The geomorphic role of large instream wood in river avulsions

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Key Points

- Channel avulsions move through a 5 stage evolutionary model
- The delivery of wood in each stage of the avulsion is driven by the relative rate of channel widening
- Instream wood has the largest hydraulic influence during the initial stages of avulsion development
- Once avulsion is complete, the hydraulic influence of individual logs is minimal, but the formation of log jams can be a moderate driver of channel inefficiencies, potentially inducing another avulsion

Abstract

The presence of large instream wood in rivers impacts the routing of sediment and flow through the channel, ultimately influencing the evolution of channels and floodplains through geologic time. The avulsion or abandonment of a river channel in favor of a new course on the floodplain is integral to the development and maintenance of anabranching planform and floodplains. Avulsions tend to occur on rivers where the rate of vertical aggradation outpaces lateral migration. In fine cohesive floodplain sediments, channel avulsions can be conceptually modelled using a five stage channel evolution model during which the daughter channel incises and adjusts to the continued capture of flow and sediment from the parent channel. In this paper we investigate the importance of individual pieces of wood and log jams in each of these five stages. A mass balance wood delivery model, and a channel evolution model was run in a Monte Carlo simulation. The potential hydraulic influence for individual logs and log jams to block the channel was calculated using the Darcy-Weisbach equation for uniform flow. Our results show that there are critical points in the evolution of avulsions when individual logs and jams can act to slow the rate of avulsion during the first two stages, but have minimal effect in the final three stages of the avulsion evolution sequence.

Keywords

Large woody debris, avulsion, alluvial ridge, wood delivery model

Introduction

The avulsion or the abandonment of a river channel in favour of a new course on the floodplain is an integral and natural process in the development and maintenance of anabranching planform and corresponding floodplain stratigraphy. How often a river channel avulses and how long the completion of an avulsion takes is a function of the autogenic and allogenic processes acting on the river. Schumm et al. (1996) developed a conceptual model of the avulsion sequence, showing that the river moves through a series of five stages. Building on the work of Schumm et al. (1996), Stout (2016) was able to reconstruct the length of each evolutionary stage of the avulsion sequence for a Holocene avulsion on the King River floodplain. In each of these bodies of work, the presence of wood has been implied, but not explicitly accounted for. The delivery and storage of large wood to the river channel is an autogenic process that has shown to be a potential driver of avulsions (Makaske, 2001; Sear et al., 2010; Phillips, 2011, 2012). Wood and live vegetation in the river channel, acts as a roughness element impeding the routing of flow and sediment through the channel (Gippel, 1995; Abbe and Montgomery, 1996; Bocchiola et al., 2002; Gurnell, 2013).

A common practice of river management over the last century has been removal of large instream wood (Erskine and Webb, 2003; Wohl, 2014). Now, as managers and researchers have realized that wood is an important factor in the types and rates of ecological(Beechie and Sibley, 1997; Beechie et al., 2000; Howson et al., 2012) and geomorphological processes (Bilby, 1984; Gurnell et al., 2002; Brooks et al., 2004; Andreoli et al., 2007; Bertoldi et al., 2011; Collins et al., 2012), catchment managers are now allowing wood to once again accumulate in river channels (Beechie et al., 2000; Fox and Bolton, 2007). In Australia, many of the lowland rivers exhibit an anabranching planform, and were desnagged or cleared in part to stop or slow developing channel avulsions (Strom, 1962). Now as wood loads begin to recover, either by natural recruitment of wood to the channel, or by mechanical placement during restoration projects, there is a concern that increasing wood loads will force a new avulsion rendering. A new channel avulsion may render ineffective any restoration projects implemented on the river, destroying infrastructure on the floodplain, and leading to a loss of private land.

As wood loads increase in recovering river channels, particularly those river where avulsions have occurred in the past (expressed as paleochannels on the floodplain) there is a need to understand the role that individual logs and log jams play in blocking the channel and diverting flow onto the floodplain. In order to understand if a recovering wood load will force new avulsions, we first need to understand the geomorphic and hydraulic impact of wood during the avulsion sequence. This paper investigates the added roughness from instream wood during each stage of the avulsion sequence. We run a simple channel evolution model coupled with a mass balance wood delivery model to estimate the load of wood and channel dimensions through time. Using results from the channel evolution and wood delivery models, and assumptions regarding flow depth and average flow velocity, we back calculate the estimated Darcy-Weisbach friction coefficients for each stage of the avulsion sequence.

Methods

Study Area

The channel modelled in this study was modelled after a section of the King River in NE Victoria. The study area is a 10 km section of the King River. The King River is a north flowing tributary of the Ovens River, with its headwaters in the Great Dividing Range of Victoria. At the study site, it has a catchment area of approximately 1356 km^2. The planform of the channel in the study section is classified as anabranching (Schumm et al., 1996), with an average channel slope of 0.004. The river has steep banks associated with cohesive sediments, an average channel depth of 3 meters and average bankfull width of 25 meters (DEPI, 2013). Flow regulation in the catchment is minimal, with only a small (13.5 x 10^6 m^3 capacity) reservoir in the upper reaches of the catchment. No major tributaries enter the river within the study site.

Components of the delivery and channel evolution model

We used the King River as a template for channel dimensions during each of the five stages. Figure 1 shows the location of the channels in different evolutionary stages on the floodplain that were used to estimate the size of the channel for each stage. Using the duration and description of process occurring in each stage of the avulsion sequence (Figure 2) from Stout (2016), and assumed relationships between discharge and channel dimensions from the literature, we developed a simple channel evolution model. Then by using the changing channel dimensions through time, and an assumed riparian forest type we estimated the load of wood from a mass balance wood delivery model. Results from each time step in the channel evolution model and wood delivery model were used to calculate the total Darcy-Weisbach friction coefficient, and the individual friction coefficient for the bed/bed forms, bends in the river, and the load of wood in the channel.

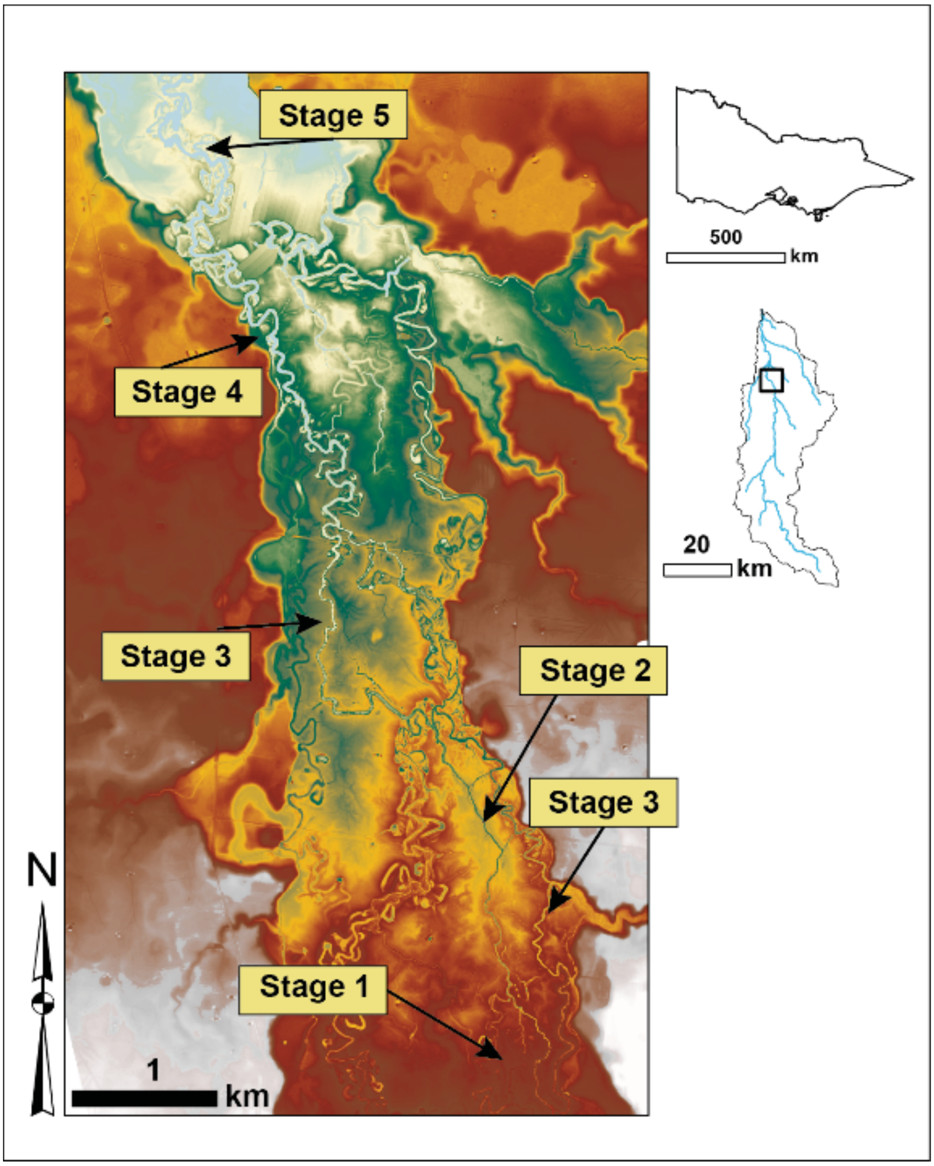
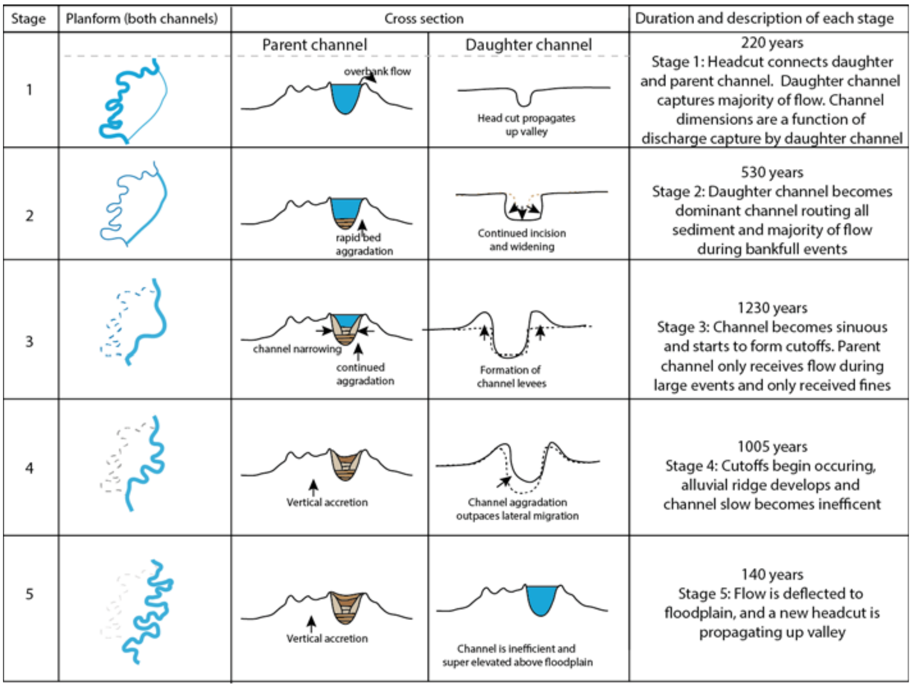


Figure 1. Location of King River. Each stage of channel evolution is present on the floodplain. Channel dimensions of each stage were used to develop the channel evolution model.

The added roughness of wood in a channel can be described using the Darcy-Weisbach friction coefficient. Similar work has been done to partition the amount of resistance in a river channel due to the bed, bends and debris (Shields and Gippel, 1995, 1996). Ideas and assumptions based on the development of gullies (i.e. an avulsion), discharge partitioning between flow bifurcations, and the Darcy-Weisbach friction coefficient (as described in Shields and Gippel (1995)) were used to predict the described added resistance to flow from both the changing dimensions of the channel, and the changing wood load during each stage of the avulsion sequence.

Table 1, provides a list of each of the different model components, assumptions regarding the component, equations used in the simulation, and a list of sources from where the ideas and assumptions were gathered. Each component of the model was calculated for each time step (1 year), and run in a Monte Carlo simulation for 1000 iterations to determine the maximum and minimum values the could be achieved given the assumptions and the equations.



Stage	Planform (both channels)	Cross section		Duration and description of each stage
		Parent channel	Daughter channel	
1		overbank flow	Head cut propagates up valley	220 years Stage 1: Headcut connects daughter and parent channel. Daughter channel captures majority of flow. Channel dimensions are a function of discharge capture by daughter channel
2		rapid bed aggradation	Continued incision and widening	530 years Stage 2: Daughter channel becomes dominant channel routing all sediment and majority of flow during bankfull events
3		channel narrowing continued aggradation	Formation of channel levees	1230 years Stage 3: Channel becomes sinuous and starts to form cutoffs. Parent channel only receives flow during large events and only received fines
4		Vertical accretion	Channel aggradation outpaces lateral migration	1005 years Stage 4: Cutoffs begin occuring, alluvial ridge develops and channel slow becomes inefficent
5		Vertical accretion	Channel is inefficient and super elevated above floodplain	140 years Stage 5: Flow is deflected to floodplain, and a new headcut is propagating up valley

Figure 2. Representation of 5 stage evolutionary model as describe by Schumm et al. (1996), and additional description of stages and timings of stages from Stout (2016). Stage lengths are based on average OSL ages reported in Stout (2016). These timings are used to drive the channel evolution and wood delivery model.

Table 1. Components of the wood delivery and channel change model using in the Monte Carlos simulation. Assumptions and equations used for the model are listed with sources while aided in the development of the ideas and assumptions

Model component	Assumption	Equation	Source
Flow partitioning	Initial discharge in the daughter channel is 10% of flows in the parent channel. Flow capture rate follows a log logistic growth curve. We assume an unstable bifurcation, so that the daughter channel gradually captures an increasing amount of flow for each time step. Flow modelled was based on the bankfull discharge of the King River (66 cms)	$Q_d(t) = \frac{Q_p}{1 + e^{-k(x-x_0)}}$ Q_d(t) is the discharge in the daughter channel at each time step. Q_p is bankfull discharge of the parent channel. K is the rate of flow capture of the daughter channel (assumed to be 0.025 $m^3 s^{-1}$ per year) and x_0 is the midpoint of the curve (assumed to occur at 375 years after avulsion starts)	(Kleinhans et al., 2013; Kleinhans and Hardy, 2013)
Width	Width changes are driven by the increasing amount of flow captured by the daughter channel and can be modelled as the development of a gully	$W(t) = W_s Q_t^{0.5}$ W(t) is the width of the channel at each time step. W_s is the initial width of the channel once the head cut has connected the daughter channel to the parent channel (assumed to be 3m wide from field observations)	(Sidorchuk, 1999)
Depth	Depth is also driven by increasing amount of flow captured by the daughter channel and is modelled as the development of a gully	$D(t) = D_s Q_t^{0.48}$ D(t) is the depth of the channel at each time step. D_s is the initial depth of the newly formed daughter channel	(Sidorchuk, 1999)
Flow depth	Assume that the flow captured by the daughter channel fills the channel to the top of the banks.	$D_f \cong D(t)$ Where D_f is the depth of water in the channel	Field observations
Channel Area	Assuming that bank angles range between 50 and 35 degrees. Area for each cross section was estimated using the area of a trapezoid	$W_t + \frac{\left[W_t - \frac{2D_t}{tan(\theta)}\right)}{2} * D_t$ Where A(t) is the area of the channel	Field observations
Average Velocity	Due to a lack of available data on flow velocities during an avulsion. Estimated manning's N from the channel dimensions and channel slope. Velocity was then calculated by solving the manning's equation	$n = 0.217A^{-0.173}R^{0.267}S^{0.156}$ Where A is channel area, R is hydraulic radius, and S is the channel slope. $V = \frac{R^{2/3}S^{1/2}}{n}$ Where V is average velocity for the reach	(Dingman and Sharma, 1997)
Wood delivery	Assume that delivery is primarily from bank erosion and mortality of trees. Also assume that 10% of the load is in transport, but that over long time periods the in/out of transported wood is equal. Wood load is reported as the volume of wood over 100 meters (m^3/100m)	$L(t) = \sum_{i=1}^{n} \Delta S_i$ Where L(t) is the load of wood in each time step. ΔS is the change in storage in the reach $\Delta S = I - O$ Where I is the volume delivered into the reach and O is the volume removed from the reach $I = [\![(BM]\!]_{vol} * E_b) + [\![(BM]\!]_{vol} * P_m) + Q_{in}$ Where BM_{vol} is the volume of biomass on the river banks, E_b is the erosion rate of the banks, P_m is the proportion of the stand that dies and falls into the river, and Q_{in} is the volume wood transported into the reach $O = [\![(L]\!]_{t-1} * D) + Q_{out}$ L_{t-1} is the load of the previous time step, D is decay rate, and Q_{out} is the volume of wood transported out of the reach	(Martin and Benda, 2001; Benda et al., 2003)
Bank erosion	During the avulsion bank erosion is calculated as the change in width from the previous year. After the avulsion is complete – average bank erosion is 1cm per year and follows a Weibull distribution with a scale of 1cm/year and a shape of 1.5. Data from M. Stewartson	$E_b = W_t - W_{t-1} + E_n$ Where E_b is the bank erosion rate, W_t is the channel width of the current time step and W_{t-1} is the width of the previous time step, and E_n is the background erosion rate. E_n is given by a random value drawn from Weibull probability distribution for that time step $E_n = \frac{a}{b}\left(\frac{x}{b}\right)^{a-1} e^{-\left(x/b\right)^a}$ Where a is the shape of the Weibull distribution, b is th scale (or central tendency of the data), and x is the observed data.	M. Stewartson (unpublished data), (De Rose et al., 2005)

Mortality	Assume that mortality rates are assumed to follow a Weibull distribution of the biomass of trees on the river bankt. Assume a shape of 1, and a scale of 0.03 (3 percent).	$P_m = \frac{a}{b}\left(\frac{x}{b}\right)^{a-1} e^{-\left(x/b\right)^a}$ Where Pm is proportion of the biomass that dies and falls into the river, a is shape b is the scale parameters of the Weibull distribution	(Monserud and Sterba, 1999)
Volume of trees on banks	During stages 1 and 2 the forest on the banks is that of grassy floodplain forest (EVC code 1040) after stage 2 assume a Floodplain riparian woodland (EVC code 0056). The spacing of trees was estimated using the EVC layers descriptions regarding the number of large trees per hectar over a diameter of 0.8m (10 and 15 respectively). Then assuming a Weibull distribution of tree diameters with a shape of 1, but not allowing for diameters less than 0.1m or larger than 1m to occur, a tree diameter was then randomly selected from the estimated Weibull distribution. A height was calculated for each random draw using a relationship between tree diameter and height, then the volume of the tree was estimated assuming a cylinder.	$D_{tree} = \frac{a}{b}\left(\frac{x}{b}\right)^{a-1} e^{-\left(x/b\right)^a}$ $H_{tree} = 0.28\ln(D_{tree}) + 0.27$ $V_{tree} = \pi\left(\frac{D_{tree}}{2}\right)^2 H_{tree}$ $S_p = \frac{a}{b}\left(\frac{x}{b}\right)^{a-1} e^{-\left(x/b\right)^a}$ $BM_{vol}\left(D_{tree}, S_p\right)$ Therefore, the BM_{vol} (biomass on the bank) is a function of the Spacing of trees (S_p) and the diameter of trees (D_{tree}).	(DEPI, 2013; DELWP, 2016)
Tree fall angle and proportion in channel	Fall angles were assigned from a uniform distribution of angles between 0 and 90 degrees. The fall angle, the height of the tree and the width of the channel was used to determine the proportion of the tree that was inside the channel. It was assumed that the trees did not span the channel, but rather broke at one point so as to form a ramp in the channel.	$\theta_{fall} = \frac{1}{b-a}\ for\ x \in [a, b]$ Where θ_{fall} is the angle of fall, a = 0 and b = 90 $P_{chan} = \frac{\sqrt{\left(\llbracket(W\rrbracket_t * \sin\left(\theta_{fall}\right)\right)^2 + (W_t)^2}}{H_{tree}}$ Where P_{chan} is the proportion of tree that intersects the channel, W_t is the width of the channel at that time step, and H_{tree} is the height of the tree that falls.	(Benda et al., 2003)
Radius of curvature / wavelength	Radius of curvature is a function of the wavelength and sinuosity of the channel. Wavelength is a function of the channel width. Assume that sinuosity stays around 1 during stages 1 and 2, and then linearly increase to reach the max sinuosity at the end of stage 4.	$\lambda = 11.0W_t^{1.01}$ Where λ is the wavelength of the meander belt $Rc = \frac{\left(\lambda K_t^{1.5}\right)}{\left[13\left(K_t - 1\right)^{0.5}\right]}$ Where Rc is the radius of curvature and K is the sinuosity of the channel at each time step.	(Leopold and Wolman, 1960; Langbein and Leopold, 1970)
Sinuosity	Initial sinuosity starts at 1, and progresses to observed sinuosities on the King River (ranging between 1.8 and 2.6)	$K(t) = \frac{K_s - K_f}{T_4 - T_2} * t, \qquad T_2 \le t \le T_4$ $K(t) = K_s, \qquad t < T_2$ $K(t) = K_f, \qquad t > T_4$ Where K(t) is the sinuosity of the channel for each time step. K_s is the starting sinuosity, K_f is the final sinuosity, t is the current year in the model, and T_2, T_4 are the start of stages 2 and 4 respectively.	(Schumm et al., 1996; Judd, 2005; Judd et al., 2007)
Channel slope	Channel slope starts as the same slope of the floodplain, and decreases through time as the daughter channel becomes more sinuous through time. Assumed that the avulsion length is 1 km	$S(t) = \frac{S_{fp}}{K_s + \frac{K_f - K_s}{T_4} * t}$ Where S(t) is the slope of the channel for that time step, S_{fp} is the slope of the floodplain, and t is the current year of the model	(Judd, 2005; Judd et al., 2007)
Channel Change	Assume that as the daughter channel adjusts to the increasing flow (i.e. widening and deepening) that a reciprocal change takes place in the parent channel (i.e. narrowing and shallowing of the parent channel)	$\frac{Q_p}{Q_d} = \frac{A_p}{A_d} * \frac{V_p}{V_d}$ Where Q_p and Q_d is the discharge in the parent and daughter channels respectively. A is area, and V is velocity, each respective to the parent and daughter channels	(Toonen et al., 2012)

Partition friction due to bed, bends, and wood load	Used Darcy-Weisbach equation for uniform flow in an open channel (assume that flow is uniform and steady for each time step. The total friction coefficient was calculated for the reach. Using methods from Shields and Gippel (1995), their equation 9, each component was set equal to the Darcy-Weisbch equation and solved for the friction coefficients of the bed/bed forms of the river, bends in the river, and the wood load.	$S_e = S_{chan} = \frac{f_t \alpha V_m^2}{8gR_{av}}$ Where S_e is the slope of the energy line, assumed to be the slope of the water surface (S_{chan}), f_t is the total friction coefficient, α is the kinetic energy correction factor (assumed to be 1.15) V_m is the reach mean velocity, g is gravity, and R_{av} is average hydraulic radius. Shields and Gippel (1995) eq. (9) is: $S_e = \frac{\tau_b}{\gamma R_{av}} + \frac{\sum \left[{}^{W_t}/_{R_c}\right] \alpha V_m^2}{gL} + \frac{\sum D_t}{\gamma A_{av} L^*}$ Where τ_b is the shear stress on the bed, λ is the specific weight of water, Rav is hydraulic radius, Wt is the width of the water surface, Rc is the radius of curvature, g is gravity, L is the length of the reach and L* is the length of the control volume. D_t is the form drag of a solid object in fluid, and was solved using Shields and Gippel (1995)equations 12,13, and 16.	(Shields and Gippel, 1995, 1996)
Spatial distribution of wood load	Assume that the spatial distribution of wood in the channel is a function of stream power, density of logs (ρ_{log}), the length/width ratio of the logs to the width of the channel (L*), and channel sinuosity (K). Spatial distribution of the load of wood can be described in Victorian rivers using a Weibull distribution (Stout, 2016) where the shape parameter is the spatial distribution and the scale parameter is the mean.	$V(x) = \frac{a}{b}\left(\frac{x}{b}\right)^{a-1} e^{-\left({}^{x}/_{b}\right)^{a}}$ Where V(x) is the load of wood as a function of distance, a is the shape of the distribution and b is the scale. $b = \frac{1}{n}\sum_{l=1}^{n} L_l$ Where b is the scale parameter and L is the load of wood in each section of the reach $a = 20.2 + \ln\left[\frac{{}^{L^*}/_{K}}{{}^{\Omega}/_{\rho_{log}}}\right]$ Where a is the scale parameter of the distribution, Ω is total stream power, and L* is the length to width ratio of the wood in the river, K is sinuosity, and ρ_{log} is the density of the dominant tree type in the riparian forest (*Eucalyptus calamundensis*).	(Stout, 2016)

Results

As the avulsion, or daughter channel begins to develop, more flow is captured in by the daughter channel, and as a result the daughter channel deepens and widens, therefore delivering more wood into the channel. Due to space constraints, the results of the channel dimensions are not reported here, but are available on request from the authors. Figure 3 reports the load of wood through each of the stages of the avulsion (top panel) and the partitioning of the resistance in the channel between the three dominant factors, the bed, bends, and the wood load (bottom panel).

Wood loads and channel resistance through time

During stage 1, channel change is minimal as the bifurcation between the parent and daughter channel slowly routes and increasing amount of flow down the daughter channel. Channel change in stage 1, is slow, as is the rate of wood delivery. As the daughter channel continues to increase in width and depth, the most rapid channel change takes place in the middle of stage 2. As a result the load of wood (m^3/100m) is largest during this stage. However, once the daughter channel becomes stable and is now the dominant channel, even though trees and logs are continuing to be delivered there is a surplus of wood in the channel, and the stored wood begins to decay away, resulting in a depleting and rotten load of wood. As the channel progresses through stage 3, delivery of new wood to the channel replaces the rotten load, and eventually the load of wood becomes stable midway through stage 3, and maintains a consistent load of wood for the remaining stages (stages 4 and 5).

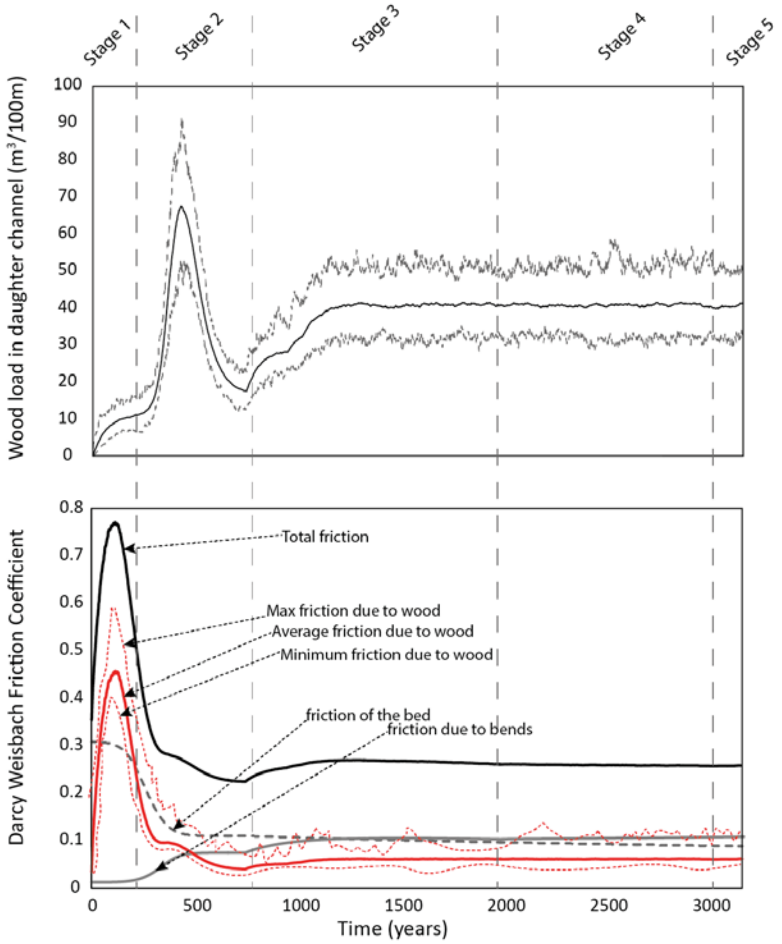


Figure 4. Top panel reports the load of wood through time in the daughter channel for each of the five stages of evolution. The load of wood peaks in the second stage due to rapid channel expansion during the capture of flow and sediment from the parent channel. And then as background erosion rates stabilize, the load of wood reaches a steady state near the middle of the stage three. The bottom panel is a breakdown of the Darcy-Weisbach friction coefficient of each of three factors estimated for the model. The solid black line is the total resistance in the channel, the grey dashed line is the resistance due to the bed, and the solid grey line is resistance to bends. The solid red and dashed lines depict the added resistance from a changing load of wood. The Influence of the wood peaks early in stage one as the channel dimensions are small. The oscillations in the maximum and minimum effects are due to the potential influence of the formation of log jams as wood becomes more easily transported as the channel widens, and the wood begins to decay.

Due to the changing channel dimensions and wood loads through time the total resistance of the channel fluctuates, peaking early in stage 1, then decreasing through stage 2 and finally stabilizing in stage 3. Individual components of resistance (bed, bends, and instream wood) fluctuate in the first two stages, but then stabilize late in stage 2. The resistance due to the bed of the channel slowly decrease as the channel widens and becomes deeper with time, until the daughter channel has reached the maximum dimension in the middle of stage 2. The resistance due to the presence of bends, slowly increases as the daughter channel develops meanders and begins to slow increase as the daughter channel reaches maturity in stage 3 and continues to increase in sinuosity through time. The added resistance due to wood loads (solid red (average) and red dashed lines (max/min)) peaks early in stage 1 and then rapidly decreases as the daughter channel reaches the maximum dimensions. The variations in the maximum and minimum resistance of due to wood loads is largely due to the spatial distribution of wood loads in the channel, and the stochastic formation of log jams.

Discussion

The results from this study provide two main ideas. First, individual logs and log jams are hydraulically more important during the development stages of the avulsion. The rapid delivery of wood to the developing channel during the avulsion creates such a hydraulically rough environment that shear stresses are reduced and the overall timing required to capture the majority of flow and sediment from the parent channel is lengthened. It is important to note that, the clearing of floodplain forests has likely increased the rate of avulsion development. This increase in the rate of capture could result in a faster avulsion (near instantaneous) with just a few floods (Brizga and Finlayson, 1990; Schumm et al., 1996). Additionally, an avulsion across a cleared floodplain will not accumulate a wood load until a riparian forest is able to establish on the banks of the new channel (30 to 40 years). Although this may not have an impact on the load of wood in the long term evolution of the river, from a management perspective the avulsion could potentially require immediate intervention, such as the planting of a riparian forest and the placement of wood in the river channel to provide habitat for aquatic fauna.

The second main idea is that the potential of for wood to cause an avulsion in the later stages of channel evolution are minimal, unless a log jam forms and persists long enough for a new avulsion to develop, interpreted here as the length of stage 5 (140 years). More importantly, as individual logs do not have a large impact on hydraulics, allowing new wood to accumulate or be placed in the river as part of a restoration project, will not cause a new avulsion to develop on the floodplain. If the river channel is nearing a stage 4 or 5, (i.e. head cuts moving up on the floodplain, evidence of channel narrowing, and the channel is highly sinuous) any restoration projects placing wood or log jams needs to ensure that a large proportion of the channel will not be blocked (Shields and Gippel, 1995). We would argue that in most cases where a new avulsion is currently developing on the floodplain the parent channel has already become inefficient and is set up for the avulsion to occur and that the placement of individual logs will have little impact of the initiation of a new avulsion. Additionally, as log jams are a potential cause of avulsions (Gibling et al., 2010; Sear et al., 2010; Phillips, 2012), the avoidance and removal of vegetation that easily transports (i.e. willows) would aid in not exacerbating the rapid deflection of flow into the daughter channel through the formation of large log jams during floods.

Conclusion

Many of our lowland rivers in Australia exhibit the anabranching planform. These types of rivers maintain this planform through the process of avulsions. During the five stage avulsion process, the added resistance of wood in the channel likely acts to slow down the avulsion in the early development stages, and unless if large log jams form in the later stages, individual logs and small log jams have minimal influence on the deflection of flow to the floodplain. As avulsions develop, a lack of forested floodplains may result in the faster completion of the flow and sediment capture by the daughter channel, and eventually require intervention by the catchment managers.

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