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Low Impact Design through the Life-Cycle Lens

Stormwater Strategies for Pittsburgh's Urban Ecology Collaborative

SEEDS / Ecological Design Collaborative

Barton Kirk, M.S., EIT

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SEEDS
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- SEEDS is a MI based 501(c)3 non-profit research, design and educational institution
- Helping communities make appropriate decisions about built and natural infrastructure

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Outline

- Part 1 - Life Cycle Assessment of Stormwater Best Management Practices
- Part 2 - Pittsburgh's Urban Ecology Collaborative and Opportunities for Optimizing Sustainable Stormwater Strategies

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The UNIVERSITY of VERMONT

Gund Institute for Ecological Economics

Redesigning the American Neighborhood (RAN) Project

Goal: To ***quantify*** the balances among environmental, economic, and social ***costs*** and ***benefits*** for ***alternative*** stormwater management ***practices***

RAN / UNH Stormwater Center BMP Life Cycle Study: Making the Case for Stormwater Low Impact Design

Rationale

- Trend toward increased construction of stormwater Best Management Practices (BMPs)

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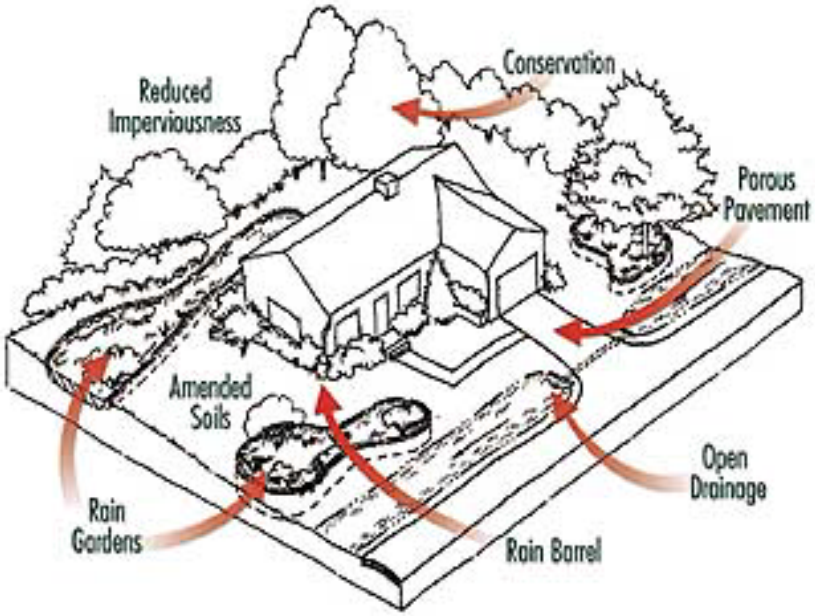
Diverging Trends



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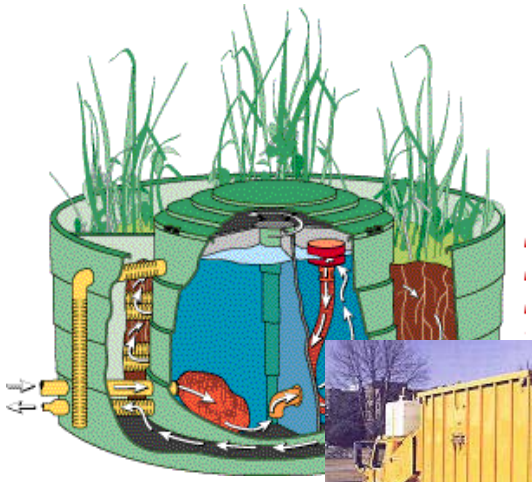
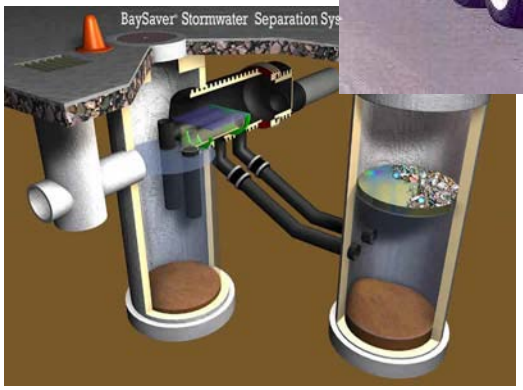
Manufactured Devices vs. Low Impact Design (LID)





Indirect Emissions and Discharges

Historical Stormwater Performance Analysis

- Effluent Quality
- Capital Cost coupled w/ Effluent Quality
- Life Cycle Cost coupled w/ Effluent Quality

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Life Cycle Assessment

- A ***quantitative inventory*** of the environmental impacts of a product, service, or process over the course of its life-cycle – “from cradle to grave”

- May include
  - ***extraction***
  - ***manufacturing***
  - ***operation***, maintenance, and reuse
  - ***disposal*** and decommissioning
  - ***transport***

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Life-Cycle Concept

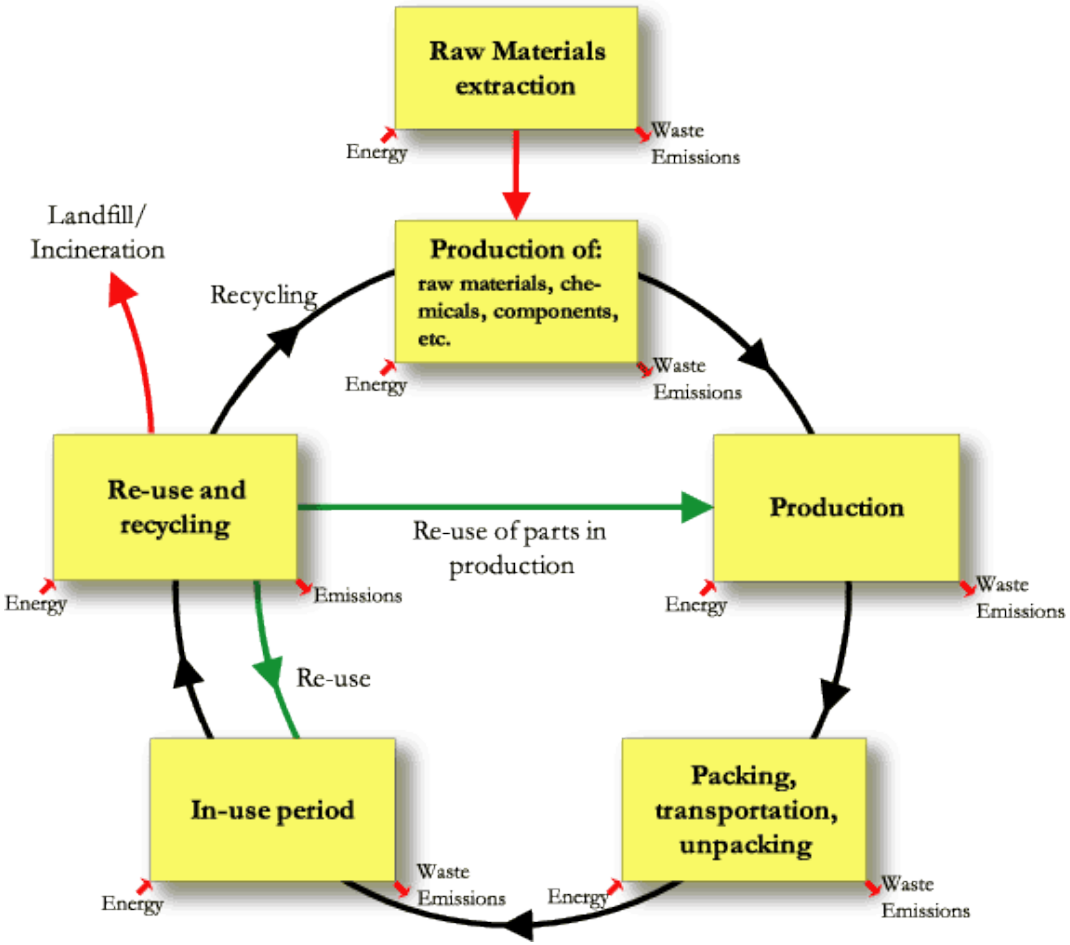

Figure courtesy of www.ecodesignguide.dk

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Life Cycle *Assessment*

- Focus on ***regional*** and ***global*** impacts

- Typical Impacts

  - Energy use
  - Material use
  - Land use
  - Global warming
  - Eutrophication
  - Acidification
  - Toxicity
  - Human health
  - Smog formation

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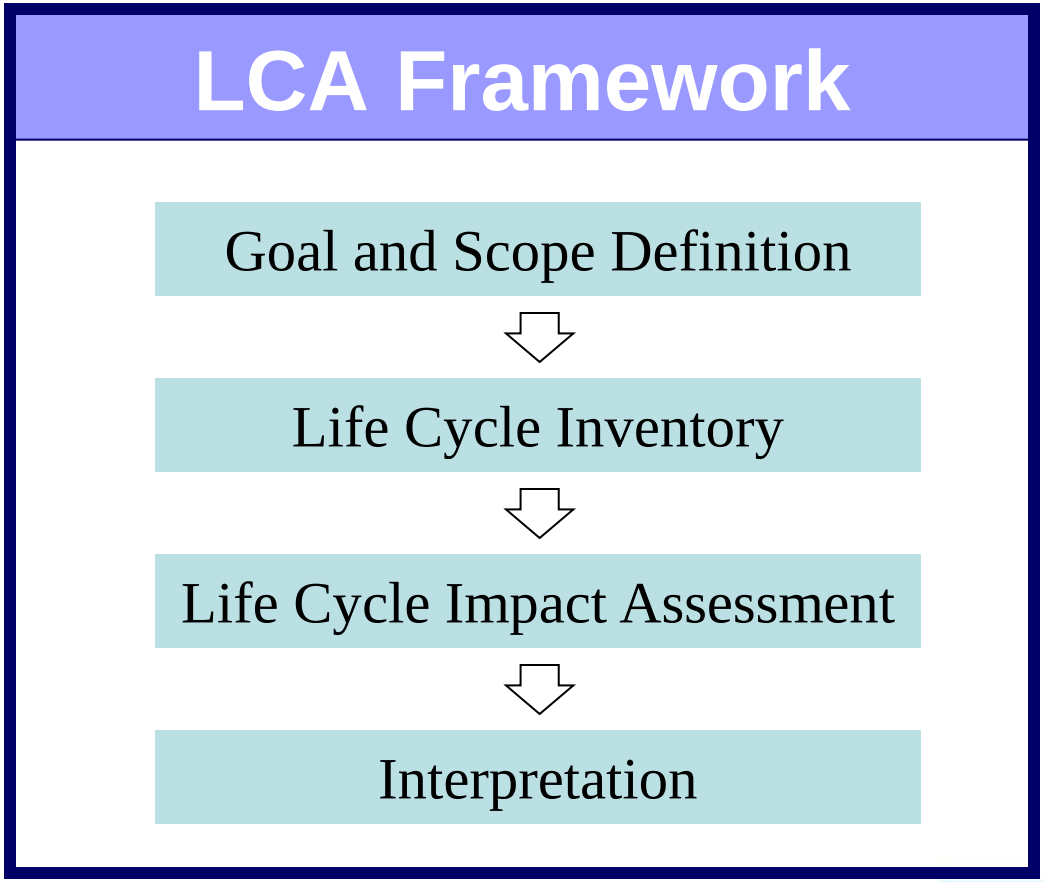
LCA Procedure



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LCA of Stormwater

- Are our BMPs resource efficient?
- What are the performance lives of BMPs?
- How does management effect the long-term costs and impacts?
- Are these sustainable solutions?

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Applying LCA to Stormwater

Impacts of providing BMP + Impacts of maintaining BMP + BMP treatment performance + Impacts resulting from BMP effects on other technical systems or services = Total Impact

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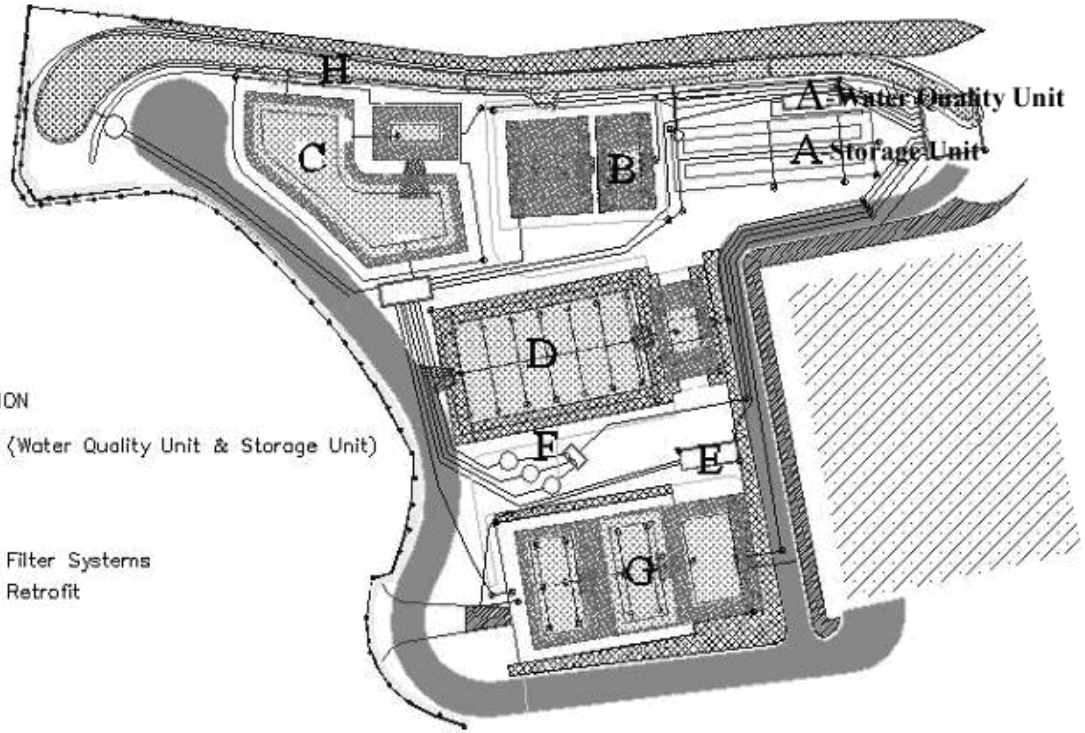
University of New Hampshire Stormwater Center

TREATMENT UNIT DESIGNATION

A – ADS Treatment Unit (Water Quality Unit & Storage Unit)
B – Surface Sand Filter
C – Retention Pond
D – Bioretention Unit
E – Aqua Swirl and Aqua Filter Systems
F – Storm Drain Manhole Retrofit
G – Gravel Wetland Unit
H – Vegetated Swale



UNH Stormwater Center BMPs

Conventional

- Retention (wet) pond
- Rip-rap swale

"Low Impact Designs"

- Bioretention
- Surface sand filter
- Gravel wetland
- Porous pavement
- Tree filter

Manufactured Units

- ADS water quality and infiltration unit
- Aqua Swirl & Aqua Filter unit
- Vortex separators
  - VortSentry
  - V2B1
  - CDS

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Scope

- Cradle to Grave
  - Design Services
  - Provision of materials
  - Construction
  - Operation
  - Maintenance (Preventive and Corrective)
  - Decommissioning and Disposal
- I/O LCA Hybrid Method
  - Process LCA based w/ missing inventory estimation
- Functional Unit
  - Stormwater management of 1 acre of impervious surface to New York State standards and NH rainfall conditions

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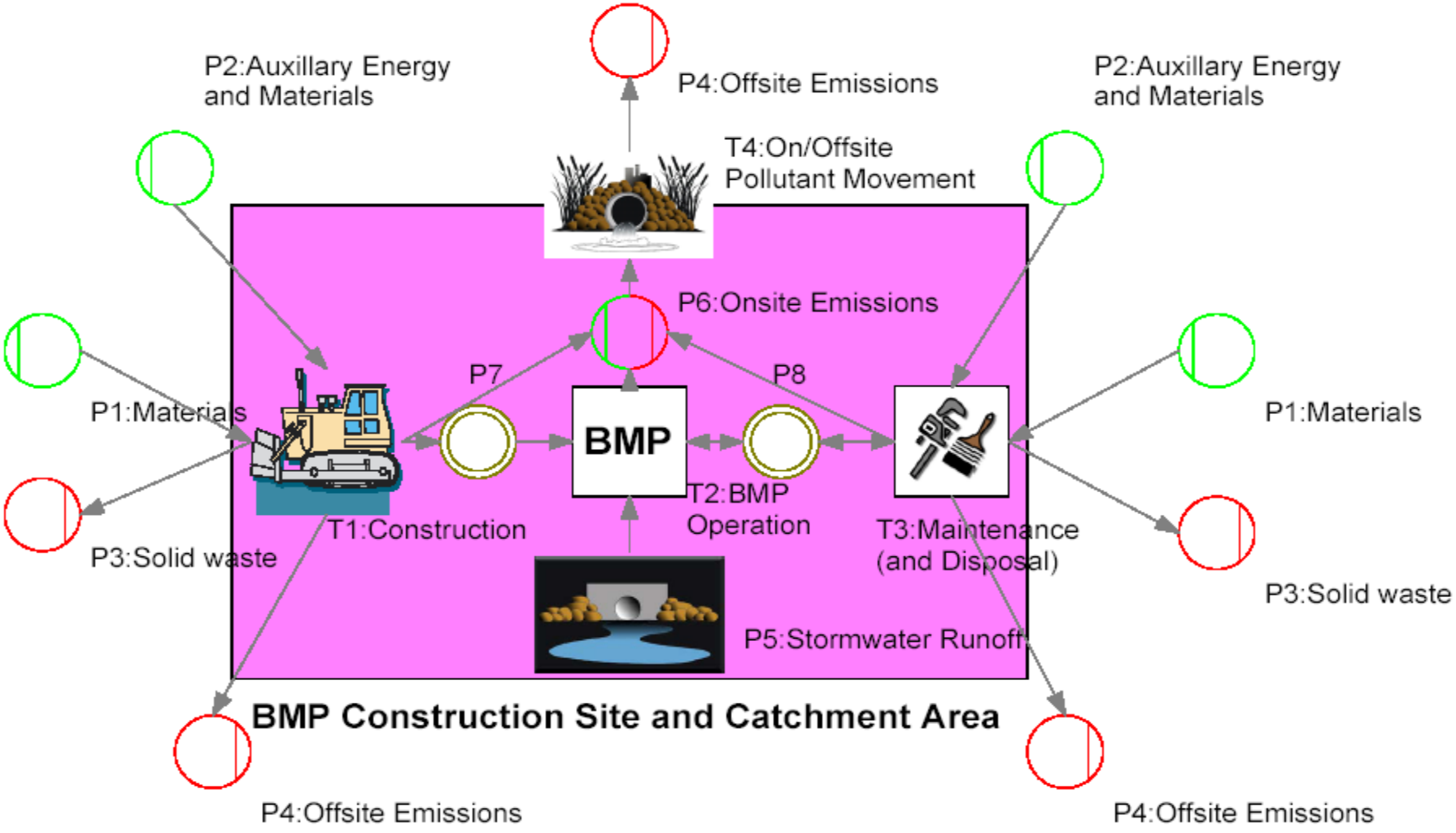
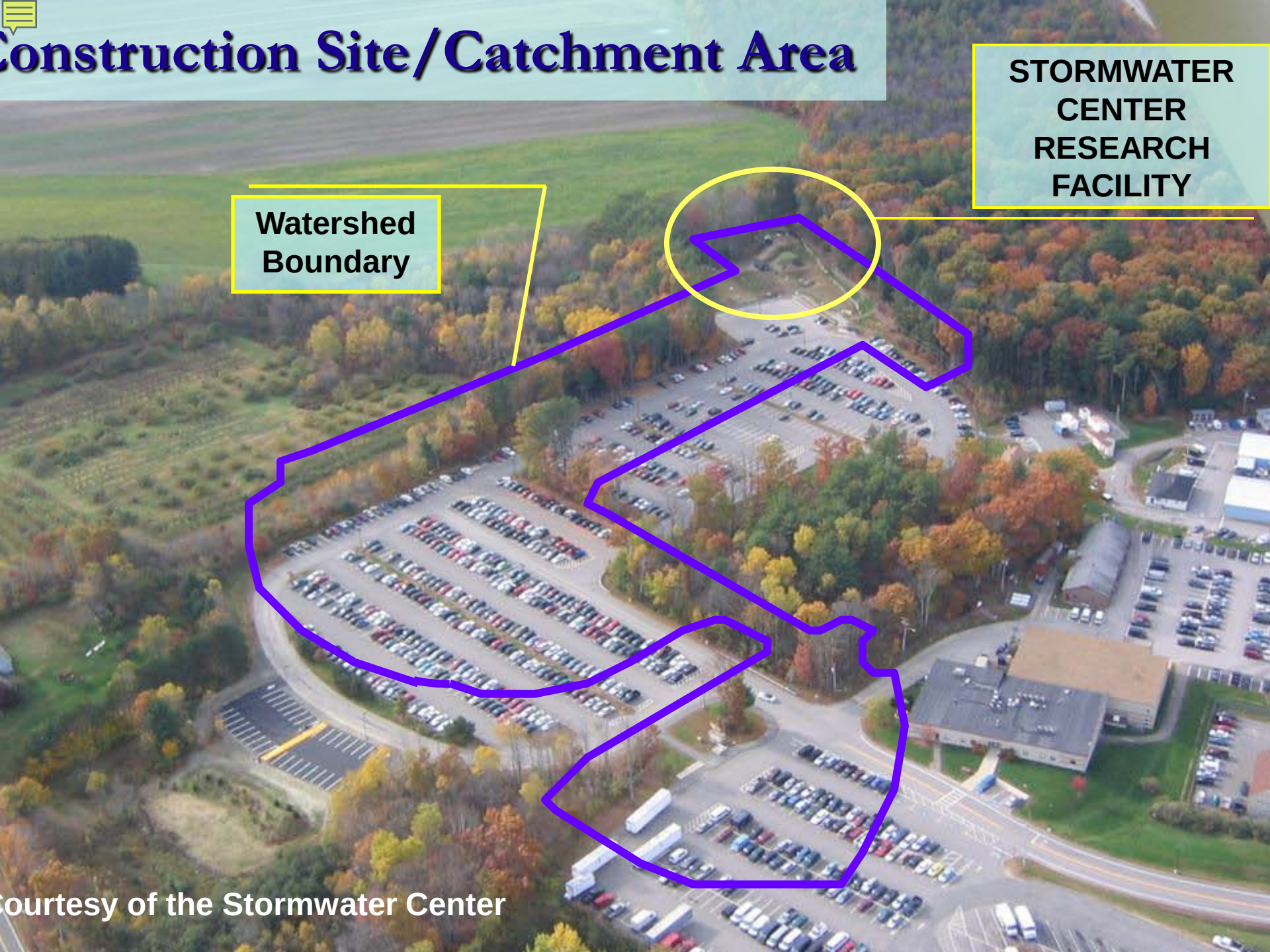
BMPs Compared

- Conventional
  - Retention (wet) pond
- Manufactured Device
  - ADS Water Quality and Infiltration Unit
- Low Impact Designs
  - Bioretention
  - Gravel Wetland

System Boundaries



Construction Site/Catchment Area



Courtesy of the Stormwater Center

LCI Calculation

- Material and Energy Flow Analysis (MFA)
- Emission and Resource Consumption Factors (EF)

LCI = MFA x EF

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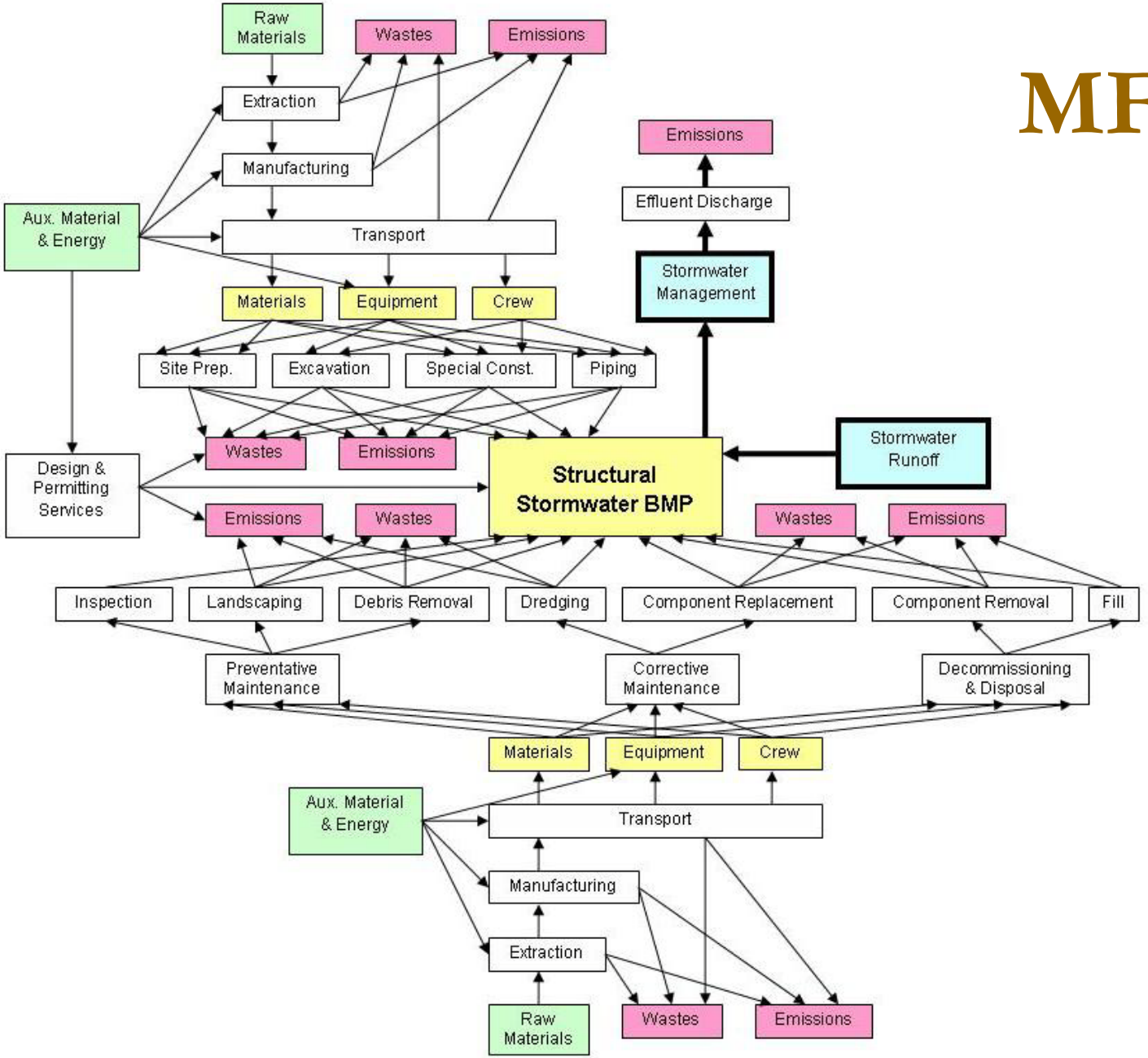
MFA


Raw Materials
Wastes
Emissions
Extraction
Manufacturing
Aux. Material & Energy
Transport
Materials
Equipment
Crew
Site Prep.
Excavation
Special Const.
Piping
Wastes
Emissions
Design & Permitting Services
Emissions
Wastes
Structural Stormwater BMP
Emissions
Effluent Discharge
Stormwater Management
Stormwater Runoff
Wastes
Emissions
Inspection
Landscaping
Debris Removal
Dredging
Component Replacement
Component Removal
Fill
Preventative Maintenance
Corrective Maintenance
Decommissioning & Disposal
Materials
Equipment
Crew
Aux. Material & Energy
Transport
Manufacturing
Extraction
Raw Materials
Wastes
Emissions

LCI Model – Data Sources

MFA Process Model

- UNH Design, Construction, & Maintenance Data
- RS Means Construction Cost & Productivity Data
- CAT Performance Handbook Engine Loading & Fuel Use
- WERF Post-Monitoring BMP Performance Study

Emission Factors

- UNH BMP Treatment Performance Data
- US EPA NONROAD 2005 Emissions Model
- US EPA MOBILE 6.2 Emissions Model
- CMU Environmental Input-Ouput LCA (EIOLCA)
- NREL US LCI Database

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Abridged BMP Life Cycle Inventory

Inventoried Substance	Units	Stormwater BMPs			
		ADS	Wetpond	Bioretention	Gravel Wetland
Local Inventory					
Resource Use					
Elec kWh	kWh	31300	3990	8020	8530
Coal kg	kg	5160	775	1610	1610
NatGas m^3	m^3	6370	794	2660	1880
Gasoline	liter	1890	1410	2180	2220
Diesel	liter	1930	1990	2550	2210
Emission, Compartment					
co2, air	mt	405	192	289	284
co, air	kg	426	254	349	342
nox, air	kg	155	144	184	190
pm, air	kg	20	27	23	35
so2, air	kg	95	26	47	45
voc, air	kg	94	36	52	51
TSS, freshwater	mt	-36.0	-21.3	-34.7	-36.1
DRO, freshwater	mt	-762.9	-56.5	-762.9	-762.9
NO3, freshwater	kg	79.6	26.6	-14.3	-37.1
PO4, freshwater	kg	-3.0	186.9	35.5	6.0
Zn, freshwater	kg	-6.1	-5.9	-6.1	-6.1
Cl, freshwater	mt	235.7	563.5	348.9	191.9
Iron, freshwater	kg	72.5	162.9	531.4	290.3

TRACI Impact Assessment

- **T**ool for the **R**eduction and **A**ssessment of **C**hemical and Other Environmental **I**mpacts
  - Developed by US EPA National Risk Management Research Laboratory (NRMRL)
  - Characterizes emissions relative to location, media, transport, fate, and effect

- Global Warming
- Acidification
- Eutrophication
- Smog
- Ozone Depletion
- Ecotoxicity
- Human Health – Criteria Air Pollutants
- Human Health – Cancer
- Human Health – Non-Cancer
- Fossil Fuel Depletion

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Life Cycle Impacts Characterized by TRACI

BMPs	Global Warming (kg CO2-e)	Acidification (H+ moles-e)	Eutrophication (kg N-e)	Fossil Fuel Depletion (MJ surplus energy)	Smog (kg Nox-e)	Ecotoxcity (kg 2,4-D-e)	HH - Criteria Air Pollutants (microDALYs)	Human Health (kg toluene-e)
ADS	73500	15900	29.9	165000	903	-12500	6.26	2680
Wetpond	38000	7720	461.0	36500	286	-12000	2.74	3400
Bioretention	64600	11000	94.6	79200	471	-12500	4.19	3650
Wetland	61200	10400	18.5	65300	441	-12500	4.06	3650

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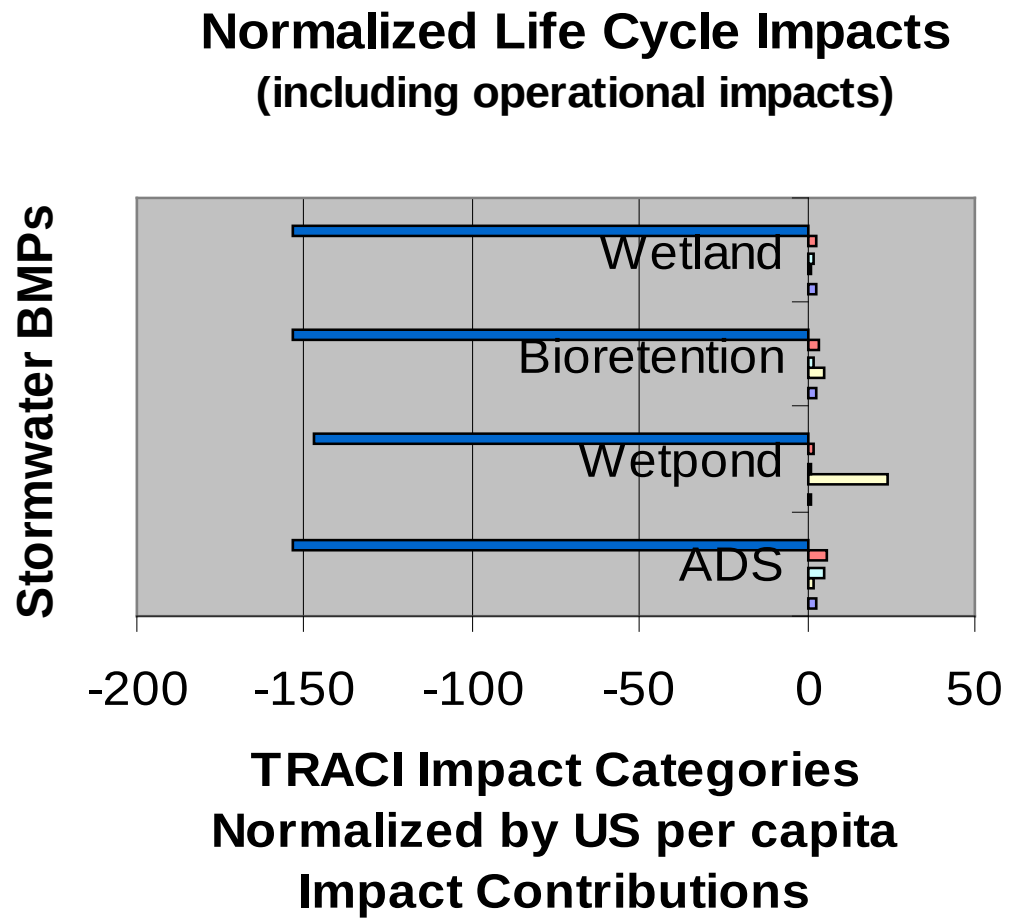
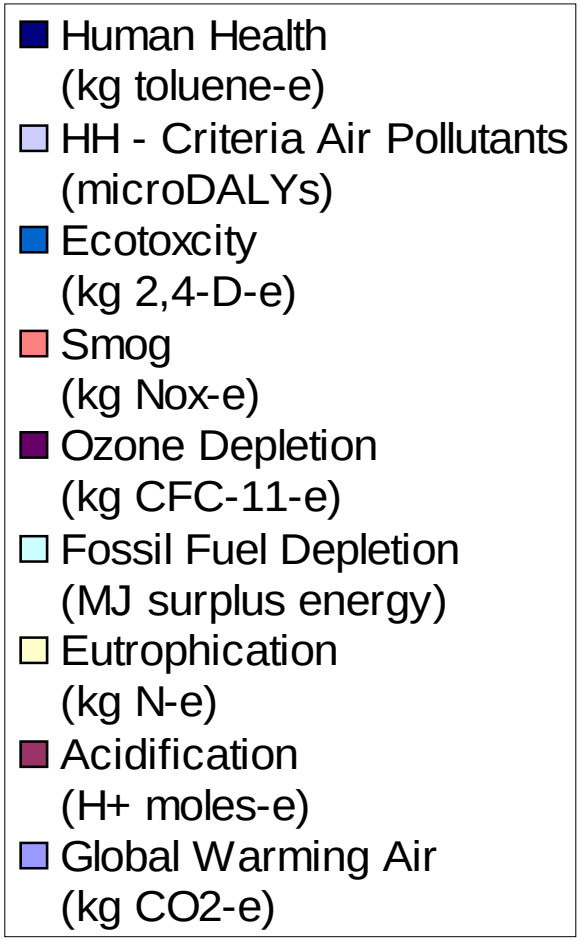
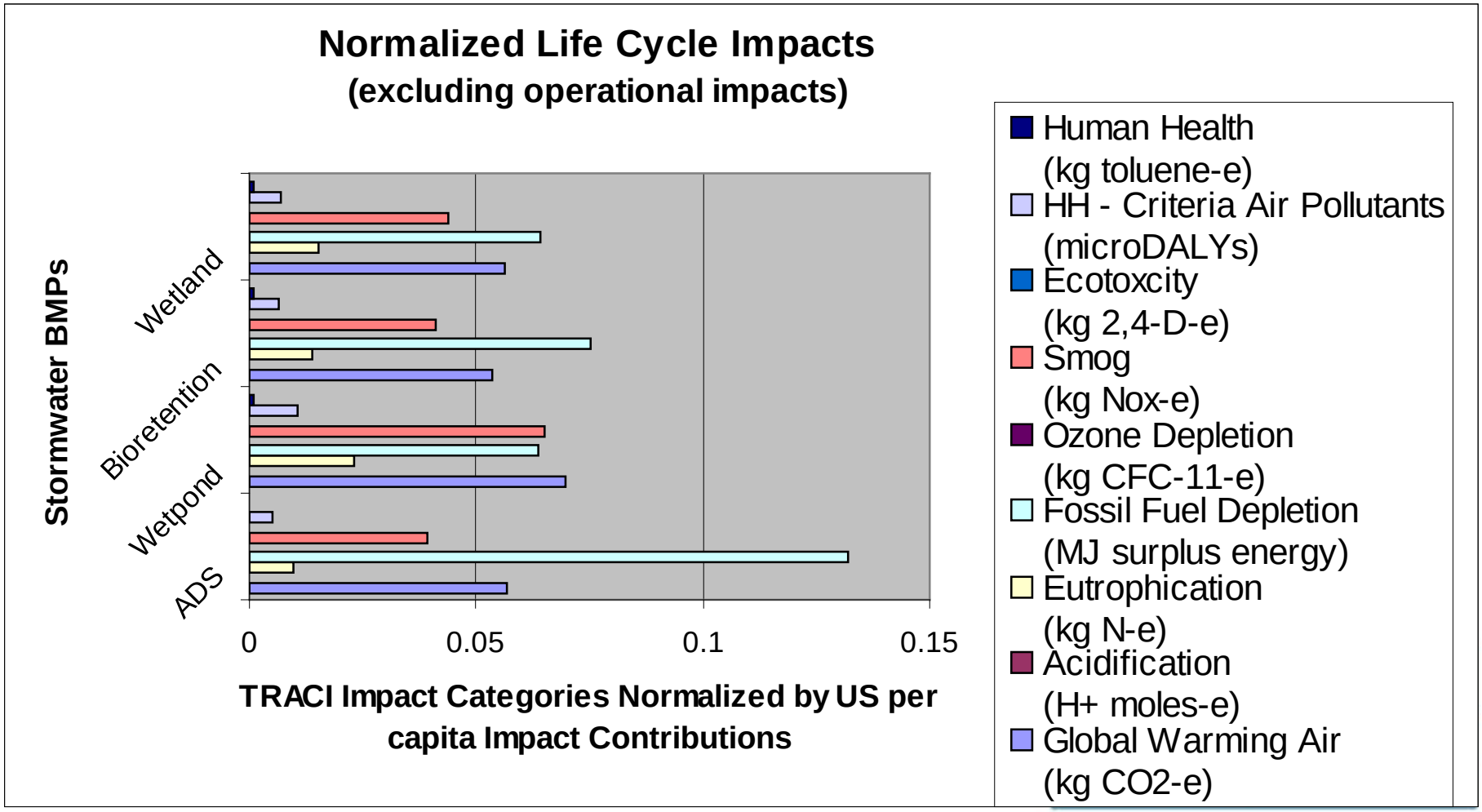
Impacts Normalized by US per capita

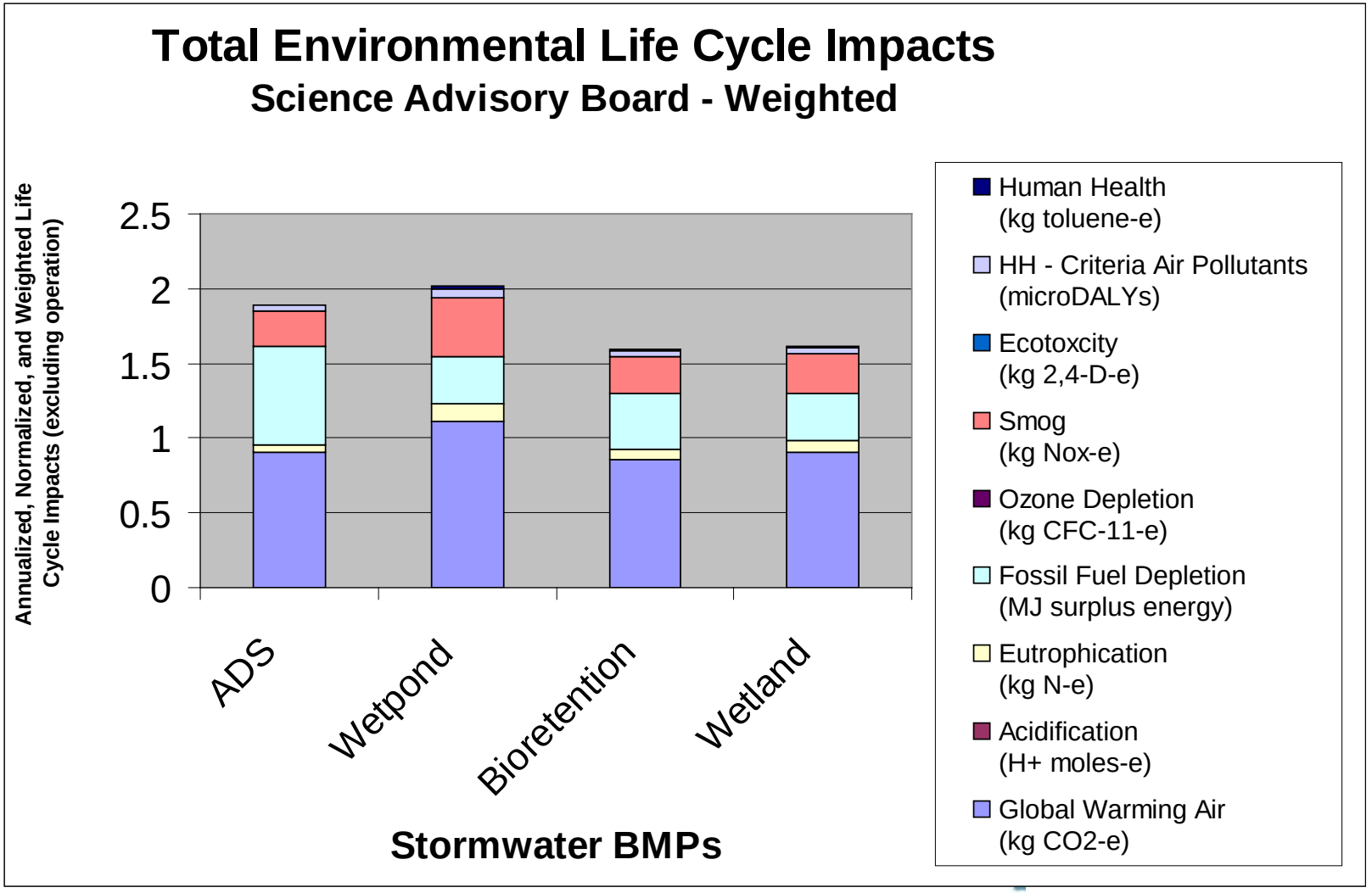




Impacts Normalized Without Operation

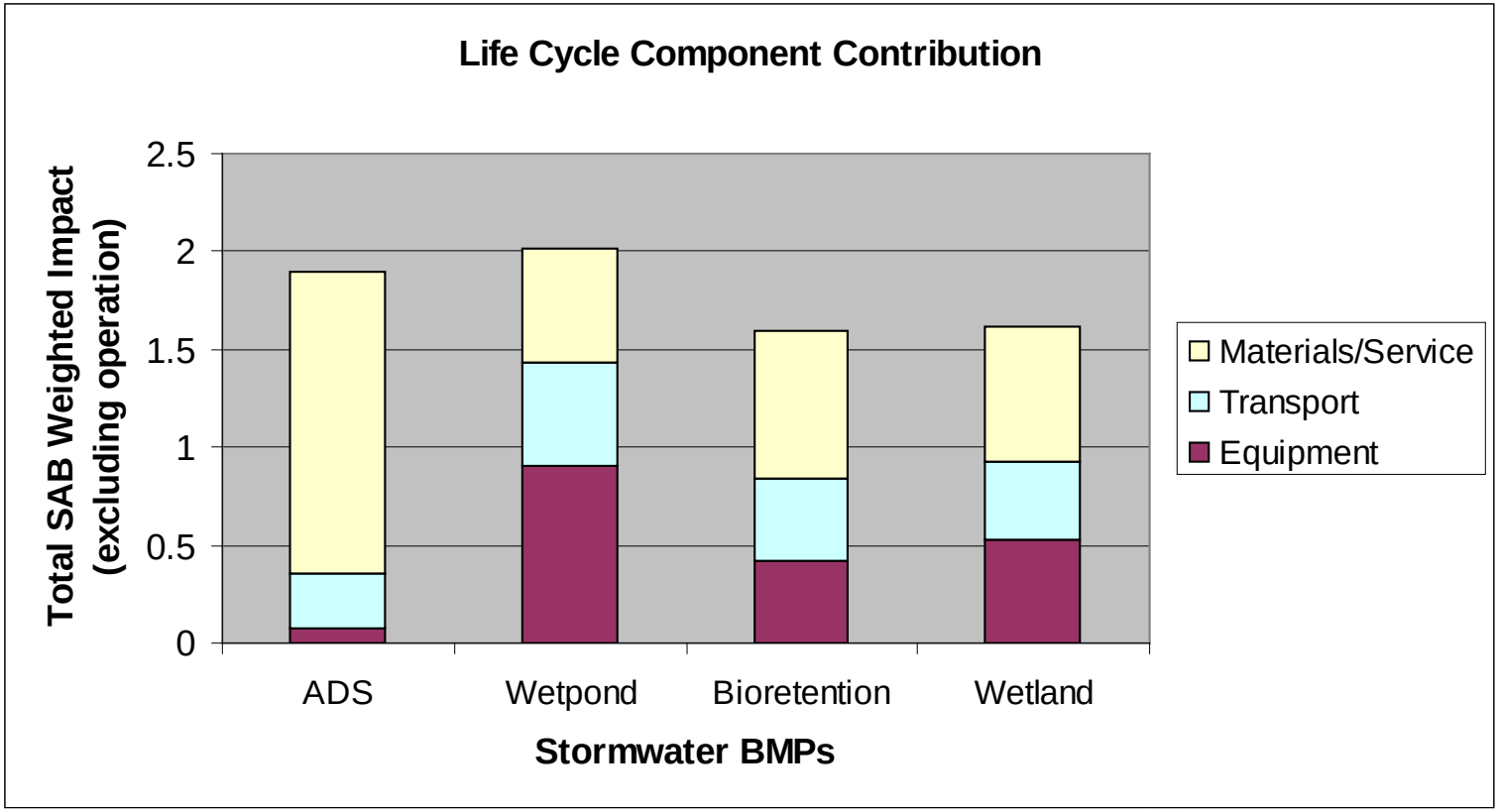


Impacts Weighted by US EPA SAB



Impacts Weighted by US EPA SAB

Component Contributions



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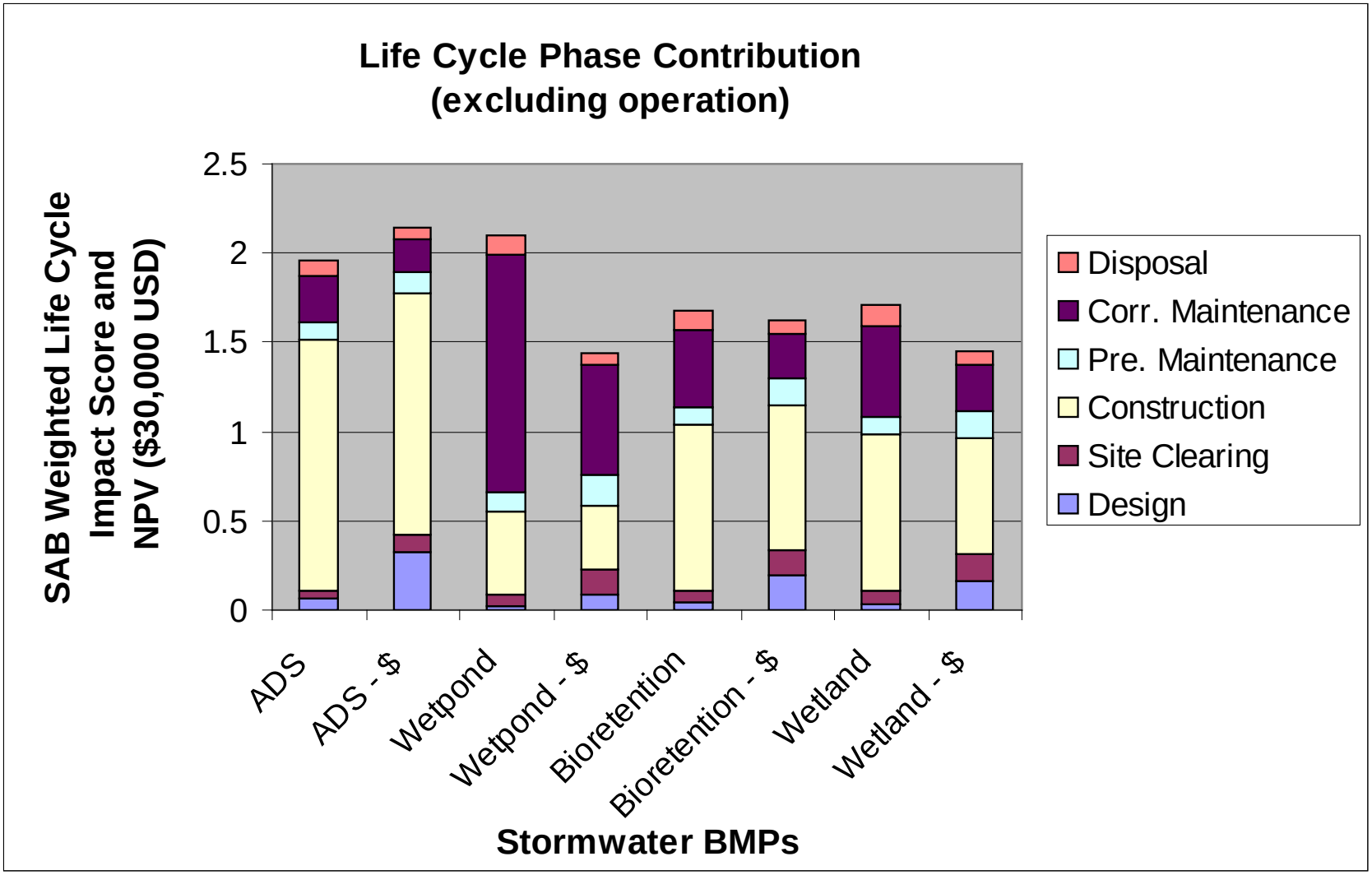
Life Cycle Cost and Impact

Phase Contributions



Limitations

- No characterization of TSS and Chloride in TRACI
- No modeling of construction erosion
- No modeling of plant and algae air emissions mitigation
- Inability to directly compare operation and other life-cycle phases

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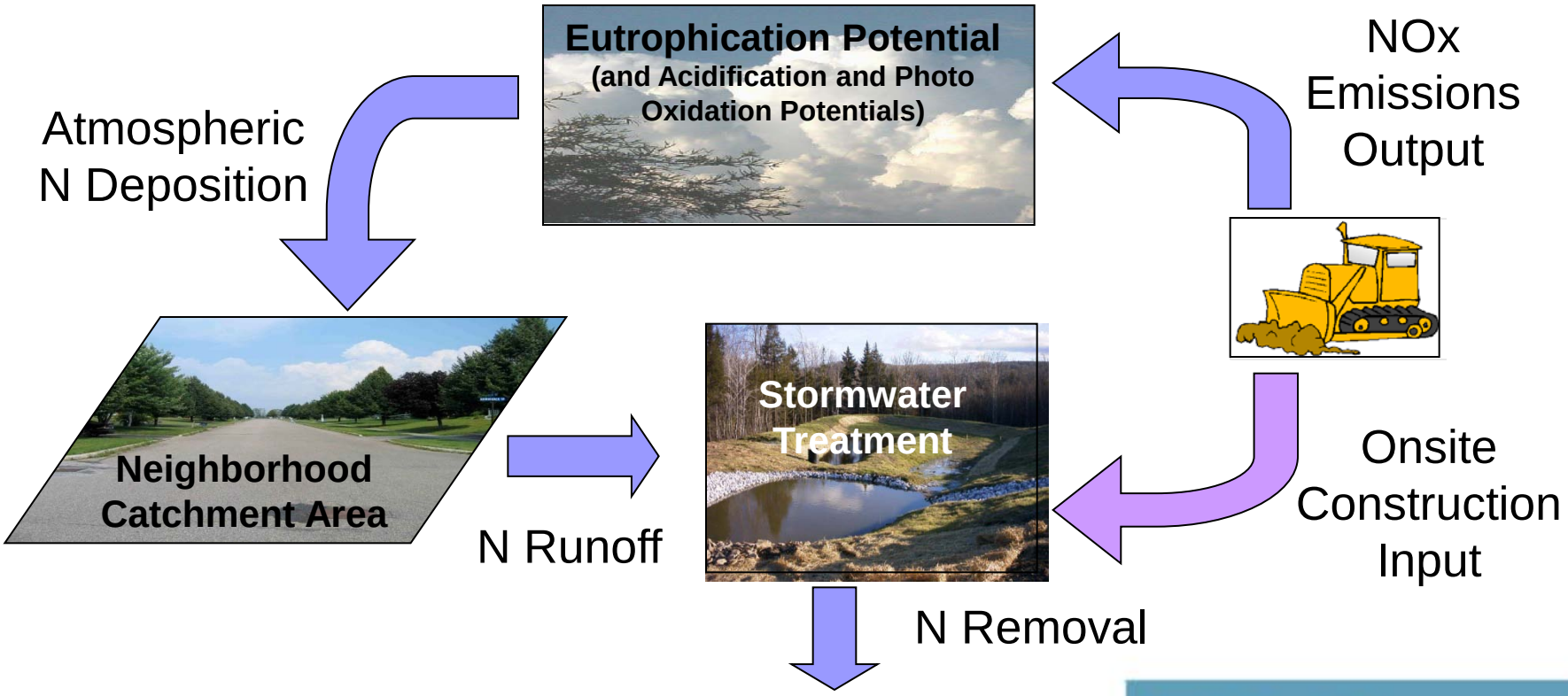
Nitrogen Life Cycle



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Environmental Payback Periods

- Example: Gravel Wetland - Eutrophication Potential
  - Operation (1yr)

    Treatment 0.297 kg N-eq removed
  - All Other Life Cycle Phases (30yrs)

    Equipment & Transport 7.70 kg N-eq emitted

    Materials 1.24 kg N-eq emitted
  - Payback Period
    - PP = Embodied Impact / Impact Averted per Year

      = (7.70 + 1.24) / 0.297 = 30 years

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Conclusions
(excluding operation)

- Life cycle cost and capital cost not good indicators of environmental impact
- Stormwater LCA most valuable in development scenario analysis not BMP comparison

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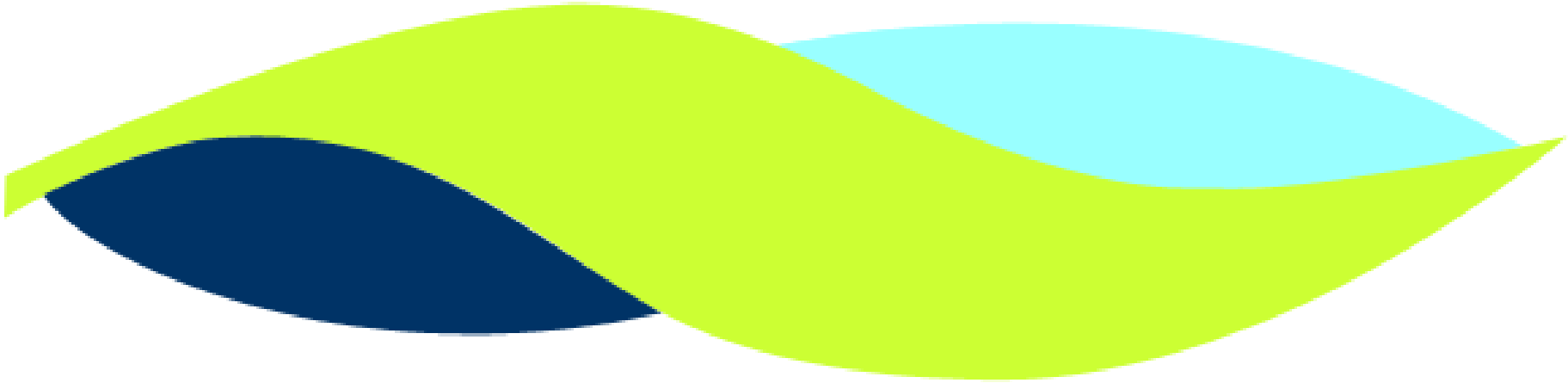
Consequential LCA Approach

Making the case for LID

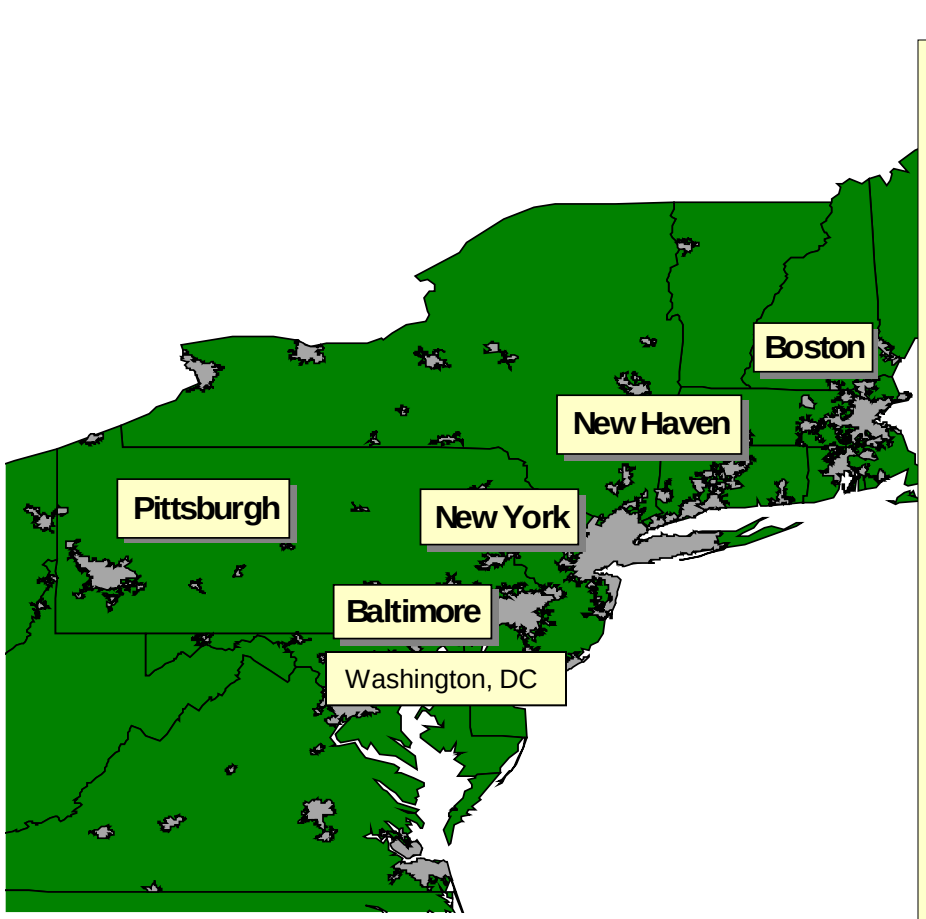


Urban Ecology

COLLABORATIVE

Cultivating healthy, safe, and vibrant cities through collective learning & united action.

The UEC is a partnership of non-profits, government agencies, & universities across the Northeast



Founding partners in other cities include:

Boston: Urban Ecology Institute, Boston Forestry Partnership

New Haven: Urban Resources Institute/Yale University

New York City: NYC Parks & Recreation Department

Baltimore: Parks & People Foundation

Washington DC: Casey Trees Foundation

New participating cities:

Providence, RI: Forestry Office

Philadelphia: Philly Green

Urban Ecology Collaborative Pittsburgh Partners currently include:

PENNSTATE College of Agricultural Sciences

PA CLEANWAYS

Pittsburgh PARKS CONSERVANCY

Conservation Consultants, Inc.
Bringing Resources Together

NINE MILE RUN WATERSHED ASSOCIATION

SCA

GROW PITTSBURGH

TreeVitalize
A partnership to restore tree cover in the Pittsburgh region

Community Education & Restoration

- Urban Eco Stewards
- MERGE Forum
- Green Education Movement
- Vacant Land Restoration

UEC Research Working Group

- Growing Interest in Green Infrastructure
  - PPC
  - NMRWA
  - FoPUF
  - WPC (TreeVitalize)
  - PSU Coop-Ext / URA
- Intention to develop a strategic plan for stormwater intervention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U.S. DEPARTMENT OF COMMERCE