APPLICATION OF AQUATIC HABITAT IMPROVEMENT TECHNIQUES AT TA-CHIA RIVER IN TAIWAN

Ching-Hao Tuan[1] and Chao-Hsien Yeh[2]

[1] Professor, Department of Soil and Water Conservation, National Chung Hsing University, Taiwan
[2]Associate Professor & Correspondence Author, Department of Water Resources Engineering, Feng Chia University, P.O. Box. 25-123, Taichung 400, Taiwan
PH (8864) 2451-0824; FAX (8864) 2451-5827 (e-mail: chyeh@fcu.edu.tw)

Abstract: With characteristics of river continuum, stream ecosystems have diverse components and environments from upstream channel to estuarine area. Therefore, the habitat requirements and composition of conservative object should be well understood before applying any improvement measure. In this paper, the causes of stream habitat changes were first illustrated with the categories and principles of habitat restoration methods. The structural restoration techniques of fish habitat improvement utilized by the authors for one three-year research project starting at 1990 were then presented. Through the introductions on the project background, planning guidelines, structure design, and ecological evaluation, this paper tried to provide some effective examples of stream restoration practices that ecological expert was invited for cooperation and advising.

Keywords: fish habitat improvement, structural restoration, ecological effects

1. INTRODUCTION

With functions of water supply, waste cleaning, trade, transportation, and agriculture irrigation, rivers have been seen both in ancient cultures and modern cities along with the problems of flow quantity, water quality, and ecology environment. To protect and support the increasing population along the rivers, various hydraulic structures (such as revetments, dams, and reservoirs) had been widely constructed such that the formations and characteristics of river habitats had changed greatly at the downstream area. In the past, people considered flood prevention and nature conservation in river management to be often two incompatible targets. But with the development of river rehabilitation, the design principles and application practices have been progressively developed to meet the goals of maintaining channel morphological change, flood prevention, ensuring stream substantial value (Downs & Thorne, 2000).

For stream restoration, the Committee on Restoration of Aquatic Ecosystems (National Science Council, 1992) suggested that decreasing the stresses of stream and river can directly improve stream ecological environment and achieve the objective of stream rehabilitation. Petts and Calow (1996) urged that the human activities effecting stream ecosystems should be managed and controlled through point-source pollution controls, landuse regulation, water allocation, channel and floodplain management, controls on human use of river for fishing, recreation etc., and controls on biota. Therefore, to avoid or solve the degrading habitat environment and increase carrying capacity of stream is one of the major purposes for fishery habitat improvement.

Techniques of habitat improvement are widely found recently in various cases, including fishway facilities, vegetation methods, natural materials (i.e., log, rock, net, and lure) habitat improvement facilities, landscape ecological restoration measures and other management/control policies (Bradshak and Brown, 1995). Hey (1996) divided the measures of habitat rehabilitation and river habitat improvement into two main categories, structural and nonstructural methods. Nonstructural methods are ways of reconstructing the natural condition in certain part of a river. These recovering construction of river meanderings, pools, shallow area, vertical stream banks, and dead zones are often applied to lowland rivers. The structural restoration methods use different artificial in-stream structures to create ponded reaches and bars form and prevent siltation to maintain substrate condition through various kinds of structures, such as weirs/dams, deflectors, and vanes (Figure 1). In this paper, several aquatic habitat improvement techniques applied in one restoration project at the Ta-chia River of Taiwan were introduced. Two stream restoration projects with concepts similar to previously described ones are introduced. With various techniques and their ecological effects, the authors report the efforts and the experiences on river fishery rehabilitation.

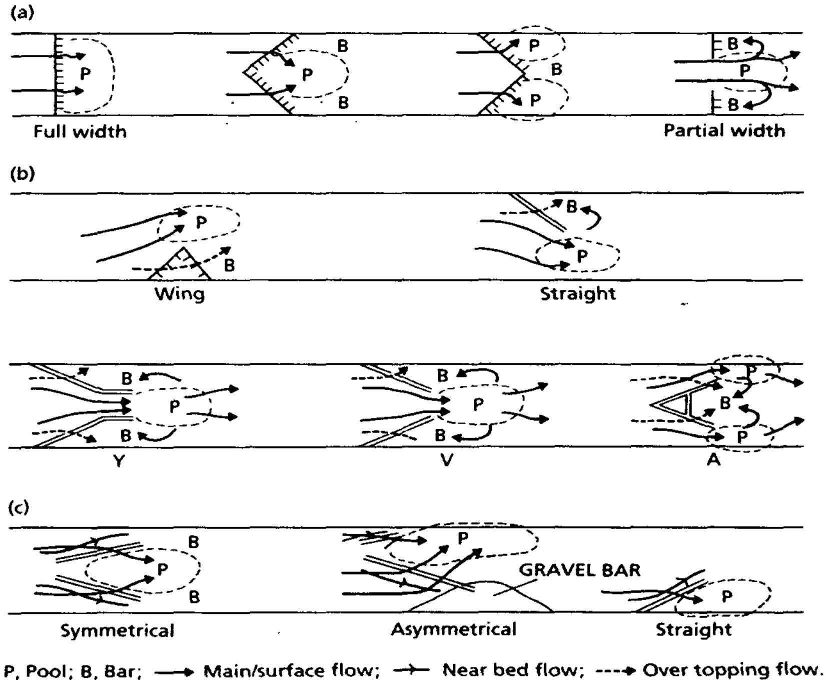

Figure 1. River habitat improvement using structural methods (a) weirs/dams; (b) deflectors; (c) submerged vanes (Hey, 1992).

2. PRINCIPLES AND TECHNIQUES

At the central part of Taiwan, Ta-chia River is a well-known natural scenic and fish habitat area for its convenient transportation, beautiful scenery, and plentiful water resources. Due to limited natural resources for electricity generation, waterpower has become one of the main power resources in Taiwan for decades. Therefore, several reservoirs and dams were constructed on Ta-chia River for its waterpower resource, while the impact on stream habitats has also increased. To meet the water demands for waterpower generation and fishery habitat, a research project spanned for three and half years was initiated at 1990 to resolve the water-use conflict problem under the pressure from local environmental association at downstream area of Ta-chia River.

With the experiences of field investigations and visits of advanced countries in this field, four planning and construction principles for downstream fishery habitat improvement were concluded as (Ho and Tuan, 1991): (1) maintain the stream landscape as natural as possible; (2) management, design, and construction of improvement techniques should be based on the characteristics of stream bed-load and channel formation; (3) emphasis should be on the persistency of artificial pools; and (4) efficiently deployment of limited budgets. Various structural techniques, including rock weir of partial width, rock deflector, tire weir with opening, channel dredge, concrete deflector with rock pavement, and riverine recreation zone, were designed and constructed based on the restoration functions of techniques and social-economic considerations of construction sites (Figure 2).

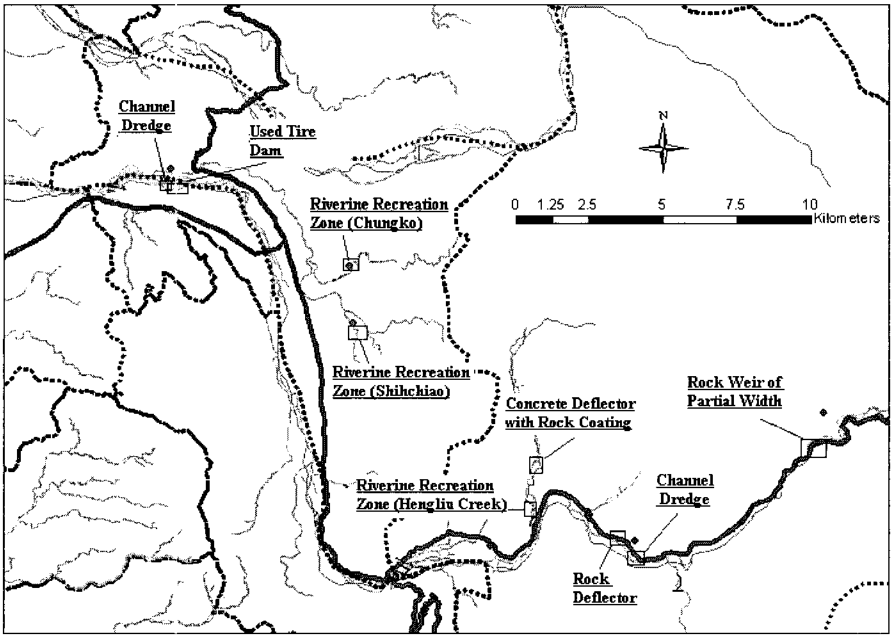

Figure 2. Locations and techniques of habitat improvement applied at downstream area of Ta-Chia River

2.1 Rock deflector and rock weir of partial width

Using the boulders with diameter larger than 1 meter, rock deflector was placed on one side of the channel and two rock deflectors on both sides then became as rock weir of partial width. These two structures were made by four rows of boulders through specific arrangement. One boulder with irregular shape is often described by its short, medium, and long diameters. While the first and fourth rows of boulders lay down on the channel bed, the second row and the third row stood by their long diameter and medium diameter in respectively (Figure 3). The boulders with iron bars were then chained by steel cables. Based on the critical velocity and critical discharge equations of sediment transportation theories, the rock deflector can stand the drag force caused by the peak flow of a 4.97 return-year flood. With sufficient bed materials, the reach at the most upstream channel of the study area was rehabitated by a rock weir of partial width (Photo 1), while two rock deflectors were installed at the downstream reach about 7 kilometers apart (Photo 2).

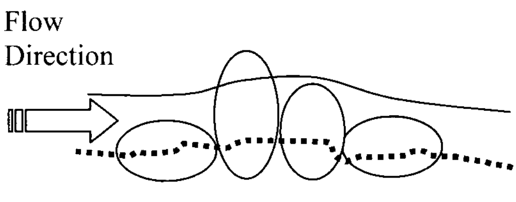

Figure 3. Side view of rock deflector

2.2 Used tire weir

With fine sediment in the channel of one tributary of Ta-Chia River, the reach beside a local village activity center remained few pools but plenty of shadow riffles. At this site, reinforced concrete columns, which are 1.4 meter high and 1 meter apart, posted on a ground sill was first constructed and used tires of 1 meter in diameter were then staked with reinforced concrete columns in their holes. While the used tires protect the structure from the impact of cobbles supplied from upstream area, an opening with width of two meter was created by dismantled one column at the thalweg of the channel. The flow passing the opening not only creates a pool for that site (Photo 3) but also provides a pathway for fish mitigation.

2.3 Channel dredge

Man-made pools by channel dredge without supplemental structures are always filled by the sediment during the flood events. However, one reach located at 40 meter upstream of used-tire weir and another reach of 60 meters long at Ta-Chia River were dredged under the request of local ecological protection society. The experimental results showed that both pools disappeared due to the dynamic equibrillium of channel sediment.

2.4 Concrete deflector with rock coating

Located at the channel reach about 2 kilometers upstream of the mergence point of Henlow Creek and Ta-Chia River, two concrete spur dikes with design strength of 3,000 psi were installed to provide functions of deflectors which lead flow to bedrock bank and create pools for fish habitat. While the height of endpoint of the structure was designed as 2 meters, the 2.5 meters high footage of the spur dike will product a sliding top platform. The spur dikes were coated with rocks of 0.5 meter in diameter to improve their habitat functions with spaces among rocks.

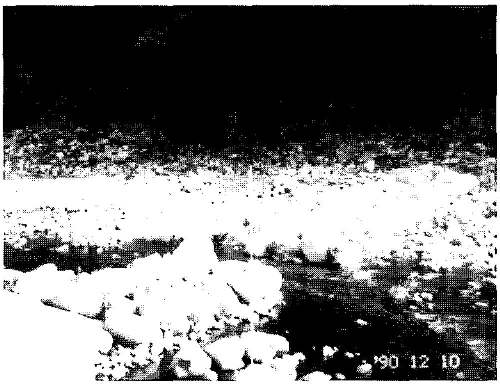

Photo 1. Rock weir of partial width

Photo 2. Rock deflector

Photo 3. Tire weir with opening

Photo 4. Channel Excavation

2.5 Riverine recreation zone

Three riverbanks of tributaries were selected as riverine recreation zones based on their superior conditions on the bountiful aquatic ecosystem, convenient access, and appropriate geological riverbanks. These zones also provide educational and conservational functions besides their leisure purpose by the steel posters and special structure design. Tuan (1992) suggested that design of riverine recreation structures has to satisfy the criteria of structural safety and ecological friendliness. Four concrete structures were applied to those three zones, including reinforced concrete frames, weir with opening, concrete spur dike, and retained wall with fishing top ledge. Riverine recreation zone No. 1 was facilitated by six concrete frames of 5 meters wide, 15 meters long, and 1.4 meter high on the channel bed connecting to the foundation of existing concrete bank (Photo 6). By breaking an opening with width of 1.2 meters at the center of existed weir, riverine recreation zone No. 2 was constructed by reinforced concrete retained wall of 80 meters long at left bank of upstream reach of the weir. At the top of the retained wall, a fishing ledge with width of 1.5 meters was attached above 0.3 meter the water level maintained by the weir (Photo 7). With the same design of retained wall at left bank, the channel of the riverine recreation zone was rehabitated by concrete spur dike on the right bank in order to create pool at the footage of retained wall (Photo 8).

Photo 5. Concrete Deflector with Rock Coating

Photo 6. Riverine recreation zone #1

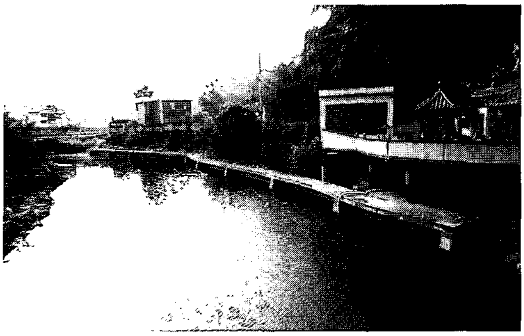

Photo 7. Riverine recreation zone #2

Photo 8. Riverine recreation zone #3

3. COMPARISONS ON THE ENVIRONMENTAL AND ECOLOGICAL EFFECTS

To verify the environmental and ecological effects of these channel improvement techniques, investigations of habitat condition and surveys of fishery population were carried out at the same time from 1990 to 1993. The analysis results indicated that only partial and mild change on stream hydrology and water quality was discovered after the construction of these measures (Wang, 1996). In general, the reaches with rock deflectors or rock weirs of partial width not only had lower landscape impacts but also had better overall improvements on fishery community and habitat complexity (Table 1).

Table 1. Habitat analysis of habitat improvement sites at downstream Ta-Chia River

	Rock weir of partial width	Rock Reflector	Used Tire Weir	Riverine recreation zone #1	Riverine recreation zone #2
Landscape Environment	Harmony	Harmony	Not Harmony	Not Harmony	Harmony
Channel Environment	Mild changes	Mild changes	Huge changes	Mild changes	Huge changes
Flow Regime	Increase of pools, riffles, & backwaters	Increase of pools, riffles, & backwaters	Increase of pools, deep flows, & backwaters	Increase of pools, riffles, & backwaters	Increase of bank slow runs & deep flows

Habitat Complexity	Increase Obviously	Increase Obviously	Increase	Increase Obviously	Increase
Catch Per Under Effort	Increase 3~14 times	Increase 1~15 times	Increase 5~19 times	Increase 0.6~2.3 times	Increase 2~8 times
Catch Density	Increase 11~48 times	Increase 4~68 times	Increase 15~38 times	Increase 1.6~4.7 times	Increase 18~35 times

4. CONCLUSION

In general, the major objectives of river basin habitat improvement project could be protection of specific species, maintaining biological diversity for river habitats, and landscape esthetics and riverbed stability (Shen & Chen, 1998). In this paper, one research project was demonstrated by the application techniques and their conservation concepts behind to provide diverse habitat patterns under the constraint of limited channel flow at the downstream area of Ta-Chia River. Upon the time the project was implemented, the authors did not have related knowledge of aquatic ecosystems and background of habitat restoration. However, the techniques applied then were designed and based on the understanding of stream hydraulic characteristics and the working experiences gained from field works. As the first research project of stream restoration in Taiwan, the ecological effectiveness of these habitat improvement techniques proved by ecological expert also indicated that appropriate human-made structures can compensate the impacts of human disturbance on the aquatic ecosystems.

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Professor, Department of Soil and Water Conservation, National Chung Hsing University, Taiwan

Associate Professor & Correspondence Author, Department of Water Resources Engineering, Feng Chia University, P.O. Box. 25-123, Taichung 400, Taiwan; PH (8864) 2451-0824; FAX (8864) 2451-5827

(e-mail: chyeh@fcu.edu.tw)