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Measuring Effect of Gravel Augmentation Using Radio Frequency Identification (RFID) in Mountainous Areas of the Trinity River, California

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Synopsis

The construction of dams and transport water from the Trinity River into the Sacrament River have had an adverse impact on habitat for aquatic animals. The Trinity River Restoration Program (TRRP) has conducted various projects to implement recovery of the Trinity River and its fish population. The objective of this paper is to estimate the mobility of the riverbed materials by tracing PIT-tags gravel using Radio Frequency Identification (RFID) system and to understand the tendency of deposition and scouring by computing the 2-dimensional (2D) model calculation for riverbed variation. From the results of the survey, we could detect the PIT-tags gravel at most 460 m downstream from the gravel injection point (IP) when floods have occurred twice after gravel injection and there is a possibility that the area of 200-250m downstream from IP seems to have a potential to catch gravel and to be a sandbar in the near future. On the other hand, from the results of the 2D model calculation, it seems that there is a periodical strong cycle for making geomorphological structure at several places. In especially, it suggests that the left bank area 325 to 400 m downstream from IP has a potential to catch the sediment. In other words, there is a possibility that sandbar is formed in the area.

Keywords: Trinity River Restoration Program (TRRP), RFID, PIT-tags, gravel augmentation, riverbed variation

1. Introduction

1.1 Trinity River Restoration Program (TRRP)

The construction of dams and transport water from the Trinity River into the Sacrament River have had an adverse impact on habitat for salmon and steelhead that the Hoopa and Yurok tribes live together for thousands of years (Stene, 1996; Kondolf, 1997 and 2009). The Trinity River Restoration Program (TRRP) has been at the forefront of putting much effort into coarse sediment management, gravel augmentation, channel rehabilitation activities and continuous monitoring below Lewiston Dam, to implement recovery of the Trinity River and its fish population (U. S. Bureau of Reclamation Trinity River Restoration Program, 2000).

1.2 Study area

(1) The Trinity River

The Trinity River is the largest tributary of the Klamath River in northwest California. Almost all basin is mountain area and there are Trinity dam and Lewiston dam in the upstream. It originates in the Scott Mountains and Trinity Alps of northern California, approximately 98 km upstream of Lewiston dam that has a function of transferring water from Trinity River to Sacramento River Basin to satisfy water demand. As figure 1 shows, the Trinity River receives water and sediment from several tributaries and joins with the Klamath River and finally flows into the Pacific Ocean (Gaeuman, 2014).

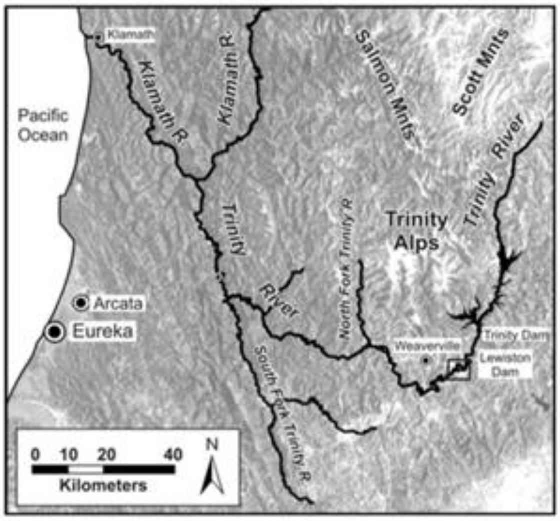

Fig. 1 Basin of the Trinity River

(2) The Lowden ranch reach area

The Lowden ranch reach area, which located about 11.5 km downstream from the Lewiston dam on the Trinity River, is one of the areas that TRRP focuses on from the viewpoint of gravel management and has conducted gravel augmentation activities since 2010 and the channel width is about 30 to 50m in this reach. As figure 2 shows, an island and a point bar were mechanically constructed in 2010 through the side channel excavation and gravel placement (Ock, 2012 and 2015).

1.3 Gravel augmentation activities

The ultimate purpose of TRRP gravel augmentations is to improve aquatic habitat with increasing quality and diversity. A complete account of where and how much gravel should be injected into the Trinity River must explain what habitat attributes are lacking and how adding gravel is expected to keep the quality or improve the situation of habitat for aquatic animals (Gaeuman et al., 2017; Sediment management in Alpine basins, 2013).

(1) Injection of PIT-tag gravel in May 2016

Now, we are focusing on gravel with Passive Integrated Transponder tags (PIT-tags) that injected in May 2016 as a good index to estimate the mobility of gravel. This gravel injection was put into operation at Lowden ranch reach in May 2016 and the total 1231m^3 of gravel containing 960 gravel that were installed PIT-tag into the inside of gravel were injected (Table 1). All gravel were injected by the loader and 40 PIT-tag gravel had been included in each loader bag. The average mass and diameter of PIT-tag gravel were 546.6 g and 73.8 mm respectively. According to the Particle distribution in this reach in 2016, D50 was 55.3 mm, therefore, the size of PIT-tag gravel was 18.5 mm larger than the average local gravel.

1.4 Objectives

The final goal of this research is to present a suitable method of gravel augmentation for aquatic habitat in the upstream of the Trinity River. As the

Fig. 2 Comparison of the channel in the Lowden ranch reach before mechanical construction (left picture in 2010) and current situation (right picture in 2016)

Table. 1 Information about PIT-tag gravel injection in May 2016 (*[1]: Bag means loader bag and each bag included 40 Pit-tag rocks and other gravels, *[2]: It's including PIT-tag gravel and other gravel injected)

	5/8/2016	5/9/2016	5/12/2016	5/13/2016	Total
Time	13:27~15:12	13:04~15:10	12:04~13:50	12:30~13:54	n/a
Total Number of PIT-tag gravel*[1]	240 (6 bags)	280 (7 bags)	240 (6 bags)	200 (5 bags)	960
Total amount of gravel*[2]	306 m^3	306 m^3	306 m^3	313 m^3	1231 m^3

first step, the purpose of this paper is to estimate the mobility of the river-bed materials by using the result of field surveys of tracing PIT-tags gravel using RFID system and to understand the tendency of deposition and scouring in the Lowden ranch reach by computing the 2D model calculation of riverbed variation.

2. Methods

2.1 Field survey with RFID devices

In the present study, we conducted field surveys from September to October 2017 at the Lowden ranch reach with devices and equipment, such as an RFID transponder, an antenna, a hand size reader, GPS, a rafting boat and an inflatable to detect PIT-tag gravel injected in 2016. Using these tools, we read information about tag-number of each gravel and recorded where and when we found them (Figure 3). Additionally, although TRRP conducted another survey in Oct. 2016 for the same purpose, a hand size antenna was used, which took much time to complete to conduct a field survey.

(1) Features of RFID

There are limitations for conducting detection PIT-tag gravel. As a functional limitation, the antenna has the range of detection due to its magnetic field strength and the maximum of it is 135 cm at the center of the circle of the antenna. This value is decreased as the distance from the center becomes larger and the minimum is 60 cm at the edge (Figure 4). There are no interruptions from substances; water, gravels, and sand (Sumi et al., 2012 and 2014). Additionally, as a topographical limitation, it is difficult to continue survey in the specific areas, such as places where trees grow up densely, water flows rapidly or the depth of the river is deep.

(2) Search methodology

This survey has been conducted in accordance with the following four terrain classification so that we could search PIT-tags gravel efficiently.

(a) Shallow area (depth is less than 50 cm): walking around the river while controlling an antenna.

(b) Plain area (depth is 30-100cm): Fixing a boat with ropes and moving along the cross-section of the river while floating an antenna, and flowing down along the flow line and controlling an antenna using a boat or an inflatable kayak.

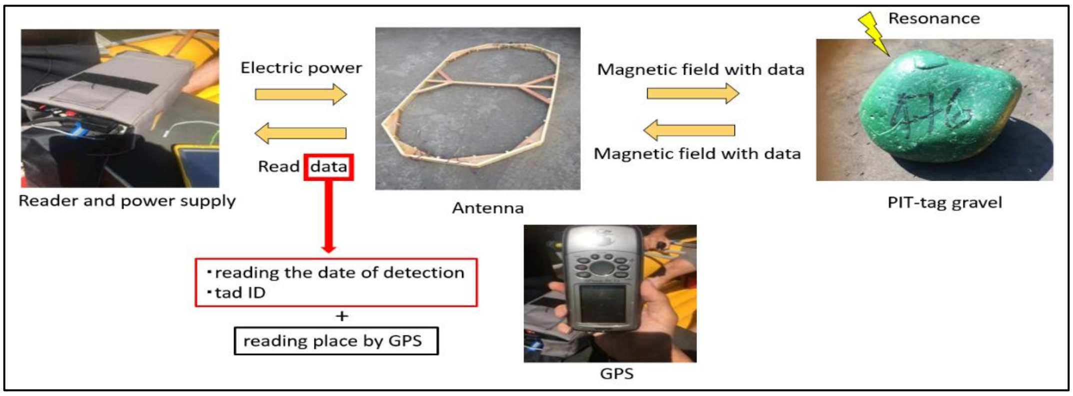

Fig. 3 The system of RFID (Bladley, 2012 and 2017; Nichols, 2004)

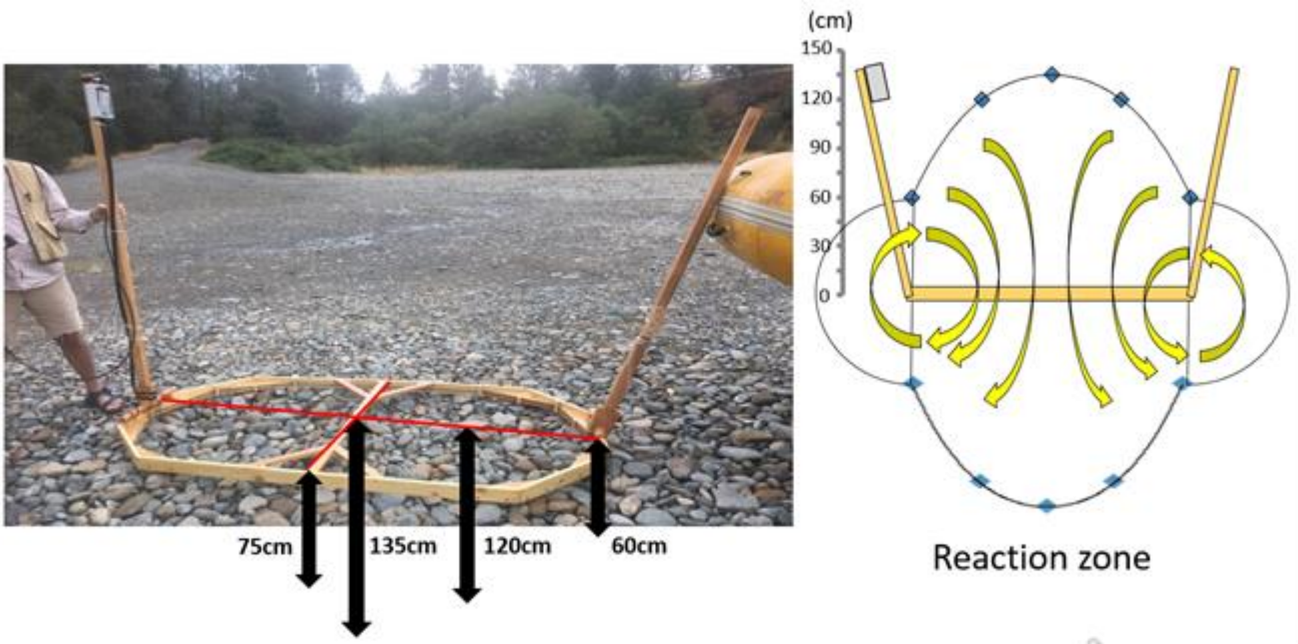

Fig. 4 Reaction range of the antenna

(c) Deep area (depth is more than about 70cm): Pushing an antenna into the river while rowing a boat.
(d) Outside of the river (On land): walking around the river while holding an antenna by two people.

2.2 Numerical calculation of riverbed variation

The variation of riverbed elevation in the Lowden area was calculated by the 2-dimensional model. The main purpose of this calculation is to understand the tendency of the sedimentation and scouring and predict a future condition of the riverbed.

(1) Model for calculation 2-dimensional (2D) plane unsteady flow and riverbed variation

We used International River Interface Cooperative (iRIC) as a riverbed variation analysis software package which combines the functionality of MD_SWMS, developed by the USGS (U.S. Geological Survey) and RIC-Nays, developed by the Foundation of Hokkaido River Disaster Prevention Research Center. As an analysis solver, Mflow_02 to calculate two-dimensional plane unsteady flow and riverbed variation by unstructured meshes of finite element method in the orthogonal coordinate system (Cartesian coordinate system). This solver has several strong features that it is possible to calculate integrally a river area and a flood area having a complex merging flow and suitable to express the shape of the sandbar due to the Cartesian coordinate system. On account of this reason, it seems reasonable to use this solver for the calculation of the Lowden area which has artificial complex side flow (http://i-ric.org/en/introduction/).

(2) Calculation target reach and period

The topographical data that is surveyed by laser profiler in 2016 before PIT-tags gravel injection project was used as an initial topographical data for the calculation. We determined an effective flow discharge for riverbed variation in Lowden area by repeated verification of calculation and it was found to be more than 170 m^3. We had two big flood events after PIT-tags gravel injection activity. In accordance with this criterion, the target period of the calculation is from 8 to 16 May (9days), 2016 and from 25 Apr. to 1 May (7days), total 16 days.

3. Results

3.1 Field survey

729 out of 960 PIT-tags gravel (75.9 %) were found in 2016 and the most downstream point where it was found is 305 m from the injection point (IP). Conversely, 790 out of 960 PIT-tags gravel (79.2 %) were found in 2017 and the furthest point from IP is gravel were detected. Figure 6 is a graphical representation of the distribution of the numbers of

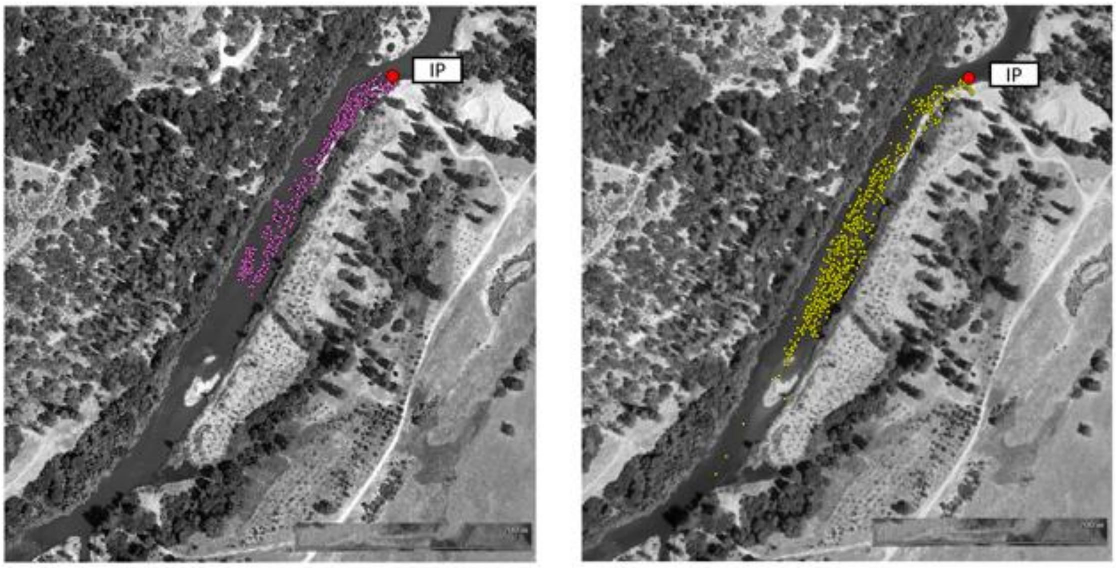

Fig. 5 Places where PIT-tags gravel were found in the survey of 2016 (left) and 2017 (right)

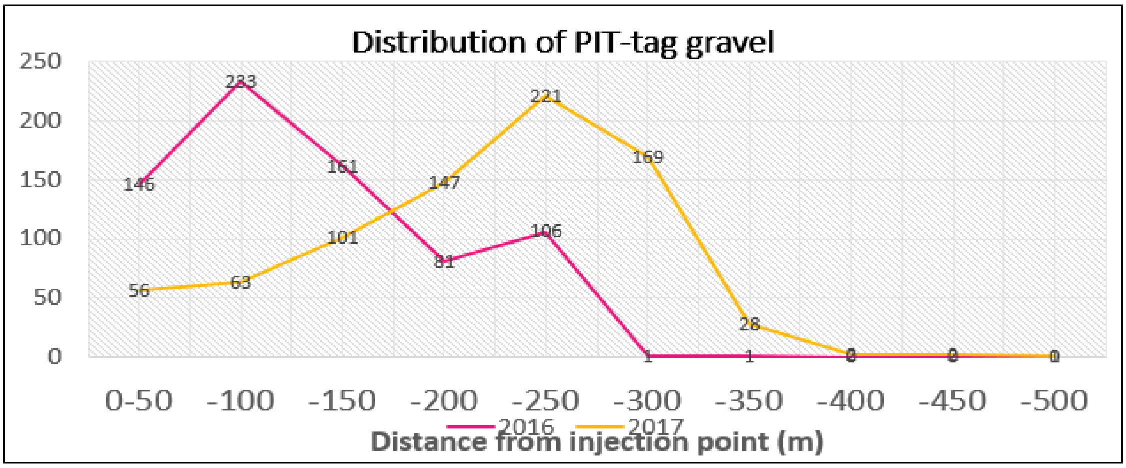

Fig. 6 Distribution of the numbers of PIT-tags gravel in the survey of 2016 and 2017

PIT-tags gravel were found are distributed to every 50 m separated.460 m. Figure 5 shows the places where PIT-tags

3.2 Numerical calculation of riverbed variation

Figure 7 shows the results of calculation of riverbed variation. This result indicates the following:

(a) A tendency to scour was seen after deposition in the peak of the flood in 2016, 125 to 175 m downstream from IP

(b) Deposition and scouring were observed widely, 200 to 250 m downstream from IP.

(c) A tendency to deposition was seen, at the left bank 325 to 450 m downstream from IP.

4. Conclusions

The detection rate of PIT-tags gravel of the field surveys in 2016 and 2017 exceeded more than 75% and PIT-tags gravel are valued highly as a good index to comprehend the mobility of sediment. Comparing the result of field survey in 2016 to 2017, the distribution curve of PIT-tags gravel number was shifted by about 150m. It means that gravel moved by 150 m on average because of the flood for 2016. To discuss in more detail, further work that tracking movement of gravel respectively by using tag-number is on the way (Martin, 2014; Habersack, 2001). More interestingly, the area of 200-250m downstream from IP seems to be a rest area or have a potential to catch gravel and to be a sandbar. However, it is just a possibility and difficult to find a strong proof from the result of river-bed variation

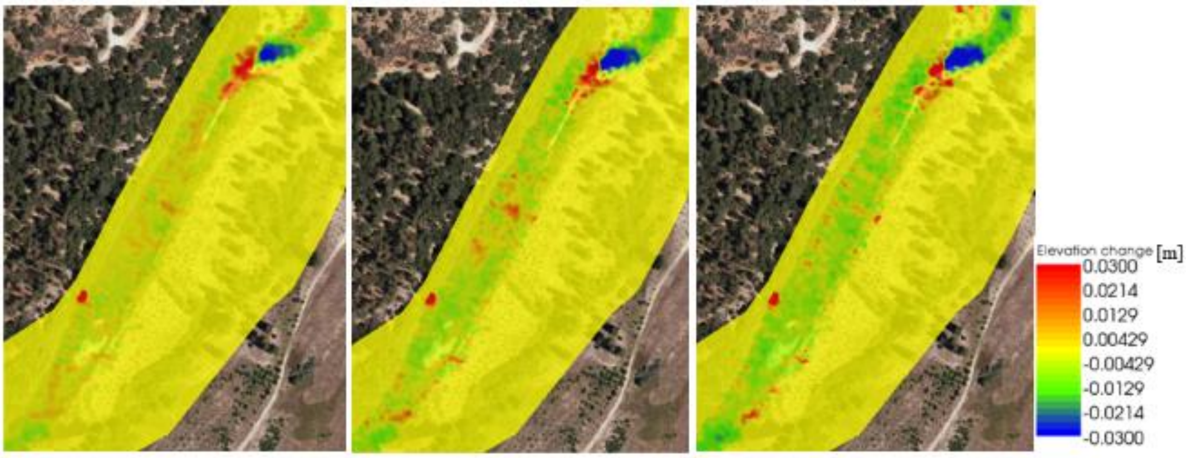

Fig. 7 The results of calculation among three timings, the calculation for 3 days, 9 days and 16 days (left, middle and right one express respectively the peak of the flood in 2016, after the flood in 2016 and after the flood in 2017)

calculation for 2016-2017. Thus, we need to keep on continuous field survey and compute the 2D calculation by giving additional flood events that are supposed to occur in the future to correlate RFID results to 2D-model result.

From the results of the 2D model calculation, it seems that there is a periodical strong cycle for making geomorphological structure at several places. In especially, it suggests that the left bank of 325 to 400 m downstream from IP has a potential to catch the sediment. In other words, there is a possibility that sandbar is formed in this area. To confirm it, the result of a survey for tracking PIT-tags gravel after 2018 is expected and we also need to calculate riverbed variation by giving additional flood events.

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References

Bradley, D. N., and Tucker, G. E. (2012): Measuring gravel transport and dispersion in a mountain river using passive radio tracers, Earth Surface Processes, and Landforms, vol. 3.

Bradley, D. N. (2017): Direct Observation of Heavy-Tailed Storage Times of Bed Load Tracer Particles Causing Anomalous Superdiffusion, AGU publications, Geophysical Research Letters.

Gaeuman, D. (2014): Analyses to support gravel augmentation recommendations for the Trinity River, California, Technical Report TR-TRRP-2014-1.

Gaeuman, D., Stewart, R., Schmandt, B., and Pryor, C. (2017): Geomorphic response to gravel augmentation and high-flow dam release in the Trinity River, California, Earth surface processes and Landforms.

Habersack, H. M. (2001): Radio-tracking gravel particles in a large braided river in New Zealand: a field test of the stochastic theory of bed load transport proposed by Einstein, Hydrological Processes, vol. 15.

iRIC project. (web): Introduction of iRIC, http://i-ric.org/en/introduction/

Kondolf G. M. (1997): Hungry Water: Effects of Dams and Gravel Mining on River Channels, Environmental Management, vol. 21.

Kondolf, G. M. (2009): Review of Draft Biological Opinion Operation of Trinity River Division of the Central Valley Project from 2010 to 2030, Trinity River salmon Bio report review report.

Martin, R. L., Purohit, P. K., and Jerolmack, D. J. (2014): Sedimentary bed evolution as a mean-reverting random walk: Implications for tracer statistics. Geophysical Research Letters, vol. 41.

Nichols, M. (2004): A radio frequency identification system for monitoring coarse sediment particle displacement. Applied Engineering in Agriculture, vol. 20.

Ock, G. and Kondolf, G. M. (2012): Assessment of Ecological Roles of Gravel Bar Features Restored by Gravel Augmentation and Channel Rehabilitation Activities below Lewiston Dam in the Trinity River, California, USBR Science and Technology Program Scoping Report.

Ock, G., Gaeuman, D., McSloy, J. and Kondolf, G. M. (2015): Ecological functions of restored gravel bars, the Trinity River, California. Ecology of England vol. 83.

Sediment management in Alpine basins. (2013): Protocol for data collection method in sediment transport, First SedAlp Milestone, www.sedalp.eu

Stene, E. A. (1996): Trinity Division Central Valley Project, Bureau of Reclamation.

Sumi, T., Ishida, H., and Satake, Y. (2012): Sediment transport monitoring in in-stream flood mitigation dam by RFID technology, Japan Society of Civil Engineers, Journal of Hydraulic Engineering vol. 68. (in Japanese)

Sumi, T., Kurahashi, M., Ishida, H., and Meshkati, M. E. (2014): Monitoring of sediment transport and deposition process in in-instream flood mitigation dam using RFID technology, Japan Society of Civil Engineers, Journal of River Technology, vol. 20. (in Japanese)

U. S. Bureau of Reclamation Trinity River Restoration Program. (2000): Summary of the United States Secretary of the Interior Record of Decision, December 19.

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