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Interactive comment on "The influence of a vegetated bar on channel-bend flow dynamics" *by* Sharon Bywater-Reyes et al.

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Interactive comment on "The influence of a vegetated bar on channel-bend flow dynamics" by Sharon Bywater-Reyes et al.

AC: We thank the reviewers for their insightful comments, to which we have responded in detail below. Major revisions to the paper include A) reframing the introduction and motivation of the research by synthesizing what we know about vegetation and channel bends from the literature; B) clarifying details concerning methodology by adding this information to the main text or referring to the Supplement, where much of the details were already housed; C) more explicitly stating assumptions of modeling approach; and D) revising the discussion by deleting portions that bordered speculative

(fine-sediment deposition and channel geometry in vegetated channels) and adding in additional insights related to ecogeomorphic feedbacks and chute channels on vegetated point bars. We believe the manuscript is clearer and more focused. Thanks for your consideration.

Anonymous Referee #1

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RC1C1: General comments: I think this is an interesting study. My main concerns are that the introduction needs to include more of a literature review on what is already known about vegetation effects on flow within meander bends because many of the results presented (at least in terms of overall vegetation effects, perhaps not effects of density/vegetation stage) here are similar to previous laboratory studies. I also think that much of the discussion is highly speculative, which can be fine, but often the speculation exceeds the amount of data needed to be presented to support the suggested hypotheses.

AC1: We have rewritten much of the introduction, including moving material about previous studies (particularly flume studies) from the discussion to the introduction, and adding new text and literature citations to better represent the state of knowledge. We have reformulated the motivation for the work (knowledge gap) as a field-scale modeling approach. See next response.

RC1C2: Specific comments: Page 2, line 2: I would argue that vegetation impacts on altering the flow velocity itself (e.g. mean flow velocities, velocity profiles) as stated here have been very well studied. Flow steering, in parentheses, by vegetation has also received attention but none of the studies that have investigated this are cited here. For example, in the discussion you review many of the laboratory studies that have investigated flow in meander bends with and without vegetation. These studies already demonstrate that vegetation can steer flow toward the outer bank, which is one of the main points of this paper. It seems like these studies should be reviewed here to highlight what is already known, and what is not known that your study is trying to address. What is this study addressing that has not been previously answered? Right now the motivation for why this work is needed is not coming through in the literature review.

AC2: As noted above, we have substantially revised the introduction to better represent the state of knowledge and to clarify our motivation and the knowledge gap we are filling. Significant blocks of new text are as follows;

. . .. "Pioneer vegetation can occur on all bar types but is most likely to survive on nonmigrating bars, such as forced alternating point bars (Wintenberger et al., 2015). Plant traits including height, frontal area, and stem flexibility vary with elevation above the baseflow channel, influencing both the susceptibility of plants to uprooting during floods and their impact on morphodynamics (Bywater-Reyes et al., 2015, 2017b; Diehl et al., 2017a; Kui et al., 2014). Vegetation effects on hydraulics, bank erosion, and channel pattern also depend on the uniformity of vegetation distribution on bars, which can vary depending on wind versus water-based dispersal mechanisms (Van Dijk et al., 2013), and on whether plants occur individually or in patches (Manners et al. 2015). Experimental work in flumes has shown that vegetation is vital to sustaining meandering in coarse-bedded rivers (Braudrick et al., 2009). Vegetation's effect on stabilizing banks, steering flow, and impacting morphodynamics furthermore depends on seed density and stand age. Uniform vegetation on bars has been shown, experimentally, to decrease bank erosion rates, stabilize banks, and increase sinuosity of meander bends (Van Dijk et al., 2013). Gran and Paola (2001) showed that vegetation, by increasing bank strength, generates secondary currents associated with oblique bank impingement that may be more important than helical flows generated by channel curvature. Other experiments have generally suggested vegetated bars decrease velocities over the bar and push flow toward the outer bank. For example, tests in a constructed, meandering laboratory stream with two reed species planted on a sandy point bar showed that vegetation reduced velocities over the vegetated bar, increased

them in the thalweg, strengthened secondary circulation, and directed secondary flow toward the outer bank (Rominger et al., 2010). Another study in the same experimental facility, but using woody seedlings planted on the point bar, also found reduced velocities in the vegetated area of the bar, with the greatest reductions at the upstream end, and the effect varied with vegetation architecture and density (Lightbody et al., 2012). In a flume study where meandering effects were simulated in a straight channel by placing dowels representing vegetation patches in alternating locations along the edges of the flume, vegetation reduced velocity within and at the edges of the vegetation patch and increased velocities near the opposite bank (Bennett et al., 2002). Experiments in a high-curvature meandering flume, in contrast, showed that vegetation inhibited high shear-stress values from reaching the outer bank (Termini, 2016), inconsistent with studies simulating moderate sinuosity channels. . . .. As the above review suggests, there have been considerable advances in laboratory and computational modelling of vegetation effects on hydraulics that complement understanding of bar and bend morphodynamics and of the reciprocal interactions between riparian vegetation and river processes (Corenblit et al., 2007; Gurnell, 2014; Osterkamp and Hupp, 2010; Schnauder and Moggridge, 2009). Challenges persist, however, in representing field-scale complexities in a modelling framework to deepen insights into the feedbacks between plants, flow, and channel morphology on vegetated point bars. Here we tackle key elements of this problem by investigating the dependence of bend hydraulics on the distribution of woody vegetation, across a range of flood magnitudes, using a two-dimensional modeling approach informed by high-resolution topography and vegetation morphology data that spatially defines vegetation drag."

RC1C3: Page 3, line 18: A bankfull Shields number for a gravel bed river of 0.01 would imply there is no sediment transport at bankfull flow given that the critical Shields stress is typically greater than 0.03 (Buffington and Montgomery, 1997) for these rivers. It seems somewhat unlikely that there is no transport at bankfull?

AC3: We have recalculated bankfull Shields number using field observations of bankfull discharge from a broader set of locations in the study reach. The previously reported bankfull Shields number of 0.01 was for one specific location in our study reach, as reported in Bywater-Reyes et al. (2015, WRR). Updated calculations, from field observations at four locations, indicate bankfull Shields numbers ranging from 0.01 to 0.07. Hec-Ras solutions indicate a reach-average Shields number of 0.02 for the Q2 (slightly overbank) and FaSTMECH reach-average Shields number for the Q2 is 0.03. These values indicate our originally reported number of 0.01 was too low and that a value of 0.03 is more accurate. The text has been revised with the new value.

RC1C4: In addition, cross stream and downstream shear stresses, as well as Shields stresses, are mentioned in the methods but I don't ever recall them being quantified in the results or discussion (except a map of Shields stresses in Figure 4). Why are they brought up in the methods?

AC4: The Shields stresses are a function of velocity, so the results were very similar to those shown for velocity. We chose for that reason to show only velocity and the planview Shields map. We removed the associated Shields stress equations.

RC1C5: How did you distribute the vegetation on the bar? Did it cover the entire bar? Was it only in a certain zone where you expect vegetation to establish? The results that you obtain seem like they will be highly dependent on this chosen location and extent of the vegetation patch. For example, on Page 14, line 15: It is stated that the u and v velocities on the right side of the downstream of the vegetated bar (Figure 5) approach or equal those in the thalweg and that this is more pronounced with vegetation density. This is where the effect of vegetation patch distribution comes into play, if the vegetation patch did not extend to the channel bank then this is what one might expect. How much of this result is driven just by the lack of vegetation between the bar and the channel wall (I am assuming this is what you modeled)? Is such a complete break in vegetation likely to occur in nature?

AC5: The polygon (vegetated area) was chosen based on the mapped extent of vege-

tation (Fig. 1) on the bar of focus. This bar was the location of previous work (Bywater-Reyes et al., 2015) where vegetation densities, morphologies, and uprooting susceptibilities were determined. The results indeed may be sensitive to the delineation of this polygon. As the vegetation is represented in the model, however, drag from trees is assigned based on the density. The extent of vegetation on the bar as modeled is representative of the vegetation currently on the bar and of the strand lines of vegetation recruitment. The extreme scenarios (e.g. dense tress) may be dependent on the location of the patch, but the progression of increasing density and tree size illustrates the overall effect vegetation can have on flow steering.

RC1C6: Page 14, line 25: v values are not shown for XS2, which is near the bend apex and it is stated that the presence of vegetation did not really affect the v velocities. If the case is being made in the discussion that vegetation will change bank scour and meander migration, doesn't this result imply that at the bend apex, although the high downstream velocity core shifts toward the left bank, the actual direction of the flow is not deflected more toward this bank with the presence of vegetation? What does this mean for bank scour at the bend apex?

AC6: We will add figures for additional scenarios, including v values for all cross sections, to Supplement in the final revised manuscript. With respect to the Discussion (which has been revised, as described below), where we discuss our results relative to Parker et al. (2011), we note that Parker et al. (2011) is based on cross-stream gradient of streamwise velocities, not of v veocities.

RC1C7: Page 16, line 15-16: A low velocity region on the bar would imply lower sediment fluxes, but would not necessarily imply sediment deposition, which is the divergence of the sediment flux. Sediment deposition would only occur if the vegetation did not reduce the steering of sediment (sediment supply) into the patch itself. Given that you show that sometimes flow is steered away from the bar on the bar sides, it seems likely that the vegetation will also impact how much sediment enters the bar, and therefore whether deposition occurs.

AC7: We have reworded to indicate that fine sedimentation could occur.

RC1C8: Page 18, lines 12-27. Much of this discussion does not seem directly related to any of the results presented above, and in particular the comparisons of three bars with/without vegetation to state that there is a difference in w/d and channel narrowness is highly speculative. No w/d ratios are provided for the bars to demonstrate this. I am not clear how only three cross-sections at one study site with no variation in vegetation type (just vegetated vs. not vegetated) can be used to infer that floodplains with herbaceous vegetation may not have narrower channels than those with woody vegetation. Further, although the vegetated bar does have a deeper thalweg, it seems to often have lower elevations on the bar, which is contrary to the earlier discussion that vegetation would cause higher amounts of sediment deposition on bars.

AC8: We deleted this text and associated figure. We will revise Fig. 1 to remove the cross section locations.

RC1C9: Figure 8 and associated text: Although there are definitely locations where sand is collocated with vegetation, there are also locations where sand deposits are not located around vegetation, or that vegetation patches lack sand deposits. Can you provide more quantitative data to show that sand and vegetation are correlated such as % of sand patches within a certain distance of vegetation or something similar?

AC9: We deleted Fig. 8; our intention in including it was to show general relationships between vegetation and sediment patches, rather than to go further in quantifying correlations, which we consider outside the scope of this paper. We have added additional text to the Discussion (4.2) about vegetation and sedimentation on bars, drawing from literature.

RC1C10: Technical questions: Page 1, Lines8-9: You mention alternating bars and vegetation but then discuss bend hydraulics and forces. What kind of forces are you discussing here? Alternating bars do not have to be associated with bends and it is not clear how the second half of the sentence is related to the first. The rest of the

abstract seems to be geared toward a bar in a bend, which would normally be called a point bar? This comment is relevant throughout the paper where bar is used. It might be better to be more specific here about what kind of bar you mean.

AC10: We have changed the text to specify that we are modeling a point bar. We have removed the discussion of forces from the abstract but have retained a discussion of how the hydraulics would alter forces in the Discussion, where we can elaborate more.

RC1C11: Page 1, Line 11: “with and without varied vegetation parameters” is not clear here. Are you eliminating the parameters or the vegetation itself? What kind of parameters?

AC11: Reworded

RC1C12: Page 3, line 17: I don’t know if the condition of “few upstream dams” implies that flow and sediment supply are relatively unregulated. You can have just one dam upstream that can completely alter the hydrology and sediment supply downstream; it is just not the number of dams that control these parameters but how the dams are operated. Do the dams not alter the flow? Does sediment bypass the dams?

AC12: Added clarifying text ("…flow and sediment supply are relatively unaltered by flow regulation, because the only significant dam in the contributing watershed is ~120 km upstream of the study reach, on a tributary.")

RC1C13: Line 9, page 8: How was U_m determined? At a cross-section upstream of the vegetation that is free from the vegetation influence?

AC13: Um is the node velocity. We have added clarifying text.

RC1C14: Lines 4-7, page 9: The dense vegetation case is two orders of magnitude higher than the sparse case but both are averages on the same bar. It seems like these two averages should be the same if the average of local densities is representative of what would occur at the scale of the entire bar. Is this partly driven by the scale over which the measurements were taken, in that the 20 stems/m2 value is a local measurement and therefore likely to be higher? Is 20 stems/m2 a realistic value of stem density for an entire bar; is such an average density found in real rivers over the spatial scale of a bar?

AC14: Values in the range of our dense scenario (20 stems/m2) have been reported in diverse settings; we have added references. Furthermore, our objective is to investigate end-member seedling-density cases.

RC1C15: Line 11, page 9: If you are using the flow depth based on the model run without vegetation to assign Ac, won't this skew your Ac values because the actual flow depths will likely be higher in the presence of vegetation? Also in Figure 2c, there are many lines but only three stages of vegetation growth, and it is not possible to tell which relations were actually used in the model.

AC15: Yes, the values would be slightly skewed. It is a limitation of the method. In the revised final manuscript, we will revise Fig. 2 to more clearly show which relations were used in the model.

RC1C16: Equation (4): What grain size is used and did the grain size spatially vary in the stream, and in this calculation?

AC16: We used the median value from data collected over the region. Added clarifying text.

RC1C17: Other methods: How were the stage and nearby discharge used to calculate Q? Why is stage needed and not just a drainage area correction?

AC17: Stage is needed because water surface elevations at the downstream boundary, for specific modeled discharges, are used as a model boundary condition. We therefore needed to combine data from our measurements of stage with nearby gage measurements of Q. Added clarifying text.

RC1C18: How many topographic cross sections were measured in the channel, what was the spacing of the cross-sections and what was the actual point density of the

DEM in the channel?

AC18: Added more details to Supplement

RC1C19: No information is provided as to how water surface was measured, where it was measured and how many data points were measured for a given flow? A 18 cm RMSE for flow depth could be pretty large, depending on the flow depth magnitude. How large were water surface elevation and velocity RMSE relative to the flow depths and velocities measured in the channel? How many measured/log profile velocities were compared to the modeled velocities to obtain the RMSE? How good were the log profile fits to the measured velocities; are there large errors in what you are assuming to be measured depthaveraged velocities?

AC19: We added details concerning how water surface elevations were measured (and density of observations) to the Supplement. We have added the mean measured and modeled velocities for the velocity calibration to Table 1. We note that in other studies that have used FaSTMECH, velocity calibrations have similar magnitudes of error, or higher. For example, Legleiter et al., 2011 modeled the effects of a point bar on force balance of flow with FaSTMECH for a simple channel ∼60m wide with a bankfull discharge of 42.5 m3/s had a RMSE Åł of 0.27 m/s. The mean of their Åł was 1.57 m/s. This is quite comparable to our Åł calibration. Segura and Pitlick, 2015 had RMSE-Åł of 0.14 – 0.28 m/s for reaches with very small bankfull discharges (7 – 20 m3/s). Average Åł were not reported in their text, but appear to be ∼1 m/s from the figures. We provide details concerning the methods used in the Åł calibration in the Supplement. We added WSE plots to Supplement as well. Methods concerning the log profiles are in the Supplement.

RC1C20: Figure 5 It would help to have the direction of the v velocity (which way is negative) noted on the figure or in the caption. There really does not seem to be any change in the v velocity in the thalweg for the Q2 flow, contrary to what is stated in the figure caption.

AC20: Reworded caption.

RC1C21: Page 15, line 15: Can you give an example of where dense trees do not have the maximum impact on the flow velocity as stated here? I don't remember this being discussed in the results. Also, you have modeled the drag coefficient for vegetation as being a constant with vegetation density or plant size, but studies on vegetation have shown that this coefficient can change with vegetation spacing. How might this impact your results?

AC21: We reemphasized the example concerning dense young trees. Vegetation drag is an often unconstrained parameter. We have added a paragraph to the Discussion (end of 4.1) about limitations of our treatment of vegetation drag.

RC1C22: Page 15, line 20: It is stated that vegetation increased the magnitude of v at the down- stream end of the channel bend in the thalweg. In the associated figure, v either did not really change with vegetation or decreased with vegetation, implying instead that cross stream flow was not necessarily directed more toward the cutbank in this cross section. Secondary circulation should be present in all of these cross-sections and therefore, the direction of the v component of velocity will likely depend on the vertical position in the flow column. So I am not sure how much information the depth-averaged v provides in terms of the process of bank erosion? Perhaps you can comment on this.

AC22: u became more negative. We believe our statement "Vegetation increased the magnitude of cross-stream velocity (v) at both the up- and downstream end of the channel bend by increasing cross-stream flow toward the cutbank at the head of the bar and around the toe of the bar" is accurate. A more negative number at the downstream cross section implies more steering around the toe of the bar, as stated. The reviewer's observation regarding secondary circulation statement is valid, which is a limitation of the model.

RC1C23: Page 15-16, lines 30-2: What is similar or different in these studies in the

outdoor lab from your study and why are there differences in the studies? The discussion on what is similar or different is somewhat vague and do not really include hypothesizes why you might see different results in your model.

AC23: Moved info to introduction and placed study within the context of what is known.

RC1C24: Page 16, lines 10-11: It is stated that the flow velocities and shear stresses in the thalweg in the upstream cross-section are reduced with vegetation but in Figure 7, u is reduced but v is increased with vegetation and it is therefore not clear what will happen to shear stress (and sediment transport and erosion), which is not shown.

AC24: Figure 4 shows the Shields number, which is reduced

RC1C25: Conclusion: Please see my earlier comments above about whether vegetation will cause fine sediment deposition. Certainty this is what others have found, but I am not sure that the data you present allow you to say that deposition will occur unless you assume that the sediment input to the bar is not changed. It is not clear why cross-stream sediment transport would be reduced by the changes in flow that are mentioned, can you provide more information on this? I think the statement that "previously only attributed to bars" is not entirely true given that previous studies in meander bends have shown that vegetation can direct the flow toward the opposite bank.

AC25: We have rephrased

RC1C26: Figure 7: In the caption it is stated that v decreased by becoming more negative but changing from a low negative value to a higher negative value means that the velocity actually increased because the negative sign only denotes direction. I think that you mean less negative or at least that is what the figure appears to show to me but I can't really tell what part of "adjacent to the patch" you are referencing hereâĔŸA ĔĞTon the left or the right side?

AC26: Reworded

RC1C27: Comments on supplemental information: You alternate between u and U being velocity at a given elevation above the bed. I think you should pick one.

AC27: Fixed

RC1C28: It is not clear to me why you used the log profile fits instead of just using the measured velocity at 0.37h. Did you not always have this measured data point because of data exclusion near the water surface? It seems like using the measured values, if possible, would lead to less uncertainties than fitting a profile and then calculating a mean value from those fits. Or do you think there are large uncertainties in a given data point, making the profile fit more reliable? How many data points were used in the velocity profile fits?

AC28: We have missing values. Profiles were fit with a minimum of four points.

RC1C29: Lines 44-46: I find it slightly confusing what is being compared in this sentence. RMSE of the modeled values calculated either using the log profile or the extrapolated velocity values? Does FASTMECH assume a log profile in its calculations of mean velocity? If so could this partly explain why you obtained lower RMSE when using the log profile instead of using the extrapolated values to the water surface?

AC29: This is certainly possible, but since the values are missing, we can't really know the real difference. Yes, the model assumes a logarithmic profile. We followed a published procedure.

RC1C30: Line 64 Is this a standard error or deviation?

AC30: Added "standard deviation"

Please also note the supplement to this comment:
https://www.earth-surf-dynam-discuss.net/esurf-2017-56/esurf-2017-56-AC1-supplement.zip

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Interactive comment on Earth Surf. Dynam. Discuss., https://doi.org/10.5194/esurf-2017-56, 2017.