes in river channel width and form that have been observed and measured for the Platte River. These predictions have been confirmed in detail through field data collection, analysis of historic photographs, maps, and other documents, and through modeling of the river as it has changed over the last 100 years.

Parsons asserts that the effects of climate overwhelmed these direct changes in river flow and sediment load, without offering any analysis or illustration, and without first attempting to disprove the effect of the primary and proximal variables. Where these more central variables are assessed by Parsons (e.g., effective discharge) their methods are improper and contradicted by analyses using the complete historic data set and triangulated with several methods. Their definitions of key concepts are unsupported by current literature or theory and only serve to confuse the issues.

The selected examples discussed from the Parsons critique illustrate the poor quality of their research and literature review, the lack of scientific rigor, and lack of understanding of key issues. The credibility of Parsons is undermined by their unsupported assertions, lack of citations, and ignorance of central concepts in geomorphology.

References

Biedenharn, D. S. and Copeland, R. R. (2000). “Effective Discharge Calculation,” US Army Corps of Engineers, Report ERDC/CHL HETN-II-4. Available online at http://chl.wes.army.mil/library/publications/hetn/hetn-ii-4.pdf

Church, M. (1992). “Channel Morphology and Typology,” in Calow, P. and Petts, G. E. (eds.) *The Rivers Handbook: Hydrologic and Ecological Principles, Volume 1,* Blackwell Scientific Publications: London, UK.

Collier, M., Webb, R.H., and Schmidt, J.C. (2000). “Dams and Rivers, A Primer on the Downstream Effects of Dams,” U.S. Geological Survey Circular 1126, Denver, Colorado, 94 pages.

Copeland, R. R., Biedenharn, D. S., and Fischenich, J. C. (2000). “Channel-Forming Discharge,” Hydraulic Engineering Technical Note, U.S. Army Engineer Research and Development Center, Vicksburg, MS. Available online at http://chl.wes.army.mil/library/publications/hetn/hetn-ii-5.pdf

Dominick, D. S. and O'Neill, M. P. (1998). "Effects of Flow Augmentation on Stream Channel Morphology and Riparian Vegetation: Upper Arkansas River Basin, Colorado," *Wetlands*, 18(4)591-607.

Friedman, J. M., Osterkamp, W. R., Scott, M. L., and Auble, G. T. (1998). "Downstream Effects of Dams on Channel Geometry and Bottomland Vegetation: Regional Patterns in the Great Plains," *Wetlands,* 18(4):619-633.

Graf, W. L. (1978). "Fluvial Adjustments to the Spread of Tamarisk in the Colorado Plateau Region," *Geological Society of* America *Bulletin,* 89:1491-1501.

Gyssels, G. and Poesen, J. (2003). "The Importance of Plant Root Characteristics in Controlling Concentrated Flow Erosion Rates," *Earth Surface Processes and Landforms,* 28:371-384.

Hedman, E. R., Kastner, W. M., and Hejl, H. R. (1974). "Kansas Streamflow Characteristics, Part 10—Selected Streamflow Characteristics as Related to Active-Channel Geometry of Streams in Kansas," Kansas Water Resources Board Technical Report No. 10.

Johnson, W. C. (1994). "Woodland Expansion in the Platte River, Nebraska: Patterns and Causes," *Ecological Monographs,* 64(1):45-84.

Johnson, W. C. (1998). "Adjustment of Riparian Vegetation to River Regulation in the Great Plains, USA," *Wetlands,* 18(4):608-618.

Lane, E. W. (1955). "Design of Stable Channels," *Transactions of the ASCE,* 120:1234-1279.

Leopold, L. B. and Maddock, T. Jr. (1953). "The Hydraulic Geometry of Stream Channels and Some Physiographic Implications," USGS Professional Paper 252.

Murphy, P. J., Randle, T. J., and Simons, R. K. (2001). "Platte River Sediment Transport and Riparian Vegetation Model," Bureau of Reclamation, Technical Service Center, Denver, CO.

Murphy, P. J. and Randle, T. J. (2003). "Platte River Channel: History and Restoration," Bureau of Reclamation, Technical Service Center, Denver, CO.

Osterkamp, W. R. and Hedman, E. R. (1977). "Variation of Width and Discharge for Natural High-Gradient Stream Channels," *Water Resources Research,* 13(2):256-258.

Osterkamp, W. R. and Hedman, E. R. (1982). "Perennial-Streamflow Characteristics Related to Channel Geometry and Sediment in Missouri River Basin," USGS Professional Paper 1242.

Osterkamp, W. R., Fenton, M. M., Gustavson, T. C., Hadley, R. F., Holliday, V. T., Morrison, R. B., and Toy, T. J. (1987). "Great Plains," in Graf, W. L. (ed.), *Geomorphic Systems of North America,* The Geological Society of America: Boulder, CO.

Randle, T. J. and Samad, M. A. (2003). “Platte River Flow and Sediment Transport between North Platte and Grand Island, Nebraska (1895-1999),” Bureau of Reclamation, Technical Service Center, Denver, Colorado.

Schumm, S. A. and Meyer, D. F. (1979). “Morphology of Alluvial Rivers of the Great Plains,” Great Plains Agricultural Council, publication no. 191, pp. 9-14.

Soar, P. J. and Thorne, C. R. (2001). “Channel Restoration Design for Meandering Rivers,” U.S. Army Corps of Engineers, Coastal and Hydraulics Laboratory, ERDC/CHL CR-01-1, Vicksburg, Mississippi.

Surian, N. and Rinaldi, M. (2003). “Morphological Response to River Engineering and Management in Alluvial Channels in Italy,” *Geomorphology*, 50:307-326

Viles, H. A. (1988). *Biogeomorphology*. Blackwell: Oxford, UK.

Williams, G. P. and Wolman, W. M. (1984). “Downstream Effects of Dams on Alluvial Rivers,” USGS Professional Paper 1286.

Yang, C. T. (1973). “Incipient Motion and Sediment Transport,” *Journal of the Hydraulics Division, ASCE*, 99:1679-1704.

Yang, C. T. (1986). “Dynamic Adjustment of Rivers,” 3rd International Symposium on River Sedimentation, Jackson, MS.

Yang, C. T. (1996). *Sediment Transport: Theory and Practice.* McGraw-Hill Companies, Inc., New York. (Reprinted by Krieger Publishing Company, Malabar, FL, 2003.)

Yang, C. T. and Song, C. C. S. (1979). “Theory of Minimum Rate of Energy Dissipation,” *Journal of the Hydraulics Division, ASCE*, 105:769-784.