

PAPER • OPEN ACCESS

## Environmental Consideration In Flood Mitigation And River Restoration

To cite this article: Saad Sh. Sammen *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **518** 022088

View the [article online](#) for updates and enhancements.

# Environmental Consideration In Flood Mitigation And River Restoration

Saad Sh. Sammen<sup>1,\*</sup>, Thamer Ahmed Mohammad<sup>2</sup> and Qutaiba G. Majeed<sup>1</sup>

<sup>1</sup>Department of Civil Engineering, College of Engineering, Diyala University, Diyala, Iraq

<sup>2</sup>Department of Water Resources Engineering, College of Engineering, University of Baghdad, Baghdad, Iraq

E-mail: [saad123engineer@yahoo.com](mailto:saad123engineer@yahoo.com) (Saad Sh. Sammen)

**Abstract.** One of the fundamental section of sustainable improvement in river basin systems and has multifunctional targets is river restoration. The targets of river restoration are to minimize the physical degradation and recover river elegance value, pollution manage and good ecosystem with biodiversity. River restoration is a multidisciplinary task in which engineer, hydrologist, geologist and ecologist can work together to enhance river environment. In decades ago, Malaysia was exposed to fast evolution and subsequently extreme flooding has happened especially in urban territories. In order to minimize flood damage, the flood mitigation measures were taken and channel improvement is mainly utilized for this goal. Due to the insufficient available river reserve and perhaps the absence of environmental awareness, previously, the consultant engineers usually advised a wider and deeper rectangular concrete river channel to mitigate the flood damage. The replacement of the natural river channel with a concrete channel outcomes are increased physical degradation and lowering of aesthetic and recreational values of rivers. Lately, there is a strong confirmation to take into account the environmental effect in rivers canalizing. Malaysian experience in restoration of the urban river will be focused on in this study, with a particular emphasis on environmentally friendly materials utilized for flood mitigation goals.

**Keywords:** Restoration, urban rivers, channel improvement, flood, environment

## 1. Introduction

Due to various human activities, radical changes to rivers and streams had been occurred in the last century. On the contrarily, the environmental awareness is grown and led to pressures on river managers to repair some of the past damages and restore rivers to previous condition so that its become more sustainable and ecologically and aesthetically desired condition. The modification of rivers in developed countries were intensive particularly in the last 50 years where the modification includes flood defense projects, development of flood plain and changing landuse within the catchment. The implemented works on rivers and their environmental consequences are summarized in Table1.

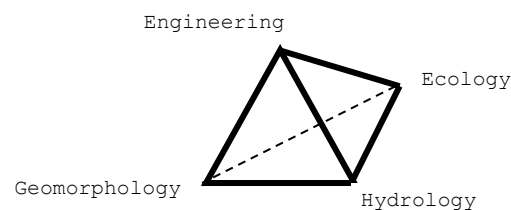
River restoration can be defined as implemented actions to rivers and their basins which are subjected to severe pollution and damage to their natural habitats in order to return them to the original conditions before damage. Restoration activities as described by Grant (2008) include increasing flows to reduce water contaminants, drive out levees to upgrading channel storage of water and sediment, adding gravel to river to increase hyporheic flow and controlling invasive species to improve native ecosystem. The above activities illustrate the range of technical disciplines required for river



restoration such as engineering, hydrology, geomorphology and ecology. Figure 1 shows the conceptual framework for restoration.[1]

**Table 1.** Types of river developments and their environmental consequences

No.	Type of Development	Environmental consequences
1	River improvements such as extensive straightening and deepening of river channels for flood mitigation projects	Damaging wildlife habitats, reducing the value of fishers, damaging or removing the aesthetic value of river landscapes
2	Major loss of flood plain wetlands through intensive agricultural use and urbanization projects	Polluting river water, destroying wildlife habitats and reducing the ability of floodplains to function as water and sediment storage
3	Intervention with the river water course through construction of hydraulic structures such as dams, barrages regulators and bridges for developmental and flood alleviation purposes	Negative impacting on the natural river processes.



**Figure 1.** Conceptual framework for river restoration. [1]

River restoration brings the following benefits:

1. Nature conservation - through the protection of wetland wildlife, not just plants and animals within the channel itself but from the recreation of the rich mosaic of floodplain habitats.
2. Improved water quality - through recreation of floodplains which intercept pollutants and act as a natural settling area for flood-borne sediments.
3. Flood defense - through the interception of storm run-off and the provision of additional flood storage areas which can help to prevent flood damage in other areas.
4. Fisheries - through the recreation of habitats and conditions suitable for a diversity of fish species.
5. Recreation - through improvements in river landscapes and river-based activities.

There are two main approaches used for river restoration:

- a. Natural recovery where appropriate streams and rivers are allowed to recreate their own natural course and flooding regime.
- b. Active restoration where intervention is required to modify rivers which are too badly damaged or have too little sediment and water power to repair themselves.

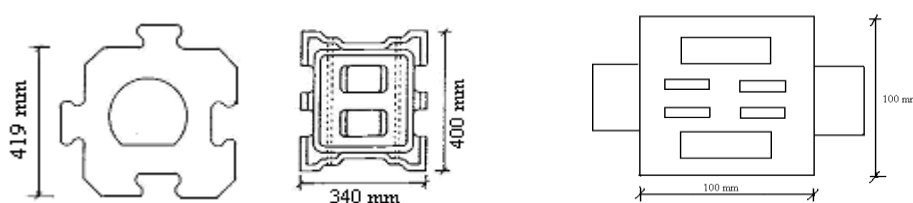
It is important to emphasize the concept of connectivity between the river channel and its floodplain. This is where the greatest benefits will come through the restoration of natural river processes and functions. River natural recovery process after restoration depends on the river condition (how bad is the damage) and it is changing from river to river. The time required for river recovery is several years for rivers with minor damage and it may take much long time for badly damaged rivers.

In this study, the Malaysian experience in river restoration is presented with special emphasis on the experience of improving rivers for flood mitigation taking into consideration the environmental, river ecological system and aesthetic value.

## 2. Types of revetment systems for river restoration

Escarameia classified the utilized river remediation and restoration revetment systems into three major part they are; bio-engineering (vegetation), structural and bio-technical engineering. [2]

Bioengineering revetment system is utilized at most for rehabilitation and restoration of rivers. The protection of the rivers bank from erosion until the point that vegetation becomes set up is the defy in bioengineering and it takes over a year. five mechanisms were discussed by Allen through which vegetation can control and remedy erosion they are: reinforce soil by roots; dissipate or dampen wave energy; water interception; water infiltration enhancement; and minimizing soil water by transpiration and uptake [3]. Nevertheless, from the engineering point of view, the utilize of vegetation alone on rivers banks, is not always typical. The channel capacity may decreased through the excessive foliage which can lead to a great flood potential upstream. planted Trees on specific area of levees can have roots weakening the levee soundness [4]. Coppin and Richards have analyzed engineering functions of vegetation and found that its impacts are both harm and beneficial and that is according to the circumstances [5]. hence, it is significant not to solve a stream bank issue by utilizing a single measure. The structural revetment system was widely utilized in 1950 to 1980 [6]. Several protective structural linings have been utilized to opposite the erosion issues. These hard-armoring methods, like stone riprap, concrete pavement, rock gabions, concrete or aluminum, sack revetments and asphalt mixes improved river bank shear strength [7]. Numerous governmental agencies favored stone or concrete riprap because over time, a high degree of precision and confidence in construction has developed from research and analysis. In engineering standpoints, these methods have been effective for their instantaneous protection. Gathering various bioengineering techniques even with structural components is indeed more powerful than utilizing any specific one individually [8]. Bio-technical is a technique for bank stabilization that incorporates the utilize of vegetation and engineering structures to increase slope stability [9]. The vegetation improves the soil strength by their root structure while the bio-engineered structure gives extra support. Also, it rehabilitates the river and improves the environmental life. However, it can be utilized as a successful solution for restrotaion projects. Figure 2 shows various types of biotechnical materials available in the market.



**Figure 2.** Selected types of bio-technical engineering blocks

## 3. Application of river restoration measures: the international experience

In the last two decades, the countries of the European Union started to focus on restoration of rivers and EU has financed a many of isolated river restoration projects. However, to increase the benefits and to disseminate knowledge and experience on river restoration acquired within Europe, a center called European Centre for River Restoration (ECRR) was established in 1995.

Pollution is the main damage caused to rivers in European even though massive wastewater treatment has remarkably minimized the concentration of organic matter and phosphorus, the nitrogen concentration in European rivers has been raised up and has a mainly high level resulting eutrophication in the marine environment. The main reason for this is the intensification of European agriculture causing increased loading of nitrogen due to an increased use of fertilisers and manure. As

a result, both the water quality and river habitat quality have been seriously degraded in numerous European rivers throughout this century. Physical deterioration of rivers and their floodplains is general all over Europe. In Belgium, England and Wales, and Denmark less than 20.0 % of the rivers are still in the natural physical state. Engineering works in European rivers have remarkably changed water retention capacity resulting in downstream flooding. The uniformity of channelised and deepened rivers provides poor conditions for aquatic life, whereas a restored watercourse provides more and better habitats for flora and fauna. The more diverse the physical and environmental conditions, the higher the biodiversity. Action program for biodiversity in Europe is given high priority and nature restoration has been specified as one of the measures to maintain and improve biodiversity. An example for rivers restored in Europe is River Rhine, River Meuse, River Skjern and Lubrzonka River.

Weller highlighted the effect of good management of flood on river restoration and particularly on reducing flooding hazards and preserving the biodiversity in the river environment. Wetlands are essential part of a functional river system and can help in improving the rivers water quality affected by sediments [10].

Diamond et al. suggested improvement objectives for river reaches of good ecological potential. They apply the water framework directive to three rivers in the United Kingdom (UK). The directive included the definition of heavily modified water bodies, development of a dynamic classification system for hydromorphology and for development of physical quality objectives [11]. Menke and Cals stated a rehabilitation vision to River Dinkel (one of the tributaries of River Rhine) which is located east of the Netherlands [12]. The river problems are pollution, unnatural discharge, and habitats structures (e.g. weirs). The vision included measure to enhance water quality, re-meandering of brooks and flood safeguard. Arnaud-Fassetta and Fort proposed restoration of River Aude, South of France. The native riparian vegetation is allowed to remain dominant, thus enhancing habitat diversity and acting as a sediment trap especially along abandoned channels [13]. Gilligan reported that 40% of the river bodies in Ireland are designated either at risk or probably at risk of failing good ecological status. Half of the above reported cases are due to channelisation and flood relief structures[14]. Menke and Nijland proposed relocation of dyke for certain stretches along River Rhine in Germany and Netherlands. The relocation includes reconnected floodplain area to create a good quality riverine habitats and improve the ecological network along the river[15].

The river systems throughout the United States of America have changed by the development pressures. Conventional engineering concepts have been utilized to issues of flood control, irrigation, highway construction, and general land management disputes. This approach has failed to incorporate natural river geometry, channel behavior, riparian function, as well as associated aesthetic and financial value. The river and stream modifications have caused in harmful habitat changes for many fish and wildlife species and have give a share into great drop in native fish populations and problems of bankfull information is absent for the major rivers. In spite of their significance to planners, environmentalists, and everyone interested in floods and flooding, data on the discharge at channel capacity or on the gauge height of the bankfull circumstances are not published or even determined in a systematic manner. Examples of the river restored in USA are Little Tennessee River and Mississippi River [16].

In Australia, the Cooperative Research Centre (CRC) for Catchment Hydrology's River Restoration research program goal is to supply stream managers with tools, and with comprehension of stream processes, that will lead to more functional spending on restoration, and finally, healthier streams. River rehabilitation for Australian streams is planned and one example of this plan is the restoration work on Latrobe River in South East Australia [17].Rutherford reported the results on modeling the physical and ecological response of Creighton and Castle Creeks system to intervention by presenting the variation of bed levels with the proposed type of solution[18].

In Japan, the concept of potential nature in riverine environment is introduced extending the concept of today's potential natural vegetation in ecology. Degradation of the quality of nature in riverine environment in modern Japan is a result of the impact of human and modern technology and industrialization. Guideline for riverine environment in Japan can be summarized as 1) natural disturbance regime, 2) continuity in a watershed, and 3) diversity of morphology. This concept is

applied for river restoration in Japan to satisfy essential requirements of environmental ethics. Nakamura reported that in Japan, 23.5% of the river banks are artificial and there are 2675 dams (with the total height more than 15 m) have been constructed and the number of restoration projects is 28,000. The Asian River Restoration Network was founded in November 2006 to boost the exchange of information relating to environmental restoration of rivers and watersheds within Asian countries[19].

#### **4. Flood mitigation and river restoration in Malaysia**

In tropical countries like Malaysia where the average annual rainfall is more than 2500 mm, flooding is considered as an inevitable problem particularly in urbanized rivers. Normally, flood mitigation measures are taken to minimize the flood harm in flood plain for urbanized areas. Channel improvement is mainly used for this purpose. The consultant engineers would normally propose a rectangular concrete section for upgrade the channel of flooded rivers. So, it often happens that the undersized natural channel section of a river is changed to a wider and deeper rectangular concrete channel in order to increase the hydraulic capacity and reduce flood hazard on public. This solution is usually suggested by the design engineers according to the limited available river reserve and possibly the lack of environmental awareness. In the last decades, environmental attitudes have changed and this led to pressures on river managers and engineers to use natural channel designs and undo some of the damaging river works of the past and restore rivers to previous, more sustainable, and more ecologically and aesthetically desirable, conditions. The consequences of replacing the natural river channel with a concrete channel in flood mitigation projects are reduction of aesthetic and recreational values of rivers and increase the physical degradation. On the contrary, natural channel designs will enhance the river biodiversity and proliferation of flora and fauna habitats. Integration of natural channel design with the river restoration requirements needs knowledge on river physical and biological processes, river aesthetic value, hydraulic and sediment transport calculations, hydraulic structures, fish habitat improvement designs, stream-bank stabilization techniques, and riparian area improvement and function. This confirms the concept highlighted by Grant as shown in Figure 1 [1]. Scouring is the main problem in natural channel design of rivers. Scouring is considered as a destroyer and killer of streams. Scouring can be reduced and its effect minimized by careful streambank protection. To reduce the maintenance work for scoured banks of rivers and streams, effort are made to produce environmentally friendly materials (bio-technical) which can be used as a revetment for river banks protection for flood mitigation projects. In the last two decades, bio-technical block systems are patented, produced and used in the United States of America (USA), Europe and Australia. Some of these systems have also been used in Malaysia. There are many advantages of using these revetment materials. These advantages are to maintain dimensions of the river channel, increase hydraulic capacity to pass the designed flood, reduce scouring, increase natural aesthetic value to the river and improve biodiversity and ecological life in the river.

Only three case studies in Malaysia will be presented. In order to avoid any promotion to the mentioned materials and also to uphold the rights of the production companies, their products names will not be mentioned in this study and a product code will be used.

Case study 1 presents the channel design of Sungai Klang at Jalan Dang Wangi, Kuala Lumpur. Product D2 was used as an environmentally friendly revetment material to protect riverbank which was experiencing massive natural scouring. The scouring occurred due to changes in current flow and seepage effect. Since Sungai Klang's riverbank consists of silty and sandy sub-soils, it cannot quickly respond to avoid relatively high pressure gradient due to discharge entering through the channel bank. The installation of product D2 was completed in 1994 for a total of 3,000 m<sup>2</sup>. After two months of installation, the site was surveyed by the Department of Irrigation and Drainage [DID, Kuala Lumpur] and growth of vegetation in the spacing of the D2 blocks was observed. Over 8 years after installation, the product is still functioning and not washed out although the maximum velocity at the river is 5.1 m/s the river section is designed to carry a discharge of 431 m<sup>3</sup>/s and the maximum water depth of this section is 3.5 m. It had recorded in the last 7 years between 1994 and 2001, the maximum water depth during flash flood in Kuala Lumpur was 4.9 m. The maximum flow velocity was 5.1 m/s in year 2000, which contributed to the maximum discharge of 627 m<sup>3</sup>/s. During flash floods, the water from

seepage and surface runoff also contributed to the increment of discharges, water depth and velocity of flow. The revetment system has functioned well and has protected the bank from high velocity flow.

Case study 2 includes flood mitigation project in which the channel of Sungai Kepayang at Seremban, Negeri Sembilan was improved using environmentally friendly revetment type B2. Installation of Product B2 was completed in 1999 and the total application of product B2 as a riverbank revetments material in Sungai Kepayang is 2500 m<sup>2</sup>. After three years, the same site was surveyed and witnessed by Department of Irrigation and Drainage, Negeri Sembilan and they found that there is a growth of vegetation between the revetment spacing of the product B2. Monitoring showed that the maximum velocity of the flow during the flood time is 3.6 m/s while the design velocity is 3 m/s.

Case study 3 includes Sungai Anak Air Garam in Seremban, Negeri Sembilan and product L3 is used as revetment system for bank protection. The bank area protected by L3 revetment system is 2800 m<sup>2</sup>. This riverbank is located between the residential, petrol Kiosks and shop houses and work is completed in 1999. Vegetation was found to be growing on the revetment.

## 5. Discussion

The increasing importance of river restoration has presented a new challenge to river managers for better effective practices to conserve river ecosystems. Recently, solutions to mitigate flood and control bank erosion in Malaysia is mainly proposed to comply with river restoration measures. The undersized natural river channel was normally changed to a wider and deeper rectangular concrete section in flood mitigation as shown in Figure 3.



**Figure 3.** A stretch of river Keypayang in Negeri Sembilan, Malaysia with concrete channel

According to Williams, the river engineering works are the main cause of environmental degradation for ecosystems of rivers and estuaries and loss of biodiversity. Concrete river channel will function as a carrying drain only and the self purification process for improving river water quality which normally happens in natural river and stream channels is severely affected or ceased[20].

The main obstacle facing river managers and design engineers in their effort to restore and rehabilitate rivers in Malaysia is the very high cost of land acquisition particularly in the town area. However, most of the rectangular concrete river channels are located in towns. Jasperse and Wind highlighted that the main problem for river restoration projects in Netherlands is land acquisition [21].

Native vegetation schemes are increasingly being used around the world with the trapezoidal earth section in flood mitigation schemes and also to manage stream scouring. Beside its environmental advantages, the vegetation increases bank shear strength due to root reinforcement and this will stabilize the sloping river banks [22]. Since river restoration aims to return natural and environmental values to river and stream channels, natural material also can be used for this purpose. Figures 4 and 5 show bank protection using natural materials.





**Figure 4.** Installing stakes to protect the river bank form erosion



**Figure 5.** A case of bank protection using natural vegetal cover

In Malaysia, most of the rivers with steep longitudinal gradient are subjected to scouring. Normally, scouring resulted from high velocity of flow in these rivers during floods. Figure 6 shows scoured river bank. To reduce the effect of erosion, several types of bio-technical systems (environmentally friendly materials) has been used in flood mitigation projects for two main objectives. The first objective is to protect the river banks from erosion while the second objective is bringing back the original condition of the river channel. The vegetation can grow on the river bank after using the revetment system and then river channel appears exactly like a natural channel. Figure 7 shows the channel of River Kepayang at Seremban town, Negeri Sembilan after restoration. Many types of materials were used in Malaysia as river revetments. Table 2 shows the code of the material and the percentage of the spacing in each one and the rate of vegetation growth after construction in river restoration projects.





**Figure 6.** Scouring of river bank



**Figure 7.** River Kepaying in Malaysia after restoration

From river restoration point of view, vegetation growth is considered as the main category to assess the environmental performance of the installed materials for river bank protection. For the studied rivers in Malaysia, almost all the installed revetment systems show potential ability to protect river banks. The growth of the vegetation eventually extends over the top of the revetment materials and provides a complete vegetal cover to the bank, which contributes to the stability as well as the ecology, and aesthetic value of the area and this is in line with the river restoration concept.

**Table 2.** Evaluation for Revetment systems Used for River restoration in Malaysia

Product Code	Spacing Allowed (%) per m <sup>2</sup>	Vegetation Growth Rating
A1-A2	6.5	Slow
B1	18	Moderate
B2	6.5	Slow
B3-B4	18	Moderate
B5	20	Fast
C1	15	Moderate
D1-D2	12	Moderate
E1-E4	5	Slow
G1-G4	>30	Fast
H1-H5	>30	Fast
J1	20	Fast
K1-K6	< 10	Slow
L1-L4	< 10	Fast

## 6. CONCLUSIONS

The ultimate goal of river restoration is the return to the pre-disturbance state of rivers and recently there is increasing scientific evidence which demonstrates that the main river engineering works have been a major reason of environmental degradation of the rivers ecosystems and a considerable agent in the loss of biodiversity in rivers environment.

In Malaysia, the river managers and engineers directed their effort towards the restoration of rivers. Increasingly, river restoration concept is being used as a guide in flood mitigation works and particularly for channel improvement. The new practice is to use environmentally friendly revetment systems instead of using deep and wide rectangular concrete channel. Land acquisition is considered as an economical constraint which affects the restoration and rehabilitation of rivers in the town areas. Environmentally friendly revetment systems which were installed in three rivers showed the growing of the natural habitat at the river bank and flood plain. The restoration of rivers in Malaysia is considered to be in its early stage and more work need to be done to save the rivers from environmental degradation.

## References

- [1] Grant, G. E. 2008 A Framework for Evaluating Disiplinary Contributions to River Restoration *Proceedings of 4<sup>th</sup> ECRR Conference on River Restoration, European Centre for River Restoration, Venice, Italy, 16-19 June, 2008, 113-122.*
- [2] Escarameia, M. 1998 *River and Channel Revetment- A Design Manual.* Thomas Telford publishing company, London, UK.
- [3] Allen, H. 1978 Role of Wetland Plants in Erosion Control of Riparian Shorelines *Proceedings of the National Symposium on Wetlands, American Water Resources Association, Minneapolis, Minnesota, USA, 403-414.*
- [4] USACE. 1999 Design of Revetments, Seawalls and Bulkheads: Sloped Revetments. Publication Department, Hyattsville: USACE, USA, (Report No. EM 11110-2-1614).
- [5] Coppin, N. J. and Richards, I. G. 1990 *Use of Vegetation in Civil Engineering.* Butterworths Publishing Company, London, UK.
- [6] Bakker, P., Klabbers, M. And Reedijk, J. 2004 *Introduction of the Xbloc Breakwater Armour Unit Report Number 94,* Netherlands.
- [7] Keown, M. and Oswalt, N. 1984 Engineers Experience with Filter Fabric for Streambank Protection Applications *Proceedings of International Conference on Flexible Armoured Revetments Incorporating Geotextiles,* London, UK.

- [8] Henderson, J. 1986 Environmental Design for Streambank Protection Projects *Water Resources Bulletin*, **22**(4): 549-558.
- [9] Ming, H. and Karen, E. 2002 Biotechnical Engineering as an Alternative to Traditional Engineering Methods. *A Biotechnical Streambank Stabilization Design Approach Landscape and Urban Planning* **60**, Texas Transportation Institute, USA, 225–242.
- [10] Weller, P. 1998 River Danube Programme. *European Centre for River Restoration, ECRR*, **2**(1), 5-6.
- [11] Diamond, M., Walker, J., and Naura, M. 2001 River Restoration and the Water Framework Directive. *European Centre for River Restoration*, **5** (2), 2.
- [12] Menke, U. and Cals, M. 2002 River Restoration –Different Scales and Aspects. *European Centre for River Restoration, ECRR*, **6**(2), 1-2.
- [13] Arnaud-Fassetta, G. and Fort, M. 2008 *Proceedings of 4<sup>th</sup> ECRR Conference on River Restoration, Venice, Italy*, 312-322.
- [14] Gilligan, N. 2008 Hydromorphology and River Enhancement for Flood Risk Management in Ireland *Proceedings of 4<sup>th</sup> ECRR Conference on River Restoration, European Centre for River Restoration, Venice, Italy*, 16-19 June, 2008, 323-328.
- [15] Menke, U. and Nijland, H. 2008 Nature Development and Flood Risk Management Combined along the River Rhine Experiences from a Transnational Co-operation within the SDF-Project, *Proceedings of 4<sup>th</sup> ECRR Conference on River Restoration, Venice, Italy*, 329-338.
- [16] Shuler, H. 2008 *Little Tennessee River Greenway Restoration Project*. Business and Industry Training, Southwest Community College. [www.littletennessee.org](http://www.littletennessee.org).
- [17] Rutherford, I. D. and Gippel, C. 2001 Australia versus the World: do we face special opportunities and challenges in restoring Australian streams?, *Water Science and Technology*, **43**: 165-174.
- [18] Rutherford, I. 2008 Restoration Ecology in Granite Creeks, Victoria. Report, Cooperative Research Centre for catchment Hydrology and River Restoration, University of Melbourne, Australia.
- [19] Nakamura, K. 2008 River Restoration in Japan. *Report, Public Work Research Institute*, Japan.
- [20] Williams, P. B. 2001 River Engineering Versus River Restoration. *ASCE Wetland Engineering and River Restoration Conference*, Reno, Nevada, USA.
- [21] Jasperse, P. and Wind, H. G. 2000 Bottleneck of Dutch Stream Restoration Projects. *Proceedings of the Second International Conference on River Restoration, European Centre for River Restoration, Wageningen, Netherlands*, 15-19 May, 2000.
- [22] Abernethy, B. and Rutherford, I. D. 2000 A scale analysis of Bank Stability: Targeting Reaches for Riparian Re-vegetation, *Proceedings of the Second International Conference on River Restoration, Netherlands*.