Modelling Urban Stream Corridor Restoration

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In Sri Lanka stream corridors can be considered as one of the major sensitive eco system and that has been threatened by urbanization. Objective of this study is to introduce proper models for restoring the urban stream corridor. Data collected for the research through image classifications, surveys on chain, vegetation, solid waste and stream loads, water test, stakeholder interviews and observations. It was found that there are many problems induced by humans such as artificial stream modification, land use change, problems with solid waste handling and water pollution were evaluated, using forty two different indicators. Accordingly, it was developed urban stream corridors stress network model. It was found that artificial modifications in stream corridors is the major problem and negatively stream corridor structure and process in four different ways and affected 12 elements, parts and values. Vegetation changes in stream corridor negatively effects stream corridor structure in 2 ways. Education and management restoration models were developed considering the stress network model to restore urban stream corridors in Sri Lanka. There should be proper demarcation of stream corridor boundary line at least in urban premises and awareness programs in headwater catchments are recommended.

Keywords: Artificial stream modification; Stream Corridor; Stress network model; Solid waste; Urbanization

Introduction

"A stream corridor is an ecosystem that usually consists of three major elements; Stream Channel Flood Plain and Transitional Upland Fringe. Together they function as dynamic and valued crossroads in the landscape" (Federal Interagency Stream Restoration Working Group, 1998).

There are more than hundred thousand kilometers of rivers and streams, along with closely associated floodplain and upland areas in Sri Lanka (Dissanayake, 2014). The radial drainage pattern that carries surface water down from the high watersheds includes 103 distinct natural river basins that cover over 90 percent of the island.

Mahaweli is the largest river (325 km) in Sri Lanka and it starts from central Highland. Its annual discharge is 7650 million cubic meters also has by far the largest catchment area (10, 327square km) covering one sixth of the country (Natural Resources of Sri Lanka, 1991). Agriculture, hydropower, day today water consumption, flora and fauna diversities and many other activities of the country mostly depend on this river catchment. Disturbance to the river catchment visible first phase prior to the independence for commercial crops and developing the infrastructure in high land Sri Lanka and second phase after independence for the multipurpose development programs under implemented accelerated Mahaweli development program (Breuste and Dissanayake, 2014). The structure and composition in upper catchment Sri Lanka land cover was considerably changed. In addition to that high intensity of rainfall and steep slopes, lack of integrated and coordinated land use planning are the reasons of rapid depletion of catchment resource base [7]. This was further enhanced through the revised government policies moving towards a free market economy in beginning 1980s. Results of economic boom influence to increase settlement growth on vacant sensitive areas such as stream corridors (Dissanayake, 2002, Chandrasekara and Gunewardene, 2001). The consequences of human induced disturbances on stream ecosystem could be visible from late part of the 20th century. River course changes (Dissanayake, 2011) sediment load changes [6], changes of water quality (Abeygunewardene et al., 2011), extinct of biodiversity, environmental hazards are the major challenges in Stream corridors in Sri Lanka. To overcome the massive environmental degradation due to plantation agriculture in head water catchments, some soil conservation strategies were introduced during the colonial period by the British. These approaches were not effective to control the degradation of highland watersheds. During The late 1970 the first holistic, broad-based watershed management projects were introduced by Mahaweli Authority and those projects lasted up to recent years (Gunewardene, 2003). Inability to set up sound education awareness programs, eco-friendly management mechanism with specific degradation level and lack of continuous evaluation and monitoring faults are the major issues to be solved restoring the in Stream corridor ecosystem in Sri Lanka. Therefore, objective of this study is to introduce proper models for restoring the upper Mahaweli stream corridors.

Methodology

To identify the urban stream syndrome and the best management actions to conserve streams in different scale, the Mahaweli River structure and process is segmented in to 5 scales such as; I. Mahaweli Catchment, II. Head water stream, III. Corridors, IV. Reaches, and V. Points and lines.

Within the upper Mahaweli catchment selected 3 head water streams and among that two corridors represent different urbanization levels base on population size and one stream selected less populated minimal disturb stream and it considered as a control stream corridor. Samples were taken from reaches scale as highly populated, average populated and less populated reaches within the streams and also from different point locations through collected the data in different ways. Such as remote sensing and geographic information systems, chain survey, solid waste surveys, stream load surveys, water tests, questionnaire surveys with dwellers and interviews with both dwellers and officials. Stream Corridor Stress Network Model (SCSNM) developed through analyzing the decision criteria for Stream Corridor Ecosystem Condition Gradient (SCECG). In the development of a quantitative SCECG, weighted forty two number of impact attributes, through narrative decision criteria (Table 1) and used for assigning 42 at- tributes to SCECG levels as excellent, good, fair and poor and identify the statues of Upper Mahaweli stream corridors (Figure 1).

Results and Discussion

In the SCECG, first four attributes that describe the artificial modifications of stream corridors and how it effects and affects the stream corridor ecosystem (A1-A4). Five attributes that describe changes of vegetation cover and its consequences (B5-B10). Twenty three (C-11 to C-35) attributes had been used to describe the human behavior in the stream corridor and its effects and affects to the stream corridor ecosystem and seven attributes had been used describe institutional capacity for restoring the stream corridor ecosystem.

Weighted SCECG table was converted into one figure as stream corridor condition gradient (Figure 1) and found the conditions of three different stream corridors. In Meda Ela, out of 42 attributes 26 (62%) numbers shows 3-4 level of stress condition (fair to poor) while 16 (38%) attributes shows 1-1.9 level minimum stress condition (Figure 1). In Pinga Oya, out of 42 attributes 24 (57%) numbers shows 3-4 level of stress condition (fair to poor) while 18 (42%) number of attributes shows 1-1.9 level minimum stress condition (Figure 1). In Heel Oya out of 42 attributes 7 (16%) numbers shows 3-4 level in condition (fair to poor) while 35 (84%) number of attributes shows 1-1.9 level minimum stress condition (Figure 1).

SCECG was provided much guidance for identification of problems, effects and affects and how those impacted to the structure and process and the elements, parts and values in the stream corridors. Research base designed SCECG (Figure 2) had given a clear picture about status of urban stream corridors for design restoration models to restore urban stream corridors in Upper Mahaweli River Sri Lanka.

First and second level of the SCSNM was explained the problems of the stream corridor identified from the study. Third level of the SCSNM was explained the stream corridor structure and process stress that was created due to the second level of problems. Forth level of the SCSNM was explained the affected parts and values stress in the stream corridor ecosystem. Fifth level of the SCSNM was explained institutional stress due to losing the natural balance of the stream corridor Ecosystem. Sixth level of the SCSNM was explained how political patronage influence to the different issues the research identified that the ownership of stream corridor boundary land is a major threat for the stream corridor ecosystem. More than 90% of the stream corridor boundary land belongs to the private dwellers and they handle the corridor activities and had created following problems common in urban stream corridors. Increase impervious surface (Artificial modification) is a major problem created by ownership of the land in the selected stream corridors as well as other urban and semi urban streams in Upper Mahaweli River; it effected to stream corridor structure and process in 5 ways, and affected 14 number of elements, parts and values in the stream corridor ecosystem.

Disposal of solid waste and waste handling behavior was identified as a second problem of the stream corridor and it effects ecosystem structure and process in 4 different ways and affected 12 elements, parts and values in the stream corridor ecosystem.

Vegetation changes in stream corridor effected to stream corridor ecosystem structure in 2 ways (Figure 2 Level 3 I and J) and affected to 3 numbers of elements parts and values (Figure 2 Level 4 N, O and P) in the stream corridor ecosystem.

When analyzing the network model it was found that artificial modification problem had an impact and changed the stream mophometry (Landscape) in stream corridor ecosystem in 3 different ways it impacted to total catchment increasing the impervious surface, impacted to stream channel as channel modification and impacted to stream channel, flood plain and upland fringed.

It was also founded that 3 different problem faces were affected to change the ecosystem structure in seven different ways (see figure 2 level 4 M to S); increasing impervious surface was led to change the stream process; storm water flows and flood hazard especially in Meda Ela and Pinga Oya and also effected to change the process of stream water chemistry.

Stream channel modification problem affected to change the stream corridor process creating smooth and thick surface effect to storm waters and floods and also contributed to change the stream water process.

Buildings close to the stream problem affected to storm water and flood effects change the stream water chemistry as well as supported to increase other problem as generate close proximity to waste waters. It also disturbed to the stream corridor structure removing vegetation for construction work. This network was clearly identified from stream cross sectional surveys.

Artificial stream corridor modification effects to change the structural and process parts, elements and values in different ways. Earth filling, excavation, mixing and sealing of soil for roads, paving areas and for buildings effected water balance. Narrowing stream widths and concreting stream bank is very common in highly and average populated reaches in stream corridors and its leads to increase the water velocity. The study identified storm water and floods was affected to the people, their properties and their happiness, flood eroded stream bank and lose the stream bank stability and increased siltation in the stream bed. Stream surface covered bridges and concreted slabs prevent sun light reaching the stream and creates an unfavorable living environment for the aquatic species. The problem further was affected to institutional party creating issues such as flood damage recovering issues, water purification and environmental protection issues.

When analyzing SCECG and the SCSNM it was found that waste handling behavior created impacts to change the stream corridor ecosystem in two different ways (Problem F and G). It change the stream water chemistry (structure). If stream containing high concentration of toxic materials or high temperatures, low dissolved oxygen or other chemical characteristics are inappropriate level stream health will be in bad condition. As many other studies similar to this study confirmed artificial constructions on very close proximity to the stream channel poor controls of erosion lack of riparian shading, excessive sources of nutrients oxygen demanding waste from urban waste, waste water outlets and storm water pollution resulted in degradation of the physical and chemical conditions in the streams and exerted undesirable impacts on stream corridor eco system and it was clearly visible from consequences due to modification , consequences of land use changes and consequences of stream water pollution.

Stream load changes (process) had impacted to increase siltation in the stream bed (elements), habitat loss (elements), loss of aesthetic values, and increase the epidemic breading grounds was identified in this study. Geomorphic processes are the primary mechanisms for forming the drainage patterns, channel, floodplain, terraces (stream corridors) and catchments. Sediments are the major character of stream and it closely related with the movement of stream water. Fine sediments intrusion in to the stream corridor from non-point sources stream bed gravel can reduce permeability and intra gravel water velocities, thereby restricting the supply of oxygenated air and also controlled the process of pools and riffles in head water streams. This situation clearly revealed that tones of demolition debris had been dumped in to the less populated stream corridors especially with road accessed highly and average populated stream corridors negatively affects to the aquatic biodiversity and its clearly revealed from the stress network analysis.

SCECG and the SCSNM was found to influence vegetation cover changing problem effect to change the stream corridor structure, decreasing the vegetation density, diversity and vegetation bands, and it was also effect to water structure and affected to parts and value such as habitat loss stream bank stability, habitat, water use limitation and economic and aesthetic values. It also creating institutional issues such as environmental planning, punitive issues (Figure 2). Whether it was a single issue impact scale will be the most highest.

Riparian vegetation changes was causing to lose numerous patterns and functions in stream corridor ecosystem as identified by many researchers (Bourque and Pomeroy, 2001; Findlay et al., 2001; and Gregory et al., 1991) as well as this study also found the facts in stream corridor ecosystem. A remarkable riparian vegetation cover loss can be identified in highly populated reaches in Meda Ela and Pinga Oya. In that respective stream corridors comprised with totally concreted or poor vegetation diversity and very poor vegetation bands. Loss of ground cover in the watershed and stream corridor led to decreased infiltration and increase runoff, leading to higher flood peaks and additional runoff volume. Reduction in base flow and increase in storm flow can result in formerly perennial stream becoming intermittent or ephemeral. That situation very clearly identified from the stream dwellers perceptions about 20 years ago regarding conditions of the stream.

Such corridors mostly covered with introduced species and mono plants species can live under extreme environmental conditions (temperature, soil, chemical parameters etc.). It reduces food availability affects stream temperature and disrupts sediment nutrient toxin uptake from surface runoff.

Typical riparian vegetation diversity and vegetation bands with well grown canopy could identified in the less populated stream (Heel Oya) as well as in less populated reach in average populated stream corridors (Pinga Oya). They very clearly correlated with elevation, gradient, availability of sunlight and other geographical factors. It also acts as a filter for sediment and control pollution from upland areas, it provided habitat for many species in that ecosystem, shade for the water cool and help to protect the bank stability. The critical situation was that highly and average populated stream corridors vegetation band damaging percentage is very high and it's mostly covered from concrete.

Relationship between slope and height of the vegetation and disparities between highly populated and less populated stream corridors also very important focal point identified in this study. In steep slope corridors height of vegetation is very low compare to with average slope corridors. Such characteristics cannot be identified in the highly and average populated stream corridors. When planning for re-planting attention should be given to the above factors.

Stream Corridor Restoration Education Model (SCREM)

SCREM was developed to fill the gap between ideal and reality in the stream corridor ecosystem. SCECG provided a clear picture about what is the ideal and reality according to that gradient number 1 and 2 can be taken as ideal and gradient number 3 and 4 can be taken as a reality (Figure 1). When applying this grading into three different stream corridors, Heel Oya stream corridor condition can be considered as ideal and Meda Ela and Pinga Oya can be considered as a reality. To reach the ideal level research identify stream corridor boundary land belongs dwellers is the main issue and it create many other problems (Figure 3).

Goals: educate the stream dwellers about the stream corridor legal safeguard for demarcating the stream corridor boundary lands and improve the human attitude and behavior of stream dwellers should be the major goal of the model. To deal with the stream corridor subject properly improve knowledge, skills and attitude of the institutional staff will be the second goal of this education model. It will be benefitted for implementing, monitoring, evaluating restoration work, and handle the punitive causes in the corridors.

Leadership and Sponsorship: Mahaweli Authority, Central Environmental Authority and Local Governments are the major responsible institutes of the respective field. Except to that other environmental friendly institutes also can take the leadership and sponsor education awareness programs.

Resource Panel: to reach the awareness goal resources panel should consist of expertise in different restoration aspects such as scientists, researchers, legal officers, policy planners.

Awareness: education programs should be designed for different targets groups to develop the knowledge, skills and attitudes on the ecosystem process and its values, existing stream corridor condition, legal frame work of stream corridors, punitive measures and stream corridor protection and restoration methods.

Target Group: Target group should be ensuring for present and future restoration work. There for Preschool, schools, stream dwellers, office staff in respective institute and university and other educational institutes should be included in the programs.

Arrows in the Model: explaining the floes of information and supports.

Stream Corridor Ecosystem Restoration Management Model (SCERMM)

Goal: creating a sustainable stream corridor ecosystem for the Upper Mahaweli stream corridor was the major goal of the SCERMM model (Figure 4). The model was designed considering the facts of SCECG (Figure 1) and stream corridor stress network model

(Figure 2) to reach the sustainable level of stream corridors have to be taken much effort to control of the key threat factors.

(1) Ownership of the stream corridor land

(2) Artificial modification

(3) Stream dwellers solid waste handling behavior

(4) Vegetation changes in stream corridors

How to Reach the Goal: Urban stream corridor restoration is an agreement between two parties as ecosystem protecting party and the stream dwellers. To reach the goal need a leadership and research was identified one of the most unique and responsible pillar as a Mahaweli authority. Government of the Sri Lanka should give attention to sustain this ecosystem and strengthen this authority via sufficient legal and other infrastructure facility. The same way should be control the over going limits in the authority.

Leadership: Leadership should be giving more attention to public hearings it will definitely profitable take correct decisions. Also it will be benefitting for more convenient restoration work. Leadership should keep in touch with the expert knowledge panel in life time and get their facility continually to reach the goal and sustaining the goal. The same time authority should be facilitating them for continued research work and planning requirements of the stream corridors.

Stream Dwellers Committee: In restoration agreement secondary party is stream dwellers. It will consist of housing, commercial agricultural and other land ownerships and their families the group is the major awareness target group in stream corridor restoration.

Stakeholders: Strengthen the bridge between stream corridor leading party and stream dwellers should be needed to bring the direct and indirect contacts between the two parties. To implementation activity, monitoring, punitive scale measuring, database handling, organizing and informing workshops, awareness and restoration activity process, leadership can be use the powerful stakeholders who are responsible for the relevant stream corridors: sub sections in Divisional secretariats, Local government authorities etc.

Leadership and relevant stockholders can give sufficient energy to formulate the stream dwellers committees and it will be benefitted for dealing with the restoration activity, legal comprehensions and awareness activity in successful scale.

Arrows indicate the information flows among the different valuable pillars in the stream corridor restoration work.

Conclusion

It was found that there are many problems induced by humans; artificial stream modification, changes of land use in stream corridors, human behavioral activities such as solid waste handling, water pollution and restoration capacities were evaluated, using 42 different attributes. To evaluate the attributes in stream corridor condition level was taken at internationally accepted standards; tropical research accepted stranded as well as local indigenous knowledge. The findings of this study provided sufficient data base to evaluate the states of Upper Mahaweli head water stream corridors in Sri Lanka. Research findings based on SCECG provided sufficient direction to identify the statues of Upper Mahaweli stream corridors.

In highly, average and less populated streams condition were represented by SCECG and level is 2-3 level (Good to poor). It was observed that less disturb streams like Heel Oya SCECG level is 1-2 (excellent to good), where the stream corridor is recovering rapidly, and active restoration is unnecessary and even detrimental. Urban stream corridors in Upper Mahaweli River are being gradually converted to almost urban waste cannels and this was identified in this study at different scales.

For sustainable stream corridor ecosystem for Sri Lanka, the government should give more power to relevant authorities to take legal actions for demarcate the boundary line of the stream corridors at least streams passing through urban premises. The process will be difficult but awareness will be much benefitting.

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Disclosure statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 1. Decision Criteria for Stream Corridor Ecosystem Condition Gradient

Parameters	**Stream Corridor Ecosystem Condition Gradient (SCECG)**			
Artificial modification	Excellent (1)	Good (2)	Fair (3)	Poor (4)
A. Artificial stream modification and its consequences				
A.1 impervious surface within the stream corridor (Image analysis/ Chain survey)	Within the corridor pervious area more than 75%	Pervious area 75% impervious less than 25%	Pervious area 50% impervious 50%	Impervious More than 75%
A.2 stream cross sectional modification	No any modifications (stream channel/flood plain/upland)	Small part of the stream modified 25%(stream channel/flood plain/upland)	50% modified 50% Natural	More than 75% modified
A.3. stream surface cover (bridges)	No Bridges	More than I km distance public use/public transport access	Distance ½ km/ limited people use	Totally concreted totally private

A.4 consequences due to modification	No consequences	Very rare consequences only from natural hazards	Many number of consequences (can control with minimum period)	Constance consequences To control take long time and cannot fully recover)
B. Changes of vegetation cover in stream corridors and its consequences				
B.1 Vegetation cover Within the corridor 40 m stream buffer	More than 75% vegetative cover Rest natural cover	More than 75%-50% vegetative cover rest natural cover	50%-25% vegetative cover rest less natural cover high constructed	Less than 25% vegetative cover
B.2 Vegetation diversity 100 m reaches within 40 m stream buffer	Many plant (over 15) specice, spread all over the corridor, Native plants, natural growth	Large number (10-14) of species, spraed much extent, native and introduced plants	Less number (5-9) mostly introduced plants	Less number (Less than 5) of species, mostly introduce plant no natural grown cover except to mono plants close tot he stream water
B.3 vegetation bands Within 10 transects	Very clear bands with dense vegetation, spead all over the corridor, environmental adaptation highet ,leave size, stem shape, native species,	Bands can be identified but some lines bands with damage More than 3 bands	Scatted bands with damages most lines no vegetation 1-2 bands	No vegetation bands totally concreated
B.4 vegetation decreasing trend Land use pattern 20 years ago	rich vegetation cover with vegetation bands,more than 80%, rich auqartic fauna, stable corridors	50% -80% vegetative, Some auqartic species natural stream corridor protection method. Less stream corridor pollution activities	Less than 50% vegetative cover, no or less auqatic specis, many stream corridor activities . stream polution identified.	Less than 50% vegetative cover.no auqatic species, More than 80% concreated. polluted stream water
B.5 Consequences	Less than 2 natural hazards	2-5 natural hazards	More than 5-7 number of natural and man made hazards	More than 7 number of natural and man made hazards
C. Human behavior in the stream corridor				
C.1 Distance between the stream and buildings	Over the 40m stream corridor maintained properly	Over the 40 m, but some activities with in the corridor road accesses	within the 40 m but less disturbances	Within 20 m many distrbanceses
C.2 Ownership of the stream corridor land	Government	Private less than 50% but demarcate the stream buffer	Private more than 50% But demarcate the stream buffer	Private more than 50% but not demarcate the stream buffer
C.3 household waste generating rate	Less than .5 kg mostly biodegradable waste	.5- 1kg most biodegradable	1-1.5 kg most biodegradable	More than 1.5 kg biodegradable/plastic/hazardous
C.4 Solid waste transfer point and non -point in the stream corridor	No transfer point or non point sources in the stream corridor/no any possibility dump waste	No any transfer point and non point sources in the stream corridors	Non points can identify possibility has dump the waste	Point sources and non points can identify within the stream corridor/

C.5 Profile of waste	Only natural waste from flora and fauna in the stream corridor ecosystem	Very limited waste catogaries can identify biodegradable and plastic waste raising from the catchment (5%)	Biodgradable, plastic, waste and less hazardous waste, demolotion debris from stream corridor (10%-50%))	Biodegrable , plastic, hazardous and large amount of demolotion debris ((more than 50%)
C.6 Waste water outlet connect to the stream	No waste water outlets connect to the sream /no effluent waste water flowing possibilities	No waste water outles but have effluent waste water flowing possibilities	1-10 waste water outlets	More than 10 number of waste water outlets
C.7 Changes of the stream surface load	Only natural surface load	Very little amount from catchment runoff	Household waste, commercial waste,demoltion deris, garden waste in small scale	Household waste, commercial waste,clinical waste, demolution debris, garden waste in large scale
C.8 changes of the stream bed load	Only natural sediments Grain size gradually decreasing from upper to lower elevation of the stream	Only sediments but impacted from upper catchment activities	Natural as well as human induced partcals in the bed load in small scale	Natural as well as human induced partcals in the bed load in large scale
C.9 Changes of stream water chemistry: Stream water temperature	15-20 ^{0}C	20-25^{0}C	25-30^{0}C	Not greater than 40
C.10 PH	6.5-7,5	7.5 -8.5	5.5 -6.5 , 8.5 -9	Not Less than 5.5 Not greater than 9
C.11 Electrical conductivity (EC) μs cm-1	250	200-300	151-199,301-499	Not Less than 150, Not greater than 500
C.12 Turbidity/NTU	2-4	1-2, 4--8	Less than 1, 8- 10	Not greater than 10
C.13 Total dissolve solid (TDS)mg L-1	500-1000	1001-1499	2-499, 1500-1999	Not less than 2 Not greater than 2000
C.14 Total suspended solid (TSS)/ mg L-1	10 -20	21-30	0-9, 31-50	Not greater than 50
C.15 Total solids (TS)/ mg L-1	500-1000	1001-1499	2-499, 1500-1999	Not less than 2 Not greater than 2000
C.16 Dissolved oxygen (DO) mg L-1	Above 7-11	5-6, 11-12	4-5, Over 12	Not Less than 4
C.17 Bio chemical oxygen demand (BOD) mg L-1	0-1	1-2	2-5	Not greater than 5

C.18 Chemical oxygen demand (COD)mg L-1	0	0-10	10-20	>20
C.19 Total nitrogen (as N) /mg L-1	4	3 or 5	near to 6 or less than 2	Not Less than 2 and Not greater than 6
C.20 Total phosphorous (as P)/mg L-1	0	0-1	1-2	>2
C.21 Chloride (CL)/mg L-1	0-200	200-700	700-1200	Not greater than 600 / ppm
C.22 Sulphate (SO42-)/mg L-1	0-200	200-300	300-400	Not greater than 400/mg L-1
C. 23 other consequences of human behavior	Less than 2 environmental problems	2-5 environmental problems	More than 5-7 of environmental problems	More than 7 of environmental problems
D. Institutional interaction for stream corridor ecosystem management				
D.1 Legal Safe guard	Legal Safe guard1 for all the features in stream corridor(water/flood plain/uplands/biodiversity)	Legal Safe guard for majour featurs in stream corridor but need some improvements in legislation (punitive measurse)	Legal Safe gurd is there but importent features neglected	No/very poor Legal Safe gurd
D.2 Legal Institutional Interaction	Specific institution for streams with Sufficient powers2 to implimenting the ruels proper inter institutional network3 & sucssesfully deal with the subject	Institutions enrich with sufficient decentralized powers , inter institutional Net work gaps.	Institutions have sufficient decentralized powers but not in use properly ,ledership4 coordination gaps.	No specific institution for streams with powers, poor inter institutional network
D.3 Institutional leaders implementing rules and regulation monitoring assessing capacity	Implementing R&R5 Problem identification capacity6 very high very good information net work7, maintained very good data base	Implementing R&R Problem identification capacity satisfactory level but Information network with some laps, data base8 not properly maintained	Implementing R&R Information net work not sufficient less attention directly on SC due to many other responsibilities , Data base can not be use may laps	Very poor Implementing R&R, information network, No data base
D. 4 Funding capacity	Government funds9 with basic infrastructre 50% Non Governmental funds 50%	Government funds with basic infrastructure 25-50% Non Governmental funds 25-50%	Government funds with basic infrastructure 5%-25% Non Governmental funds 5%-25%	No Possibility
D.5 Environmental	Successfully handle cases without any influences,	handle cases but between or end	Handle cases but between or end	Handle cases but between or end with some influences,

violation and punitive10 capacity	Process transparent11, fixed punitive rates for relevant violations, well documented	with some influences, Process not fully transparent, fixed punitive rates for relevant violations, well documented not public.	with some influences, Process not transparent some institutions handle cases with good accuracy well documented punitive rates for relevant violations.	Process not transparent,poorly handle documents, no fixed punitive rates.
D.6 Non-Governmental Organizations capacity12	projects with funds posibility 50% participation for restoration work more than 50%	projects with funds posibility 25-50%% participation for restoration work 25%-50%	projects with funds posibility 5%-25% participation for restoration work 5%-25%	No involvement
D.7 Stream dwellers active participation14 capacity	methods and ideas more than 50%, Supplying Labor more than 90%, financially at least 10%	methods and ideas 25%-50% by Supplying Labor more than 50% - 90% financially at least 5%	methods and ideas 0-25% by Supplying Labor 40%- 50% financially at least 0-1%	No ideas/methods
D.8 Education15 Level of Stream dwellers	50- 75% Ordinary Level 25-50% Advance level and above	25-50% up to grade 10 25-50% above Ordinary level	High literacy rate 90%	Poor literacy rate
D.9 expert knowledge13 Academics in all discipline/ Scientist different institutes	Research on stream ecosystem,planning restoration projects consultant and awareness posibility more than 50%	Research on stream ecosystem,planning restoration projects consultant and awareness posibility 25%-50%	Research on stream ecosystem,planning restoration projects consultant and awareness posibility more than 0-25%	No contribution
D.10 School children / University students (Future capacity building)	Participation for research work and restoration work more than 50%	Participation for research work and restoration work 25%-50%	Participation for research work and restoration work 0-25%	No contribution

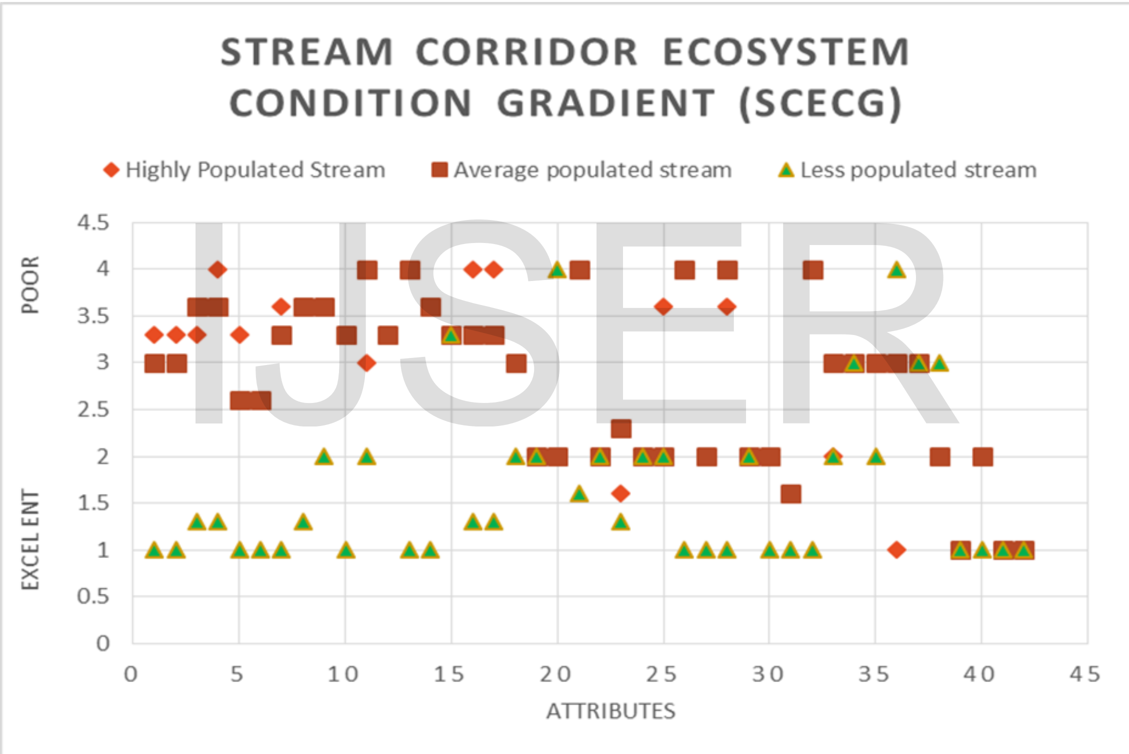

Figure 1. Stream Corridor Ecosystem Condition Gradient (SCECG)

Source: Dissanayake, 2014

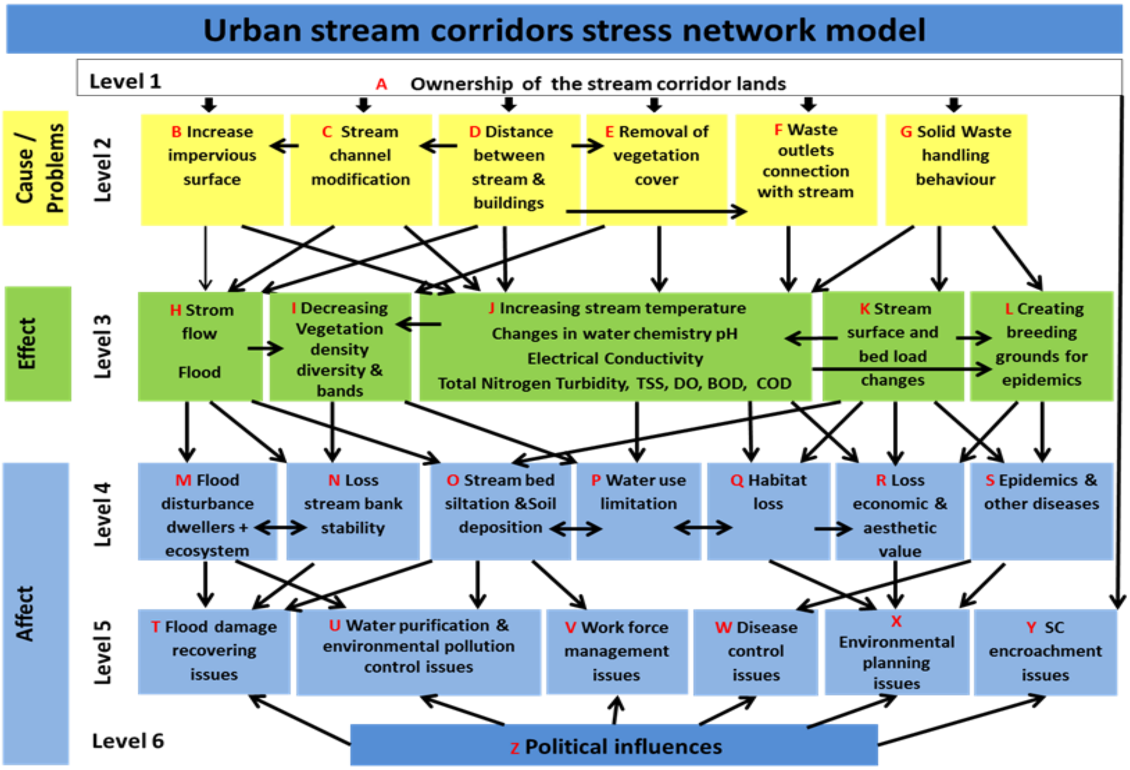

Figure 2. Urban Stream Corridor Stress Network Model (SCSNM)
Source: Dissanayake, 2014

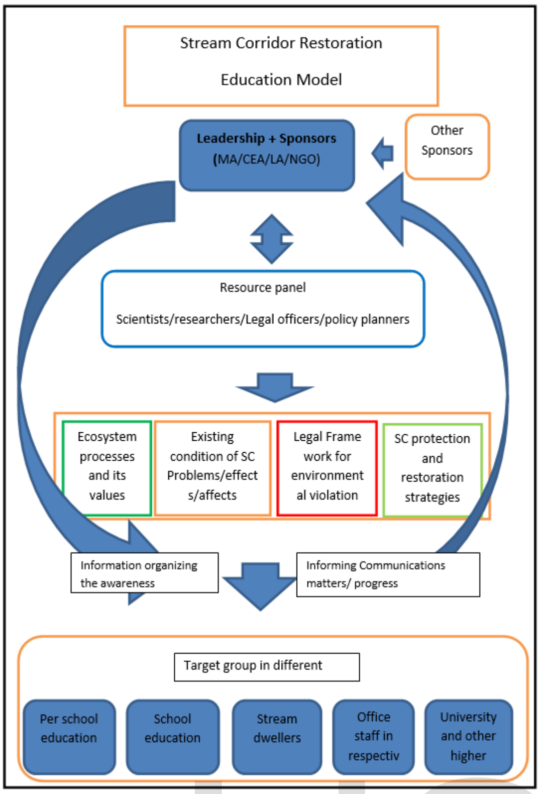

Figure 3. Stream Corridor Restoration Education Model (SCREM)

Source: Dissanayake, 2014

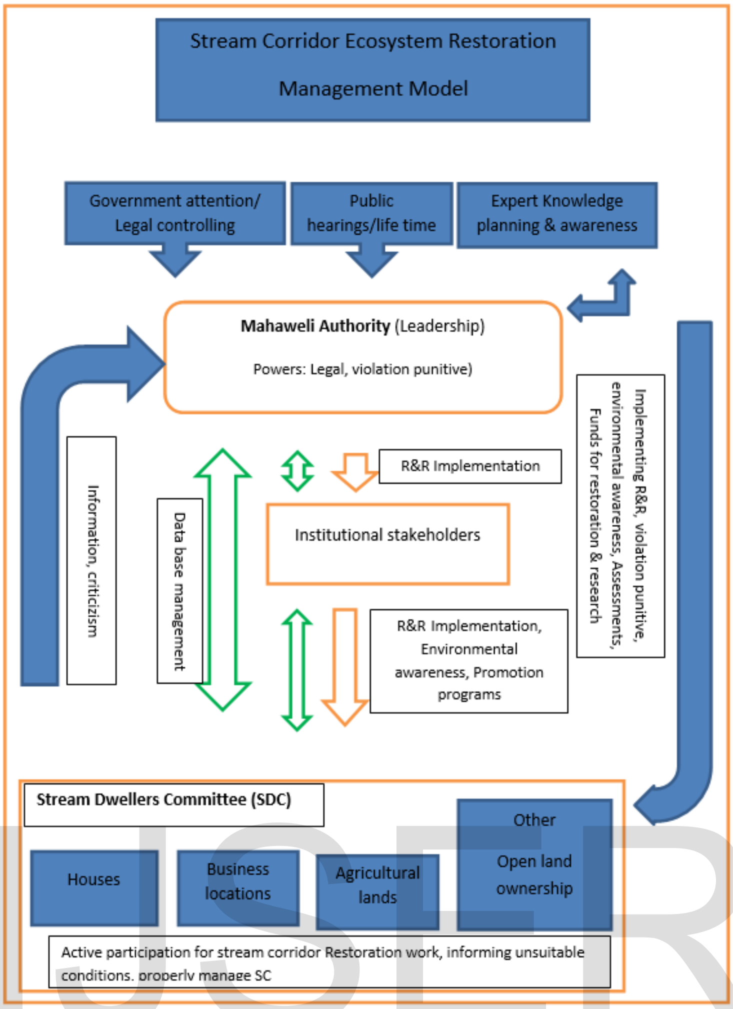

Figure 4. Stream Corridor Ecosystem Restoration Management Model (SCERMM)

Source: Dissanayake, 2014