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Interactive comment on "Development of a meandering channel caused by the plane shape of the river bank" *by* T. Nagata et al.

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I am grateful that you spared your precious time to review this article. Please accept our sincerest thanks for your useful feedback. Responses to each point made by the reviewers are given below.

1. Please refer to Comment #2 in my responses to Referee 1.

2. In identifying dominant factors in phenomena that occur in the field, it is more appropriate to conduct model tests under simplified conditions than to analyze complex field data. Therefore, the authors had already conducted a movable-bed hydraulic model test under various conditions before conducting this study. The reproducibility of the sediment transport formula used in this study was tested on the basis of measurement

values obtained in this model test. In the model test, in order to maintain the similarity of the hydraulic and sediment transport phenomena between the site and the model,various experimental conditions in the model test were set such that the values of the dimensionless quantity (Fr, τ*), which have a dominant impact on both phenomena, would be consistent. This resulted in maintaining the similarity of width/depth ratio (B/h), which greatly affects the formation and configuration characteristics of alternating bars, at the same time. However, perfect similarity can not be maintained between the actual river and the model (similarity of the Reynolds number of the particles is not fulfilled). Therefore, it is unclear how much applicability the sediment transport formula, whose reproducibility was confirmed in the model-scale experiment, will have in a full-scale experiment. In addition, it is difficult to measure sediment transport during a flood, which means that it is also difficult to perform comparative verification using measured values. Given the above, it was determined to be appropriate to perform the analysis at a model scale that was confirmed to be able to reproduce hydraulic and sediment transport phenomena, and then to convert the obtained results to those at actual scale and discuss the phenomena that occurred at the actual place.

3. The structure of text might be somewhat complicated and confusing; however, the analyses of steady flow and unsteady flow were conducted with the following objectives in Section-1, and the results obtained for each are shown. The text from sections 3 to 5 of chapter 3 is summarized below. 1) First, in the analysis, three patterns of steady flow were given in order to see how the river channel would respond to the flows with different discharge scales. The analysis was made under the calculation condition that allows the characteristics of double-row bars to appear if a channel is straight; however, as the result of the analysis, fairly clear alternating bars formed immediately downstream of the bend in the river channel, regardless of the scale of discharge. (The original text: chapter 3, section 3, p. 8, L 14 - 26, Fig. 10) 2) Next, the analysis of an actual flood was performed to see how the river channel responded to the unsteady flow. The analysis found that, as in the the case of the steady flow, clear alternating bars formed immediately downstream of the bend in the river channel. That

is to say, it was indicated that factors other than scale of discharge and unsteadiness of discharge might have had a dominant impact on the formation of the alternating bars. (The original text:chapter 3, section 3, p. 8, L 27 - p. 9, L 11, Fig. 11) 3) Therefore, after that, focusing on the curvature of the river channel, another analysis of the actual flood was performed under the conditions where only the meander angle was changed. The analysis found that a bed morphology that was close to normal double-row bars appeared when the meandering angle was 0°. However, clear alternating bars came to form with increases in the meander angle. That is, it was presumed that the curvature of the river channel promoted the development of alternating bars. (The original text: chapter 3, section 5, p. 10, L 8 - p. 11, L 3, Fig. 14)

4. As boundary conditions for Section-1, it was assumed that the uniform flow depth was maintained at the downstream edge and the dynamic equilibrium (fixed) of riverbed elevation was maintained at the upstream edge. In the actual simulation, an approach zone of adequate length was connected to the analysis section so that the upstream edge would not affect the analysis zone (16 times as long as the width of the low-water channel, length = 1,600 m, straight channel). However, in response to the matters pointed out, the simulation section was further extended by 1,200 m in the downstream direction, and an additional test was conducted (Fig. 1). The sandbar formation process described in the figure indicates that the characteristics of double-row bars regulated by the river width and by the discharge first appeared in the approach zones (straight river channel) upstream and downstream of the analysis section. However, at this stage, bed morphology similar to the topography of alternating bars, which was distinctively different from the bed morphology at the upstream and downstream sections, had already been naturally produced at the bend in the river channel only in this section (the Section-1 bend in the figure). This phenomenon was remarkable at M-1, and the figure shows that the influence gradually propagated downstream. This result confirms that, as described in section 5 of chapter 3, the formation of alternating bars at M-1 was induced by the curvature of the river channel and was not dependent on the boundary conditions of the downstream edge.

5. Within the rangeof meander angel θ = 0 - 7° in Fig. 14 of the text, probably because of the gentleness of the angle, the relation between individual meander angle and sandbar formation position is not very clear. However, it is considered that a distinct point bar formed at M-1 after the meander angle exceeded 10° and the characteristics of meandering flow (wavelength, amplitude) propagated upstream and downstream, taking this point bar as the starting point, and eventually, the configuration characteristics of alternating bars appeared throughout river channel. As a typical case, the sandbar development process at the meandering angle of 13° is shown in Fig. 1.

6. The greatest difference between the two sections (Section-1 and Section-2) lies in the degree of bend in the riverbank planar shape, and this is considered to have had a dominant impact on the development process of the meandering channels in both sections. The degree of bend in the two sections can be expressed by using the meander angle of the normal line in the low-water channel and the wave length as follows (Fig. 2).

1) Section-1: Meander angle = 13°, Wave length = 3,200 m

2) Section-2: Meander angle = 32°, Wave length = 600 m (approximate values)

As shown in Fig. 5, it is possible to understand that the transition points of characteristics of river channel in the two sections are determined by the difference in the degree of bend in the low-water channels in the development history of the river channels in the two sections. As already discussed, river improvement work was done in Section-1, and in that project, the gently bending low-water channel with a linear shape close to a straight line and a few kilometers of wave length were constructed for the purpose of lowering the water level during floods. Therefore, it is considered that the straight water flow during the 1981 flood resulted in phenomena similar to those that can be seen in the sandbar development process in a straight channel. In this sandbar formation process, it was presumed that, first of all, a point bar formed due to the the curvature of the river channel at M-1, and then, characteristics of alternating bars propagated upstream and downstream, taking this point bar as the starting point. In Section-2, however, this point bar at M-1 that formed in Section-1 gradually developed into having a high wave height over a period of several decades, and before the 2011 flood, the highly curved low-water channel with a 600-m wave length and a meander angle of 30° had formed. In addition, the section immediately downstream of M-1 came to be a sublinear river channel due to work for straightening the low-water channel in 2005. The topography left in the channel like this (M-1) can produce strong meandering flow during a flood. It is believed that this topography led to the development of the meander channel accompanying the bank erosion at the early stage of the flood; thus, the scale of the development of the meandering channel that took place for the duration of one flood was amplified.

Interactive comment on Earth Surf. Dynam. Discuss., 1, 1019, 2013.

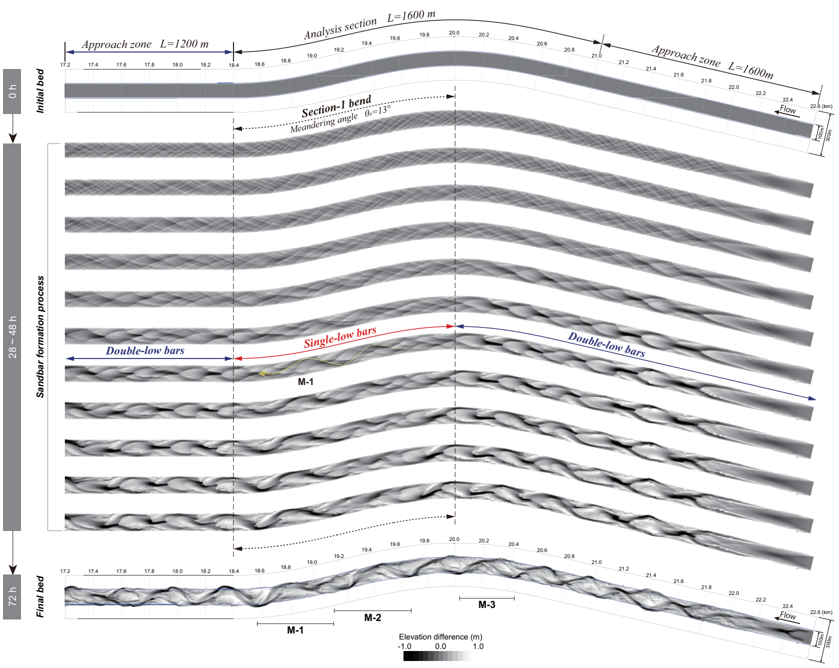

Fig. 1. Additional calculation in Section-1

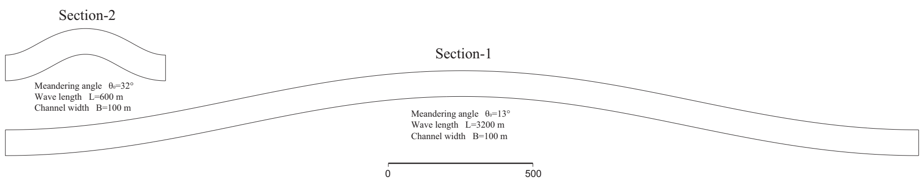

Fig. 2. Difference between Section-1 and Section-2