The Economics of Stormwater BMPs in Tehran, Iran

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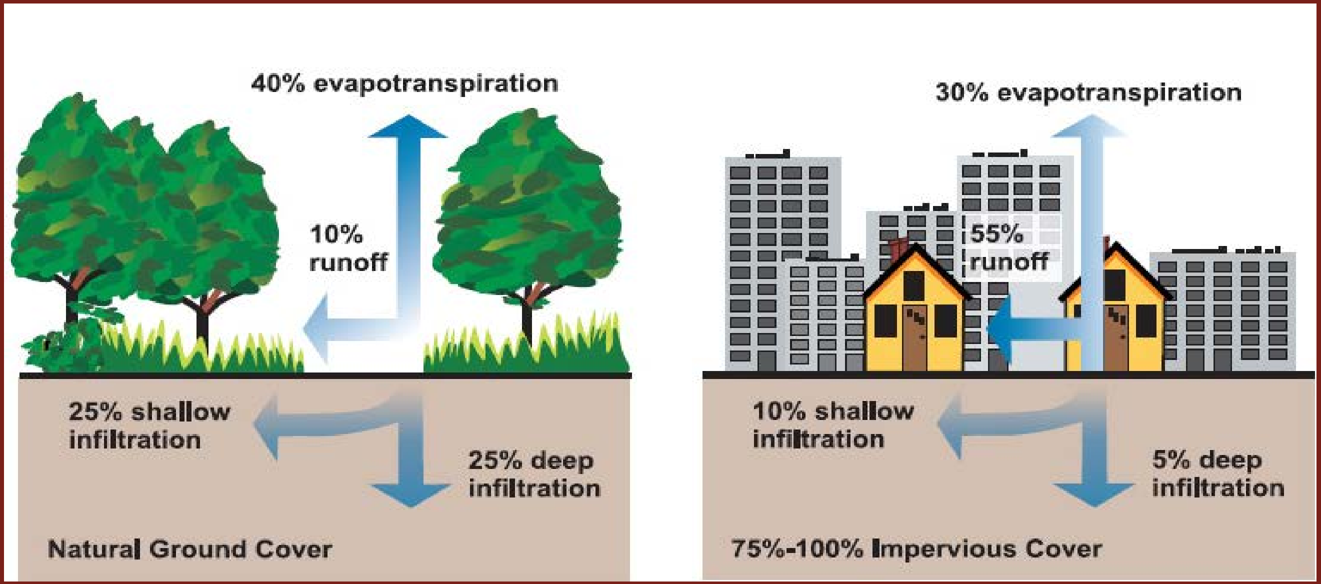
Introduction

- Urban Development
- Increased Imperviousness
- Enhanced flow velocities & Stormwater runoff volume
- Water Quality Degradation



Stormwater Management

- Water quantity control (Flood control)
- Water quality control
- Nutrients and Suspended Solids
- Non-Point Source pollution control
- Complex decision making problem
- Best Management Practices
- Find minimum cost combination of BMPs regarding pollutant outflow limits

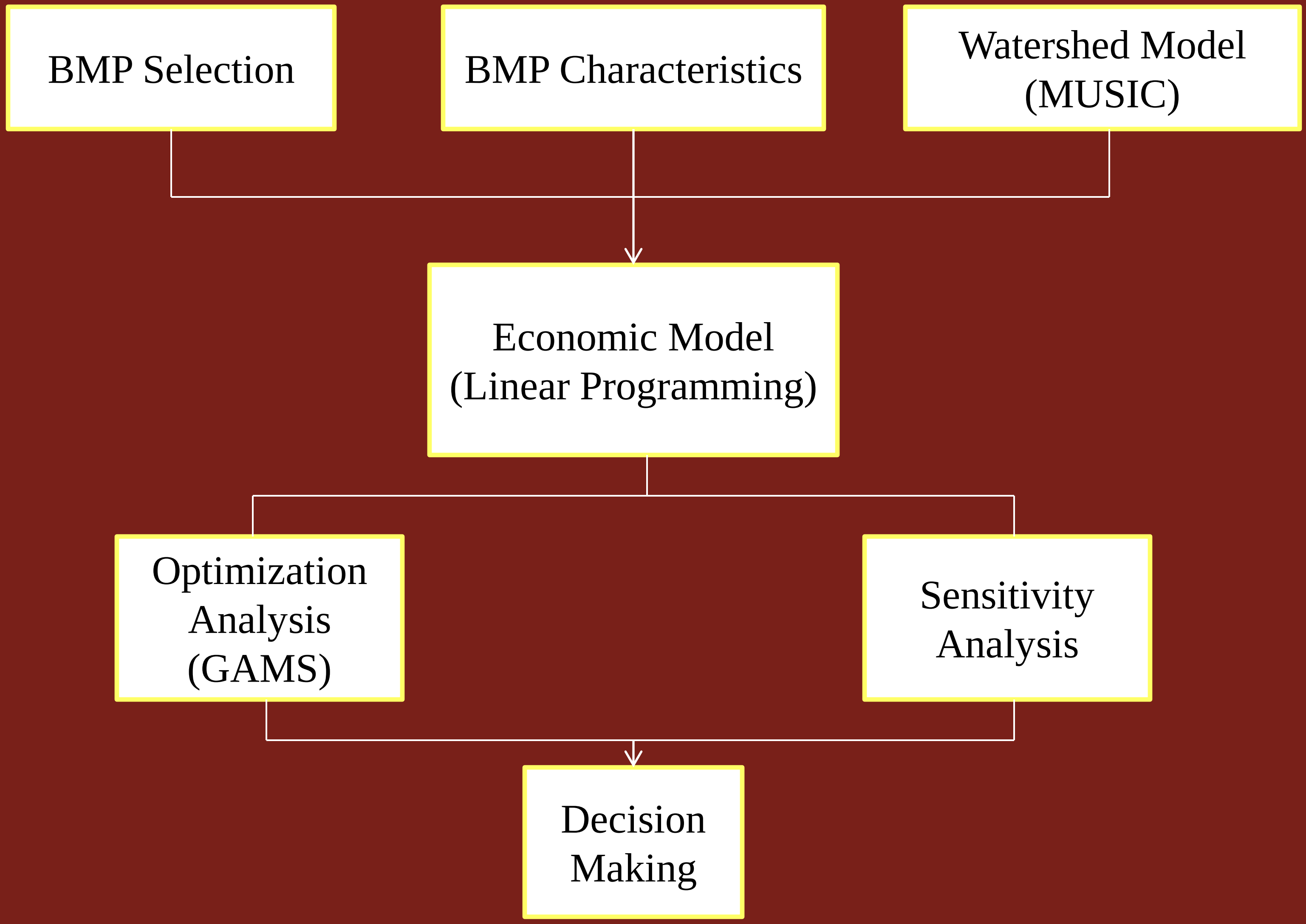
Study Area

- Maqsudbeig watershed in Elahiyeh the north of Tehran, Iran
- 350 ha drainage area
- Semi-arid climate
- Average annual precipitation of 250 mm
- Stream collects surface runoff and aesthetic objectives
- 3.3 km long
- No point source pollution
- Main source of pollution

Non-point source pollution resulting from stormwater runoff

Study Area

Methodology



BMP Selection

1. Site investigation

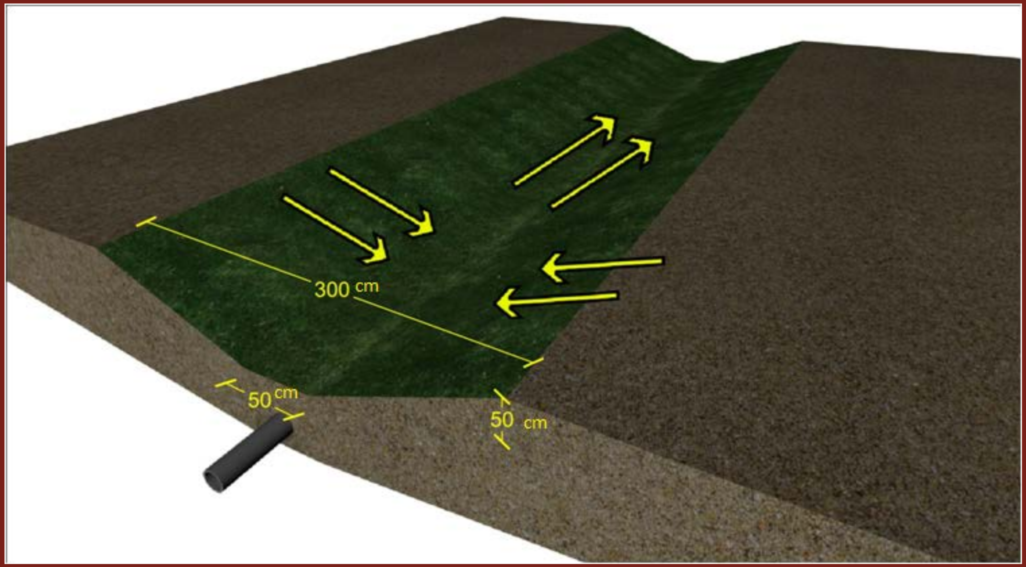
2. BMPs requirements

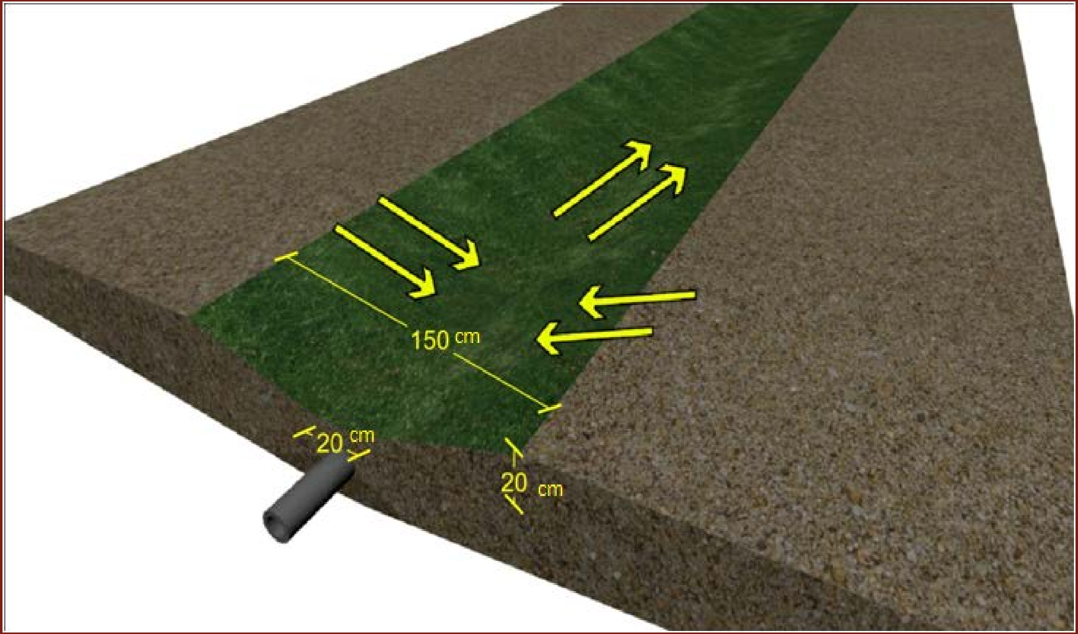
1 & 2 ⇨ Three types of BMP

Typical sizes for BMPs

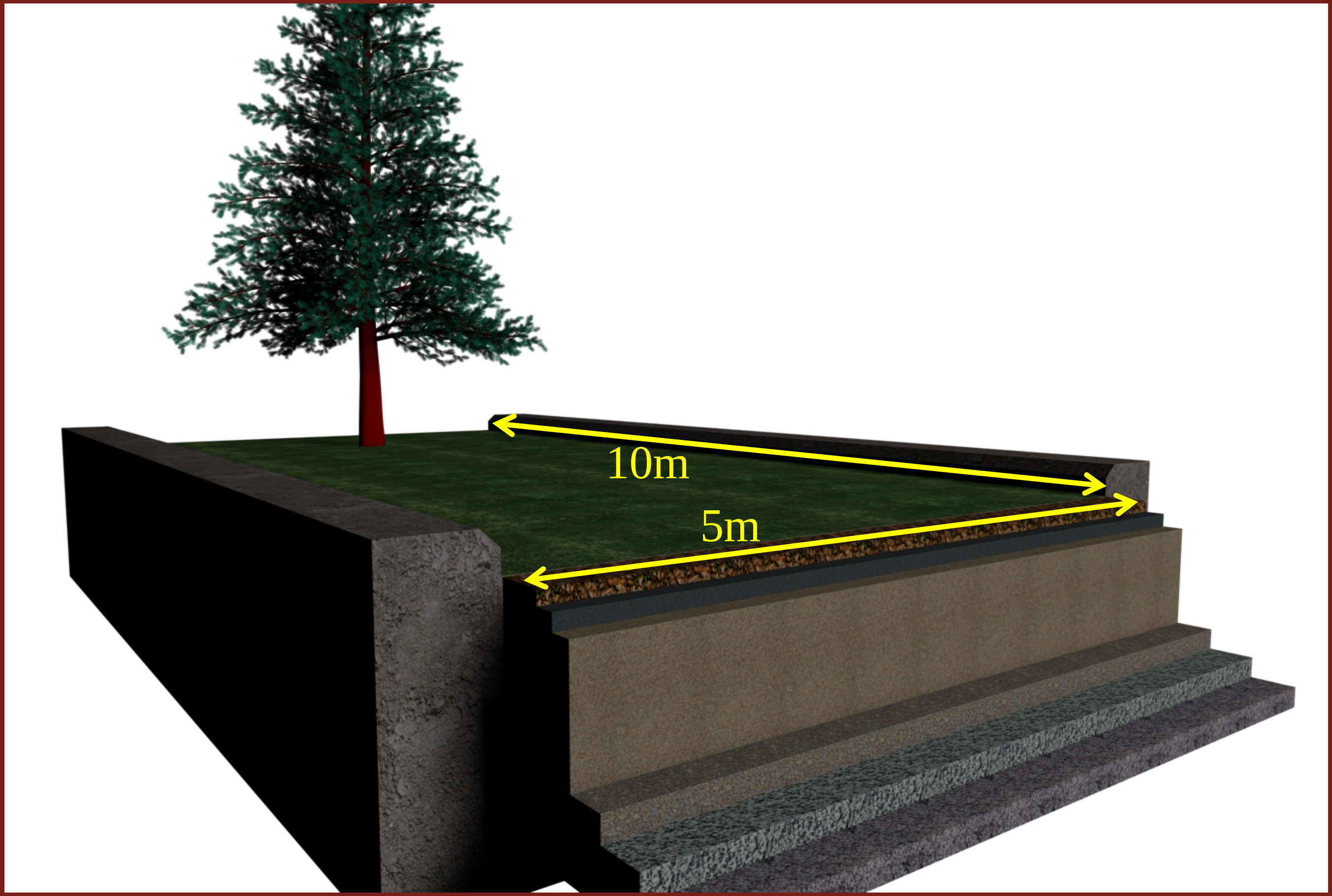
BMP	Length (m)	Width (m)	Area (m^2)
Swale	100	3	300
	100	1	150
Bioretention	10	5	50
Pond	15	4	60

Schematic of Swales

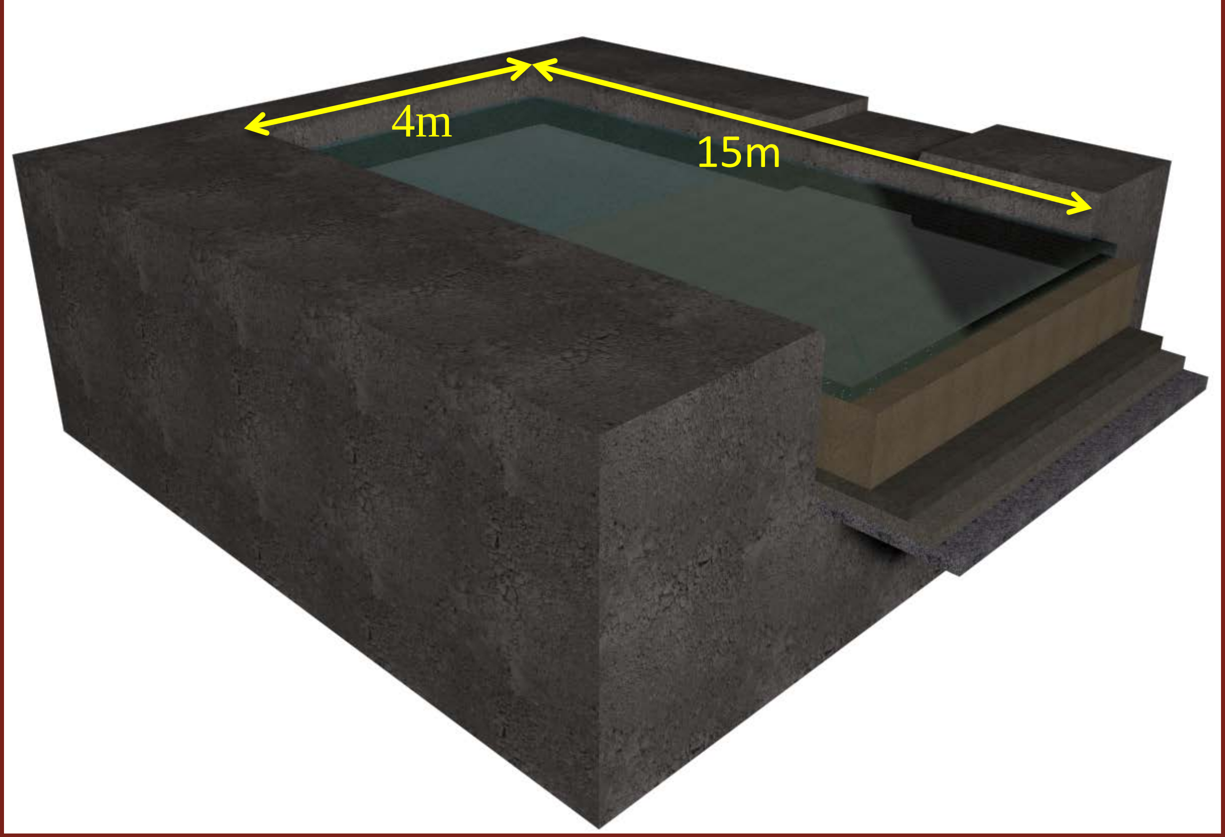




Schematic of Bioretention Systems



Schematic of Pond



Watershed Model

- MUSIC (Model for Urban Stormwater Conceptualization), CRCC, 2005
- Decision support system
- Predicting stormwater treatment measures
- Removal rates for TSS, TP and TN

TSS Removal Rates for BMPs

Combination	BMP			
	3 m width swale	1.5 m width swale	Bioretention Systems	Wet Pond
1	42%	28%	24%	7%
2	55%	34%	29%	12%
3	62%	35%	33%	12%
4	71%	38%	38%	16%
5	81%	42%	44%	17%
6	85%	42%	51%	27%
7	86%	45%	53%	29%
8	86%	47%	55%	30%
9	90%	51%	59%	32%
10	90%	51%	65%	32%
11	92%	57%	67%	41%
12	93%	64%	70%	48%
13	95%	77%	79%	67%
14	100%	100%	91%	83%
15	100%	100%	99%	100%
16	100%	100%	100%	100%

Economic Model

- Cost effective method
- Minimum cost combinations of BMPs
- Environmental standard
- Two major issues in economic model
    - ❑Cost of stormwater BMPs
    - ❑Associated pollutant removal efficiencies

Economic Model Structure

- Model Objective

$$TotalCost = \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{p} C_{ijk} X_{ijk}$$

C_{ijk}: Total cost of k number combination of BMP i installed in subcatchment j

X_{ijk}: The number of k number combination of BMP i installed in subcatchment j, a binary variable

i: type of BMPs

j: indication of subcatchment

k: number of BMPs combination (contribute to form X_{ijk})

Model Constraints

a. Pollutant Removal Efficiencies

$$I_{TP}\left(\prod_{i=1}^{m}\prod_{j=1}^{n}\prod_{k=1}^{p}(1-a_{ik})^{x_{ijk}} \le I_{s,TP}\right.$$

I_{TP}= initial concentration of total phosphorus, before implementation of stormwater BMPs

$I_{S,TP}$= standard concentration of total phosphorus that is expected to achieve after stormwater BMPs implementation

a_{ik}=total phosphorus removal rate of k number combination of ith BMP (%)

$$I_{TN}\left(\prod_{i=1}^{m}\prod_{j=1}^{n}\prod_{k=1}^{p}(1-b_{ik})^{x_{ijk}} \le I_{s,TN}\right.$$

$$I_{TSS}\left(\prod_{i=1}^{m}\prod_{j=1}^{n}\prod_{k=1}^{p}(1-d_{ik})^{x_{ijk}} \le I_{s,TSS}\right.$$

Model Constraints

b. Installation Area for a BMP

$$\sum_{k=1}^{p} X_{ijk} S_{ik} \leq A_{ij} \qquad \forall_{i,j}$$

S_{ik}=area of k numbers of BMP i

A_{ij}=area available for BMP i in subcatchment j

(available land for each type of BMP was defined by site investigation)

Costs

- Total Capital Cost
  - Land cost
  - Construction cost
- Design, Permitting and Contingencies Costs (unexpected costs)
  - Percentage of construction cost
- Operation and Maintenance Costs
  - Post-Construction activities
  - Prevention odour, turbidity, trash and sediment
  - A fraction of construction cost

Total Present Costs

$$P = A * E$$

$$E = \left[\frac{\left(\frac{1+r}{1+i} \right)^n}{r - i} \right]$$

P= present worth of annual O&M costs

A=annual O&M costs; r: inflation rate(20%)

i= interest rate(12%)

n= number of years (i.e. 20 year life period of BMPs)

Total Present Costs of BMPs

BMP	Design and construction costs (million Rial*)	Annual O & M costs (Million Rial)	Longevity (year)	Total Present Cost (Million Rial)
3m width swale	46.1	2.4	20	134.5
1.5m width swale	19.1	1	20	54.9
Bioretention Systems	36	2	20	110.8
Wet Pond	29.2	1.2	20	74.2

*Iranian Rials (IRR), 1 USD= 13000 Rial

Results

- Ignoring Land Cost
- The least cost BMPs to construct and maintain

Swale

BMP	k	Number	Area (m^2)	Removal Rate (%)			Cost (Million Rial)
				TSS	TP	TN	
3 m width swale	1	1	300	42	54	32	134.5
1.5 m width swale	1	7	1050	28	48	30	494.1
	2	1	300	34	54	36	
Bioretention Systems	-	0	0	0	0	0	0
Wet Pond	-	0	0	0	0	0	0
Total	-	9	1650	-	-	-	628.6

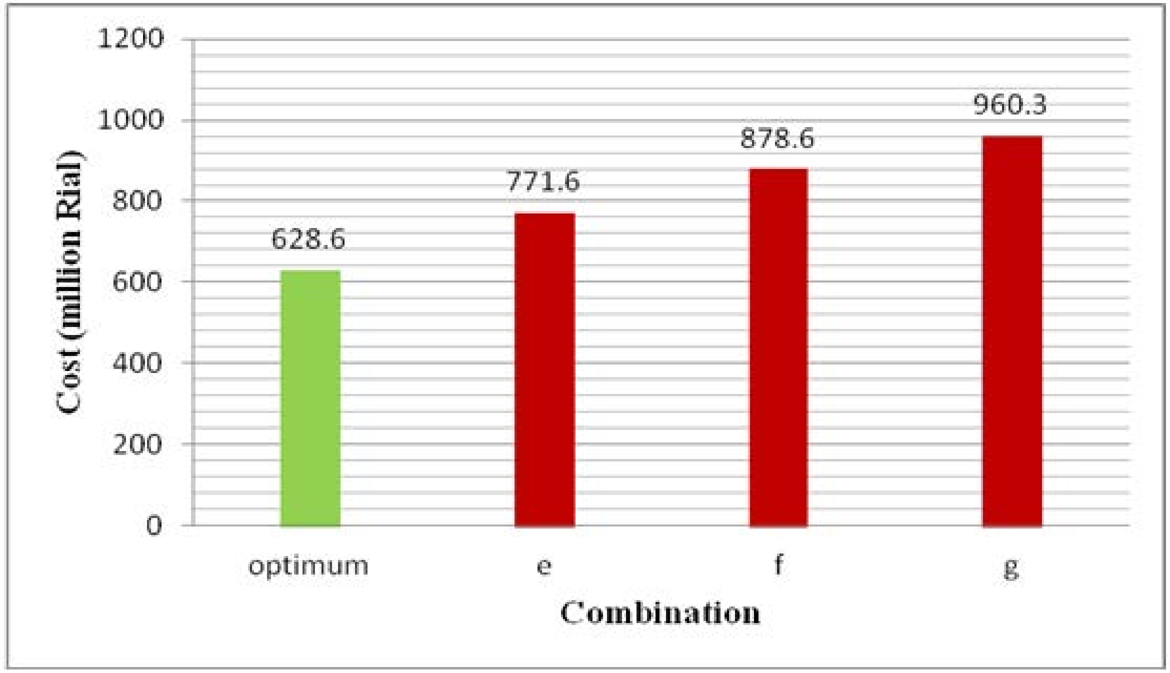
Discussion

- Random Combinations
- Do they meet the standards?

Combination	Definition	Does the combination meet standards?
a	300m^2 of 3m width swale+150m^2 of 1.5m width swale+50m^2 of bioretention+60m^2 of pond	No
b	1200m^2 of 1.5m width swale	No
c	900m^2 of 3m width swale+150m^2 bioretention	No
d	600m^2 of 3m width swale+300m^2 of 1.5m width swale+100m^2 of bioretention+120m^2 of pond	No
e	1200m^2 of 1.5m width swale+ 150m^2 of bioretention	Yes
f	2400m^2 of 1.5m width swale	Yes
g	300m^2 of 3m width swale+750m^2 of 1.5m width swale+250m^2 of bioretention	Yes

Cost Comparison for Different Combinations

- For Combinations that meet the standard



Summary and Conclusion

- A methodology was developed to find optimal solution for controlling NPS pollution caused by urbanization.
- General modelling approach involves a pollution simulation model and an optimization model.
- Effectiveness in reducing TSS, TP and TN concentration by each type of BMPs has been assessed by watershed model.
- Life cycle costs of swale, bioretention system and pond were calculated.
- Optimization procedure was used to find the optimum solution.
- Results show that, swales have been the least expensive BMPs to construct and maintain if appropriate land is available.


Thank you for Paying attention
Ecological engineering is the design of human society with it’s natural environment for the benefit of both…