

STEP 1:  
STORMWATER IS THE COMMUNICATOR

# RIVERS IN SYNERGY

A WATERFRONT VISION FOR PITTSBURGH'S OHIO BASIN

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# RIVERS IN SYNERGY

A WATERFRONT VISION FOR PITTSBURGH'S OHIO BASIN

STEP 1: STORMWATER IS THE COMMUNICATOR



# Contents

<b>Section I. Introduction</b>	<b>page 06</b>
A Waterfront Vision for Pittsburgh's Ohio Basin	
Stormwater is the Communicator	
<b>Section II. Water a Precious Resource</b>	<b>page 07</b>
Water in our Culture	
Water in Cities	
Water System Ecology	
<b>Section III. The Current Situation in Pittsburgh</b>	<b>page 10</b>
Hydrological Basics	
Analysis of Problems	
Stormwater at the Waterfront	
The Bigger Picture	
<b>Section IV. Design Goals and Decision Criteria</b>	<b>page 18</b>
Urban Context	
Ecological/ Habitat System	
Stormwater Management	
<b>Section V. Sustainable Development - Guideline</b>	<b>page 26</b>
<b>Section VI. Sample Project Area A.C.01</b>	<b>page 66</b>
<b>Section VII. Steps into Reality</b>	<b>page 77</b>
Guiding the Process	
Public Excitement (Outreach)	
Public Involvement	
<b>Section VIII. Glossary and Treatment Tools</b>	<b>page 79</b>
Primary Functions of Stormwater Management Systems	
Treatment Tools	
Levels of Stormwater Runoff Pollution	

Pittsburgh's waterfront gives the impression that it is caught in a Snow White sleep. Glimpses of its potential blink through when someone takes a moment to look down to it from above or takes time (and is up to the challenge) to walk along the waterfront, squeezed between streets and trail tracks, crossing heavy traffic bridges and following overgrown and waste sprinkled river banks. It will take courage and a strong vision to awaken this forgotten pearl to a bright future.

Many ideas and concepts have been developed in the past and some projects have already been realized, like Allegheny Riverfront Park and Point State Park. However this is not enough. The waterfront itself is only the starting point and catalyst for development that must be more integrated and spread out into the city. The idea of a river town must become alive in the minds of Pittsburghers and then the idea will step by step grow into reality. Stormwater is certainly the perfect tool to start creating the connection of the city with the river. Surface run-off cleansed, reduced and designed in a compelling, functional and traceable way has the ability to tell a story ....

... a story of a new approach and understanding the needs of people, of the city, of flora and fauna. Water brings people together. It is an intuitive act to rest or gather at a fountain when passing by one. This deeply incorporated connection to water can be a starting point of a more conscious reconnection.

The individual interests of various stakeholders and property owners for Pittsburgh's waterfront are diverse. There is just one issue all can agree upon and understand, which is the need to handle and treat stormwater in a different way. It is agreed that water management in urban areas is not only a necessary infrastructure, but it is also a valuable resource and opportunity to provide an aesthetic and cultural experience to the city. It provides the possibility to reintegrate people, the city, flora and fauna.

Let's talk about stormwater....

In developed countries water has to fulfill many purposes: drinking supply, disposal of waste, all kinds of cleansing, recreation, play, etc. It is easy and almost endlessly available and used without much thought. Only few ask where it comes from and where it goes, once water is used.

This was different in the past. In many cultures water was an integrated and spiritual basis for their lives and not reduced in its purposes. Our idea and aim is to reintegrate water as a living aspect of our culture. We know that water is special and even nowadays still a scientific unrevealed wonder. Water needs to be reintegrated in our daily life and culture in a respectful, creative and humorous way.

Pittsburgh now has the chance to create a different and sustainable storm water management system and a new relationship to its rivers. It will be very important to integrate the wishes and dreams of the Pittsburghers. For us this project has to be a intensive collaboration between the design team, the client, the stakeholders and the city of Pittsburgh.

Traffic, social, green, urban planning

and other infrastructural needs have to be balanced. We see stormwater as the central element, as the starting point and communicator between these aspects.

As the waterfront is redeveloped, the river should be „buffered“ from impacts of human development. Past damages should be healed in the landscape and a new understanding and awareness should begin. The overall goal is to restore the quality and health to the river from which we drink.

Guiding principles for this may be:

- Redesign the Sewer System to meet the natural water balance for Pittsburgh
- Reconnect the city and it's people to the rivers/nature
- Reestablish habitats (flora/fauna)
- Reduce Contamination of the Rivers



Section II. Water a Precious Ressource





How do we treat water in our cities today? In many urban regions only two out of every ten drops of water reach the soil and recharge the aquifer. The rest is constricted in a labyrinth of underground piping, where there is no space and no time for rest and contact with the earth, plants, animals and people. We treat rainwater like a menace which should be hurried out of sight and out of mind. This results in a myriad of problems such as flooding, pollution and aquifer depletion. Water management in urban areas is not only a necessary infrastructure, it is a valuable resource and opportunity to provide an aesthetic and cultural experience to the city while furthering environmental awareness and citizen interest and involvement. Pittsburgh has now the chance to make a difference!

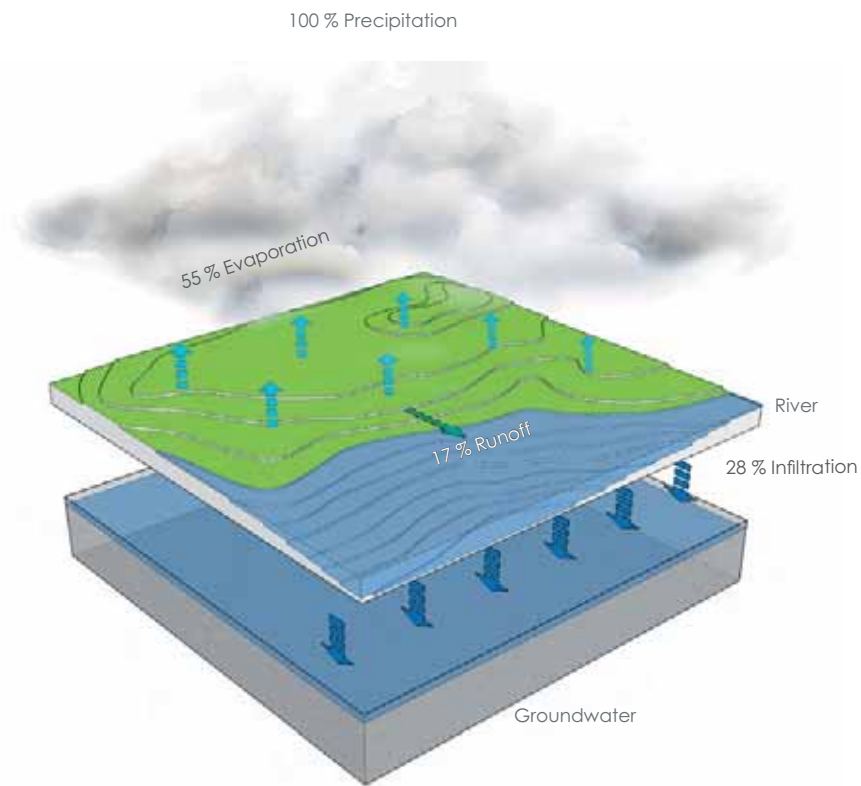




Rainwater is a treasure. It is the only water supply we know that refills all water sources on earth. Water gives life to the complex and dynamic web of minerals, plants and animals which compose a habitat. In reintegrating on-surface stormwater management elements, it is vital that there is also a place for natural habitats. Nature is not the opposite of the city: natural processes can be translated and integrated into a vibrant urban areas.



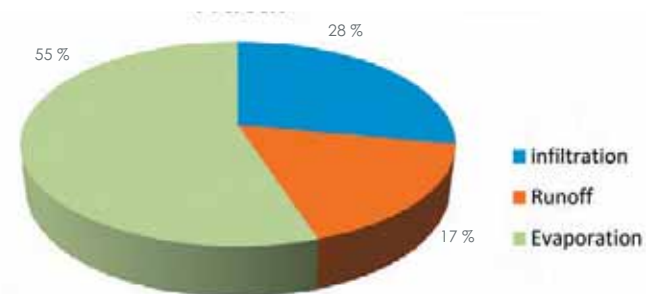
## Natural Waterbalance (annual)



The annual hydrological cycle for an undisturbed area in the Allegheny Plateau creates the benchmark for the new stormwater management strategy.

Imagine a one acre parcel of land that receives 38" per year of rainfall. Most of the water infiltrates and returns as evapotranspiration (21") and a small amount runs off (6.5"). Perhaps 10.5" per year infiltrates. This is what recharges groundwater and keeps streams running. (Cahill Associates Dec. 2005)

Natural waterbalance (annual)  
Hardsurface 0 % (Estimation)



Existing water balance (annual)  
Hardsurface 90 %

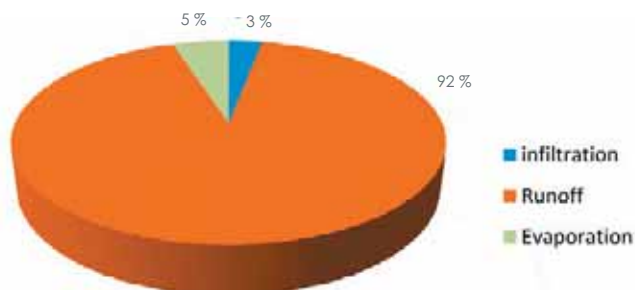
Runoff Increase from impervious areas:

- Natural runoff – 6.5"/yr.
- Impervious runoff – 37"/yr.
- Increased Runoff – 30.5"/yr.
- 2.5 FEET OF RUNOFF FOR EVERY SQUARE FOOT OF PAVEMENT/ ROOF

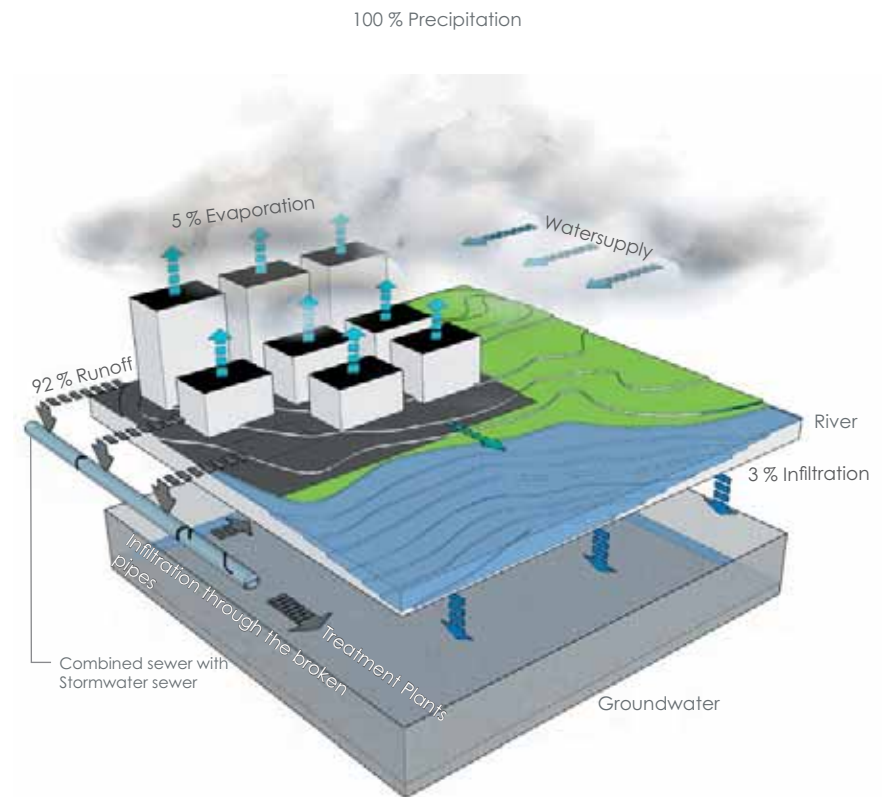
The infiltration and groundwater recharge is strongly reduced by regraded and compacted soils.

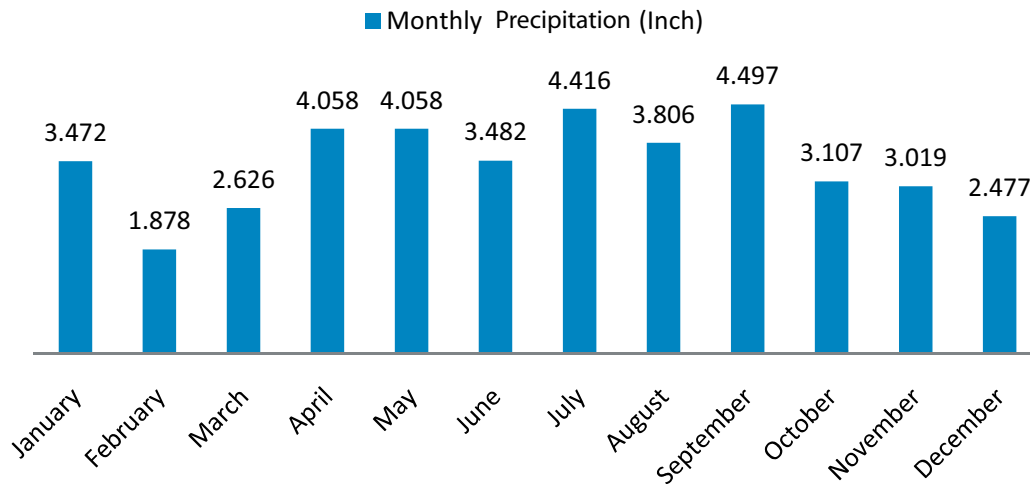
The evapotranspiration is only possible on green grass and a few trees.

Existing waterbalance (annual)  
Hardsurface 90 % (Estimation)



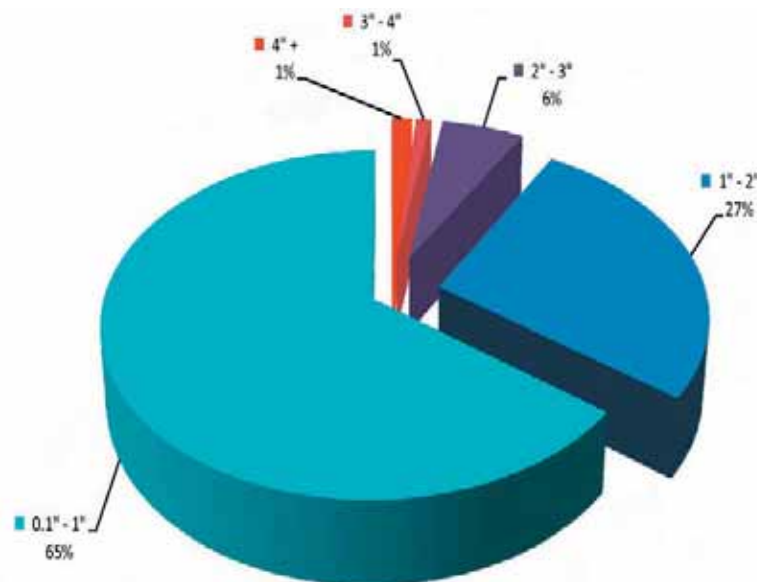
Section III. The Current Situation in Pittsburgh





The yearly precipitation averages ca. 40 inches. There is a relatively constant distribution of precipitation throughout the year. Therefore most rainfall events have a relatively low intensity.

Average annual rainfall distribution of Harrisburgh: ca. 90% of all storm events produce a precipitation volume with less than 2 inch, and 65% with less than 1'. (Cahill Associates Dec. 2005)



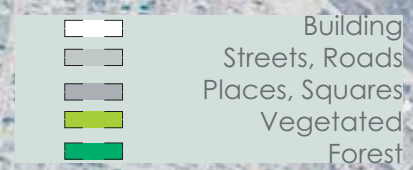
**Storm Size (Intensity Inch) and its distribution  
(Rainfall Vol.%) within 77 years** (Cahill Ass.)



Birdseye view of the rural Allegheny Plateau shows a hilly landscape mostly covered with trees, some fields and a lot of valleys. Little streams were formed by glaciers runoff. Nearly 100% is covered by green land.

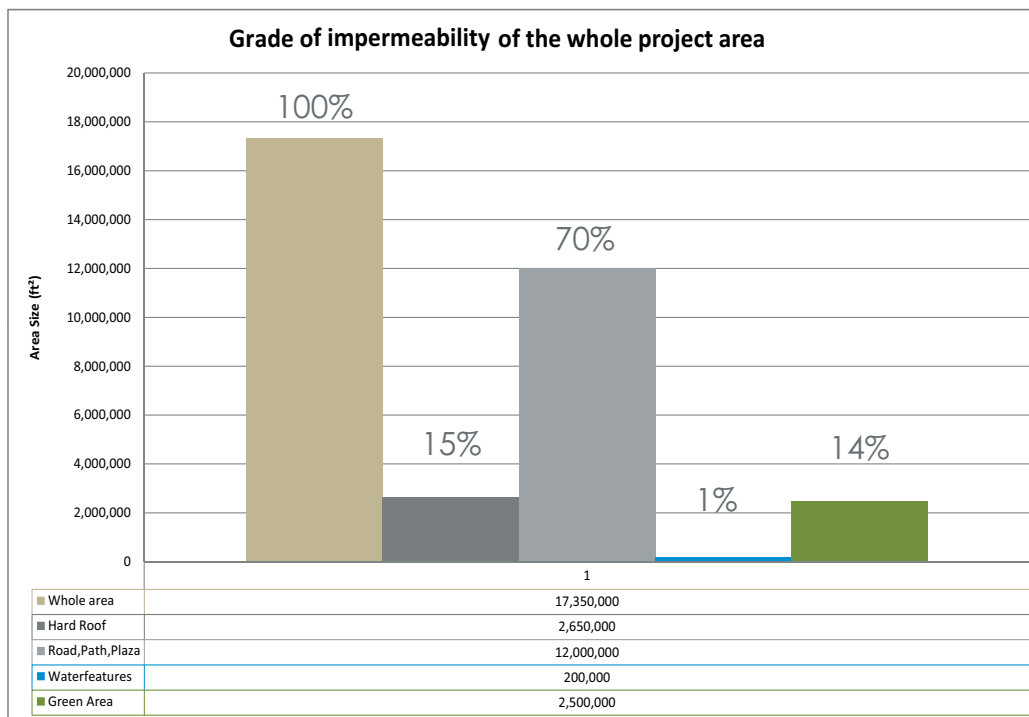






The project site area covers ca. 160 hectare. Seventy percent of this area is covered by roads and parking lots, fifteen percent by roofs. The rest of the fifteen percent is mostly green area, concentrated on the hilly catchment area of Saw Mile Run. There is no doubt that the water balance has been totally destroyed from decades of development. Nearly a third of the County's

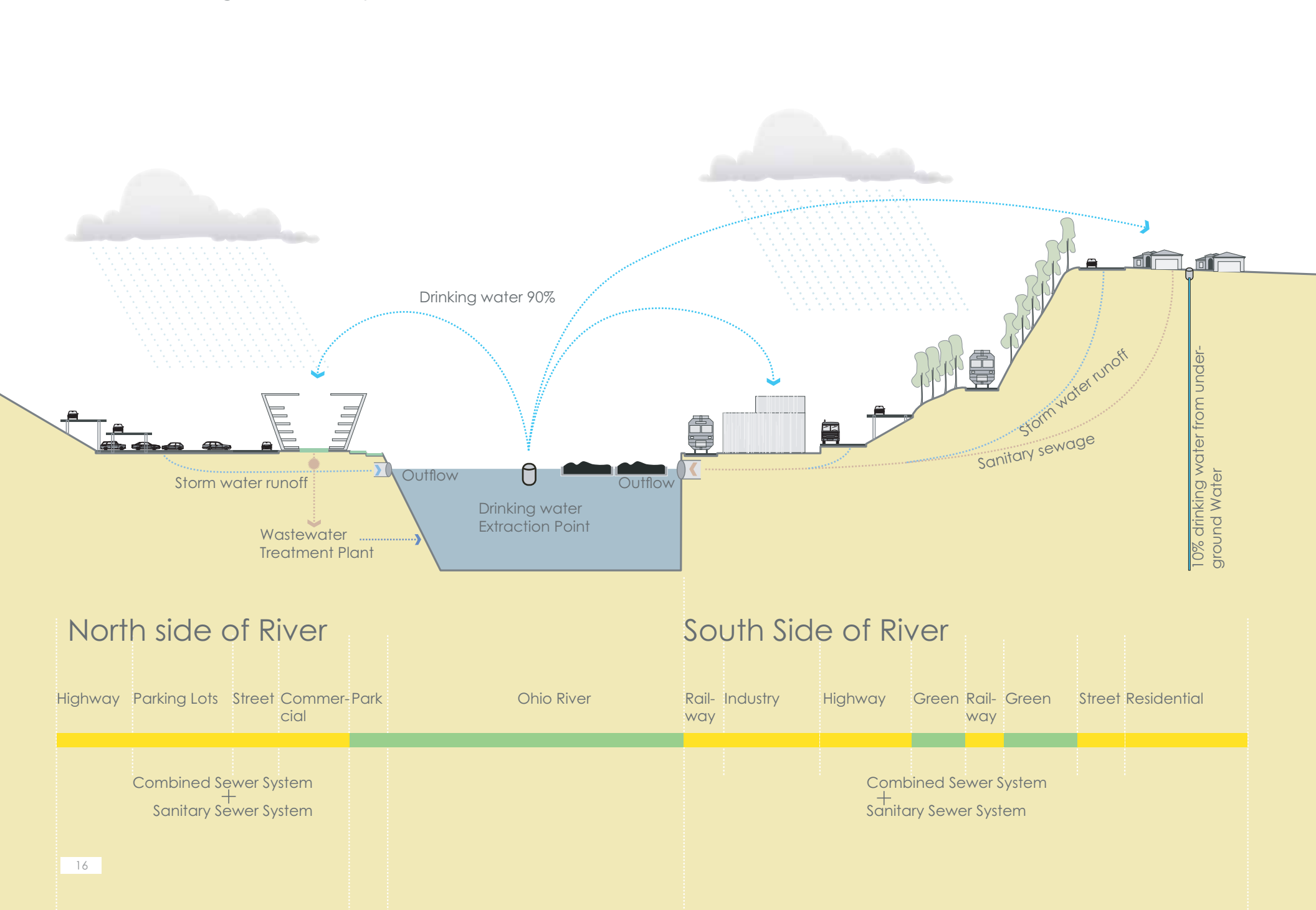
municipalities are served by combined sewer systems. The existing combined sewer system (CSS) is heavily overloaded. One tenth of an inch of rain is enough to cause raw sewage to overflow into the county's rivers and streams. Additionally storm water runoff from urban areas which flow out in a separate storm sewer system can contain significant concentrations of harmful pollutants, contributing to adverse water quality impacts in receiving streams. Effects can include such things as beach closures, shellfish bed closures, limits on fishing and limits on recreational contact in waters that receive storm water discharges. Contaminants enter storm water from a variety of sources in the urban landscape. The large majority (90%) of public drinking water supply comes from the Three Rivers, Monongahela, Ohio, and the Allegheny. The costs for maximization of the storage, for maintenance of the underground sewer system and on the other end purification of drinking water will rise from year to year.





Section through the river system

Stormwater at the Waterfront



## Siteplan of existing sewer system and its unloading points into the river

- Combined Sewers
- Interceptor Sewers
- Sanitary Sewer
- Stormwater Sewers
- Overflow Sewers
- Storm Water Outflow Point
- Combined Wastewater Overflow Point

The Bigger Picture

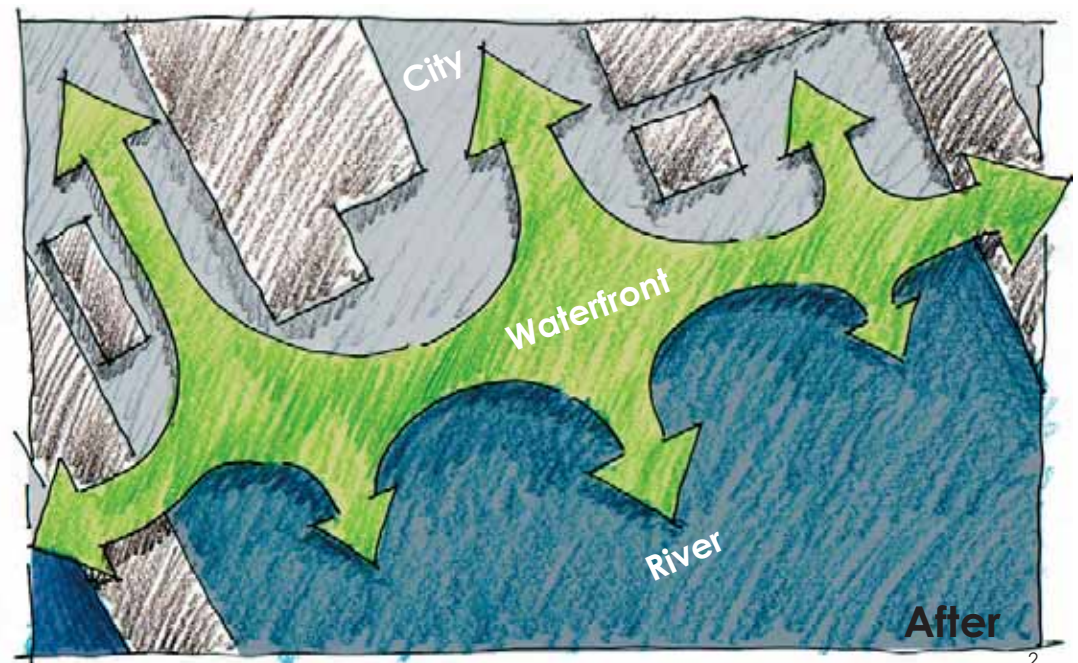
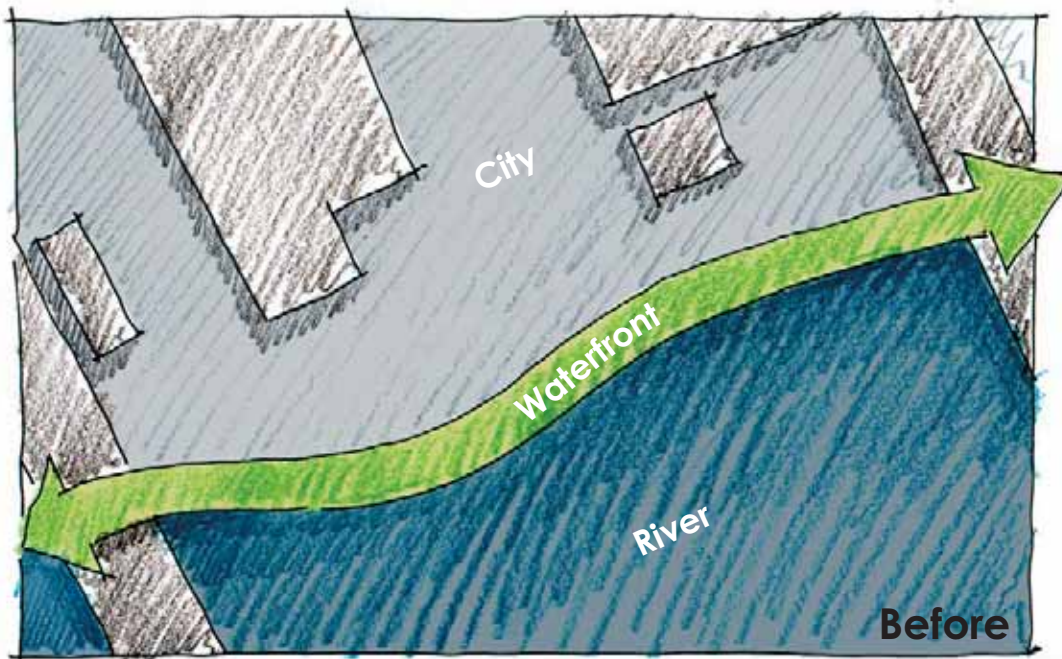
ALCOSAN, the county's largest provider, has at least 450 combined and separate sanitary sewer overflow structures from which untreated sewerage is discharged into local waterways during wet weather.

Section III. The Current Situation in Pittsburgh









The renewing of the Waterfront opens the opportunity to reconnect the cityscape and the river, to integrate green structures and daylight to the underground drainage system and natural streams. It enriches the variety of natural structures within the city and gives a livable environment back to people.



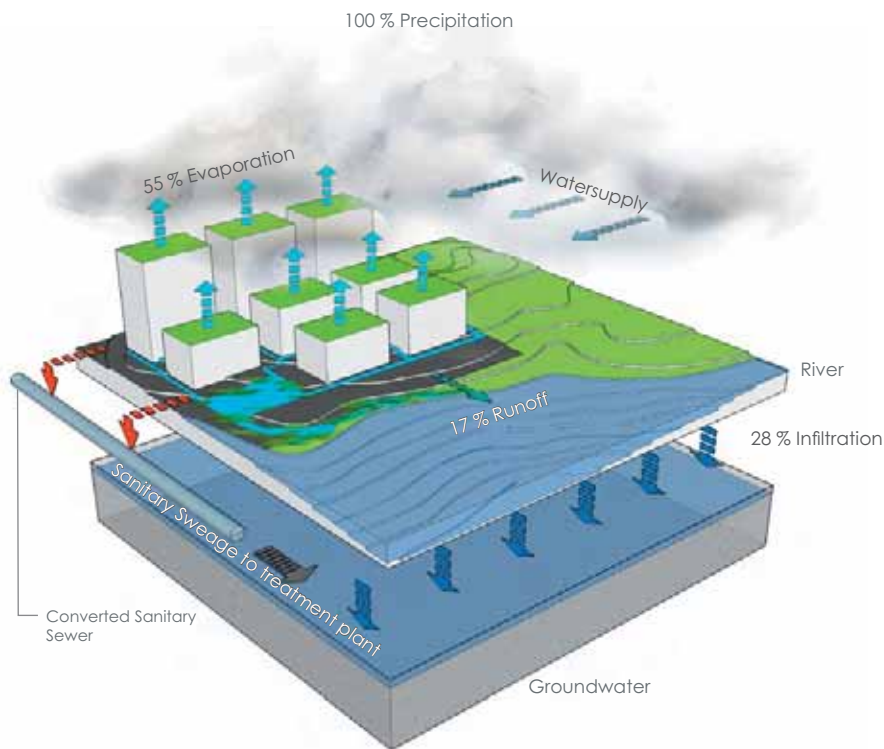




Natural structures open new ecological niches for flora and fauna within the city and even for the river. The Paddlefish is a symbol for the repressed nature. He needs shallow and temporary flooded wetlands adjacent to the river for his reproduction. Biological structures like bio-engineering techniques for shoreline stabilisation will offer new habitats.

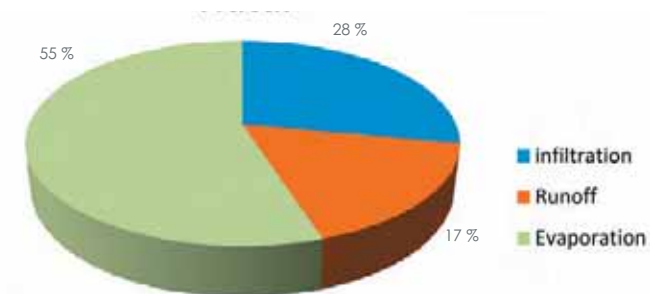
# Stormwater Management

General Goal of water balance (annual)  
Back to Nature Balance



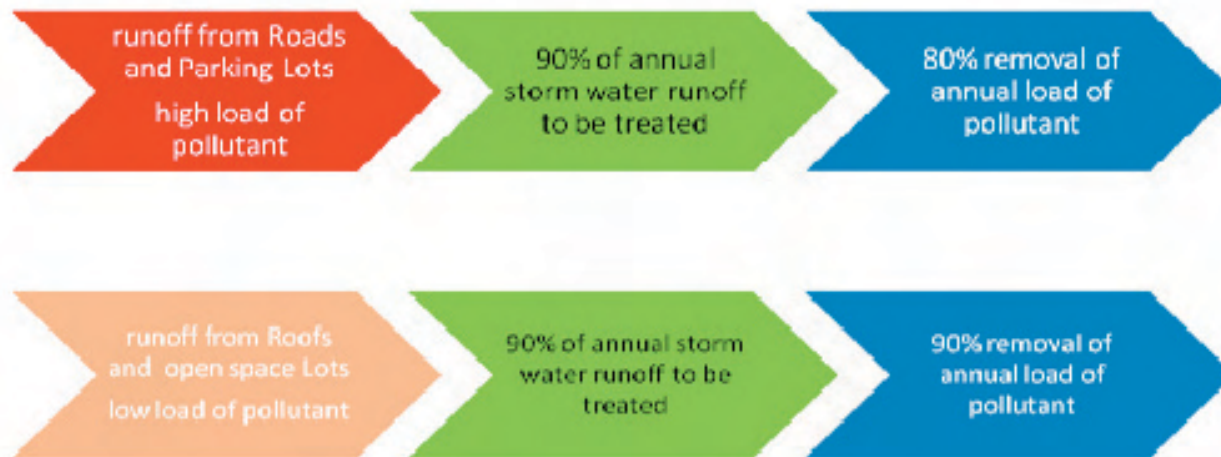
The design for the Pittsburgh's Ohio Basin and the neighborhood residential development proposes a surface stormwater management system which closely mimics the flow of water in the natural landscape. Using this type of system will allow stormwater to first be retained, cleansed and infiltrated long before excess amounts overflow into the Main River. Such a project, with its sustainable stormwater management system, will be a major step forward in mitigating the impacts of stormwater on Pittsburgh City's urban areas as well as the environment and will act as an example for the sustainable development of architecture and landscape in the future.

General Goal (annual)  
Hardsurface 70 % (Estimation)





## Storm Water Quantity – Design Goals:



### •Pollution Reduction:

Pollutant of concern include:

- suspended solids
- heavy metals
- nutrients (nitrogen and phosphorus)
- Organics (oil, grease, hydrocarbons, pesticides, fertilizer)
- floatable trash and debris

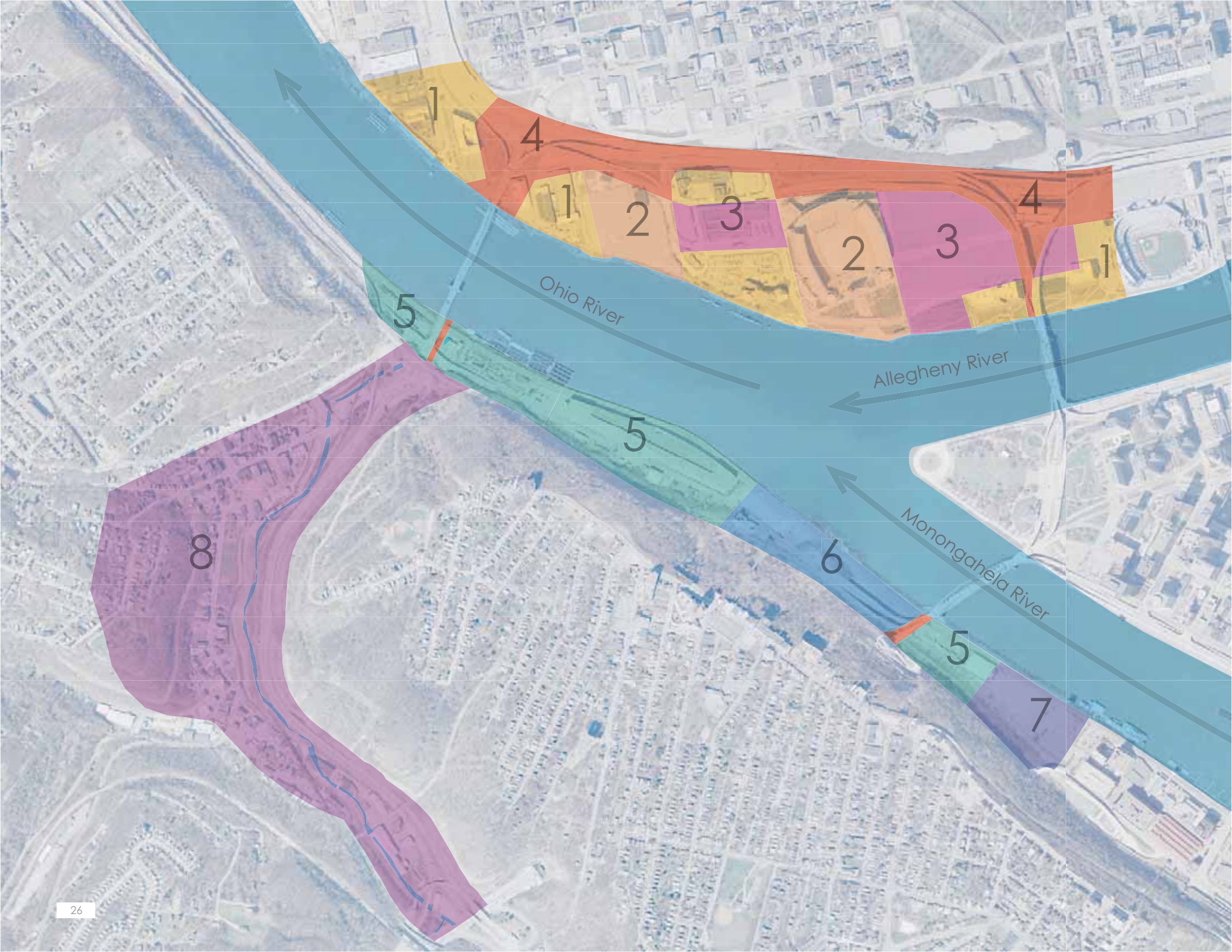


As the waterfront is redeveloped, the river should be „buffered“ from the impacts of the human development. Past damages should be healed through the landscape and a new understanding and awareness should begin. The goal is to restore the quality and health to the river that we drink. Guiding principles for this should be:

- Rainfall runoff should no longer be invisible and hidden in pipes that simply pour runoff into the river.
- Rainfall runoff from the project sites should be captured and held by vegetative and soil based systems, especially for small frequent rainfalls (1-inch and less).
- Where there is a need to convey water, this should happen in open soil and vegetation systems that slow, absorb, infiltrate, and clean water. Water should never be conveyed quickly to the river in a pipe or concrete system without the opportunity of soil and sunlight.
- Open water will not be possible everywhere, but systems that allow water to seep into soils or planting areas can be used even in very structured areas.
- Every opportunity should be taken, no matter how small. Even water that comes off roofs can be seen and heard for a moment. Many small things add up to a bigger change. People should see and remember the rainfall runoff in a good way.
- Changes in materials and surfaces – vegetated roofs, porous pavements, the removal of pavement – should be encouraged.
- Projects should look beyond their footprint to take the water from uphill – from roads, other buildings and paved areas – and reconnect the water to the soil and vegetation. Water should not be “conveyed” through the project unless it is buried too deep to reach.
- The path of the combined sewer should be recognized, people reminded of where the stream was buried and where it reaches the river.
- If people see the water efforts along the waterfront, and carry that approach upstream, the flow from the combined sewer will become less over time.

all text by Cahill Associates „**Stormwater for the Three Rivers Park**“ Feb. 2007





Area Types - Composition of Elements	
1	Streets with Planting Strips + Multi-storied Buildings with Water Demands + Green Areas
2	Streets with Planting Strips + Multi-storied Buildings with Water Demands + Square + Green Areas
3	Streets with Planting Strips + Parking Lots + Green Areas
4	Highway + Parking Lots
5	Streets with unusable Planting Strips + Highway + Railway + Multi-storied Buildings with Water Demands + Green Areas
6	Streets with unusable Planting Strips + Highway + Railway + Parking Lots + Green Areas
7	Streets with unusable Planting Strips + Highway + Railway + Parking Lots + Sport Fields
8	Saw Mill Run Situation

In this section, the current situation of the project area is described, analyzed and sustainable development is proposed.

In order to describe and analyze the entire project area related to the stormwater system, eight distinct area types and stormwater treatment systems have been identified. Each system intends to address the various situations found within it according to its combination of city structure elements, such as traffic, squares, buildings, planting strips, green areas and sewer systems.

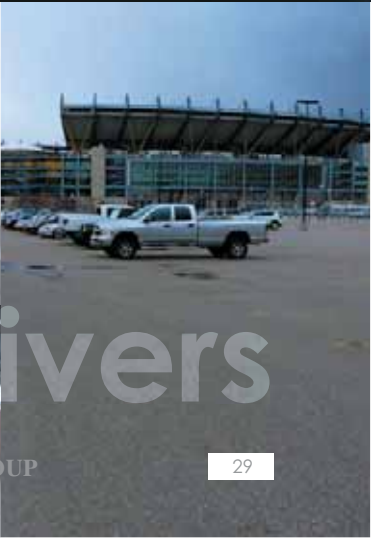
Because each area type has different usage, various levels of pollution are produced (see the chart page 91). The pollution levels of each area type are evaluated and solutions (stormwater treatment tools) are proposed. Possible scenarios show how these treatment tools work together with the topography.

Sample projects that have the same situation are also shown.









# North Side of Three Rivers

Section V. Sustainable Development Guideline

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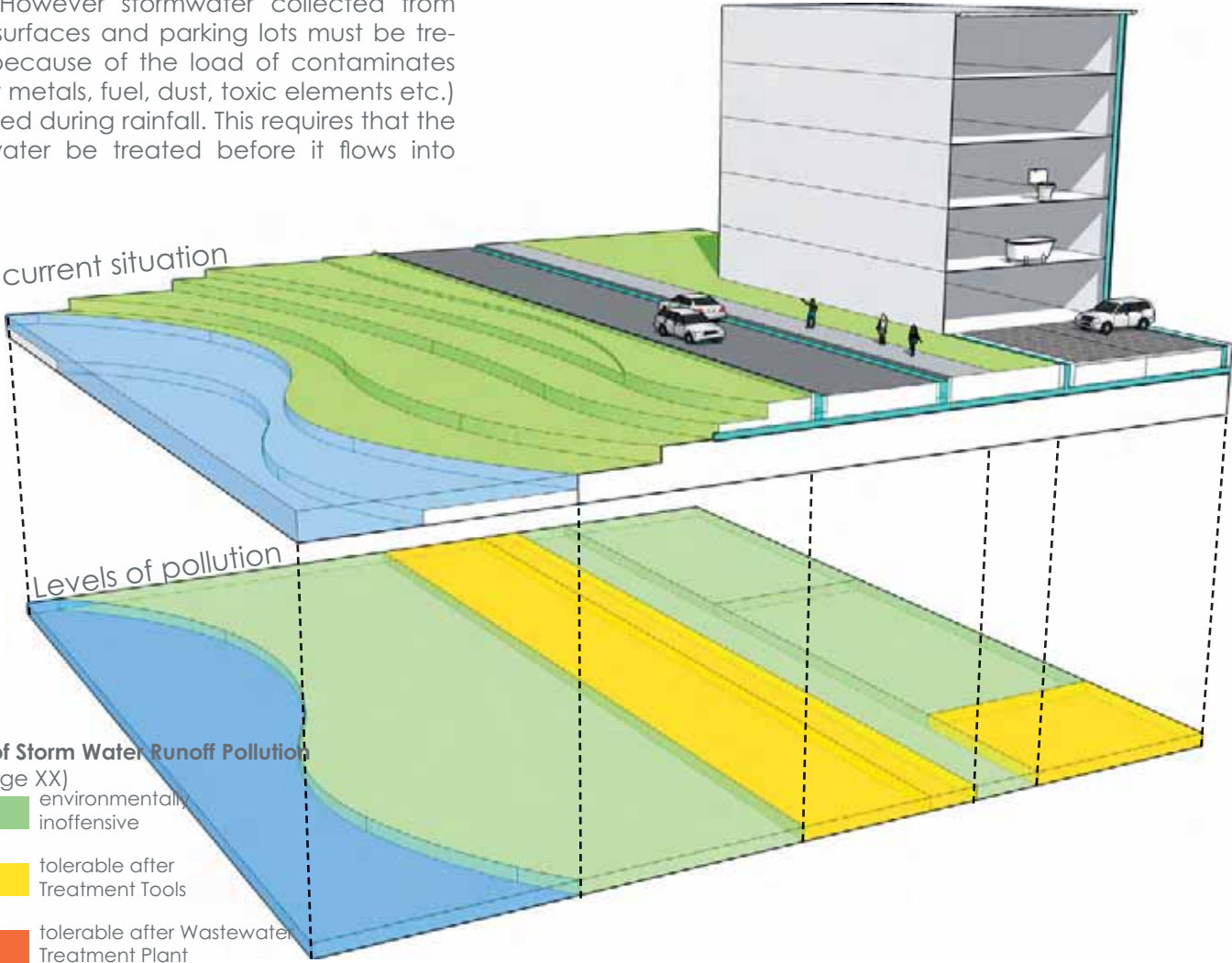


# Analysis of current situation



Location.  
Streets with Planting Strips + Multi-storied Buildings with Water Demands + Green Areas

The stormwater coming from building roofs and green areas does not need to be treated. However stormwater collected from street surfaces and parking lots must be treated because of the load of contaminants (heavy metals, fuel, dust, toxic elements etc.) collected during rainfall. This requires that the stormwater be treated before it flows into river.

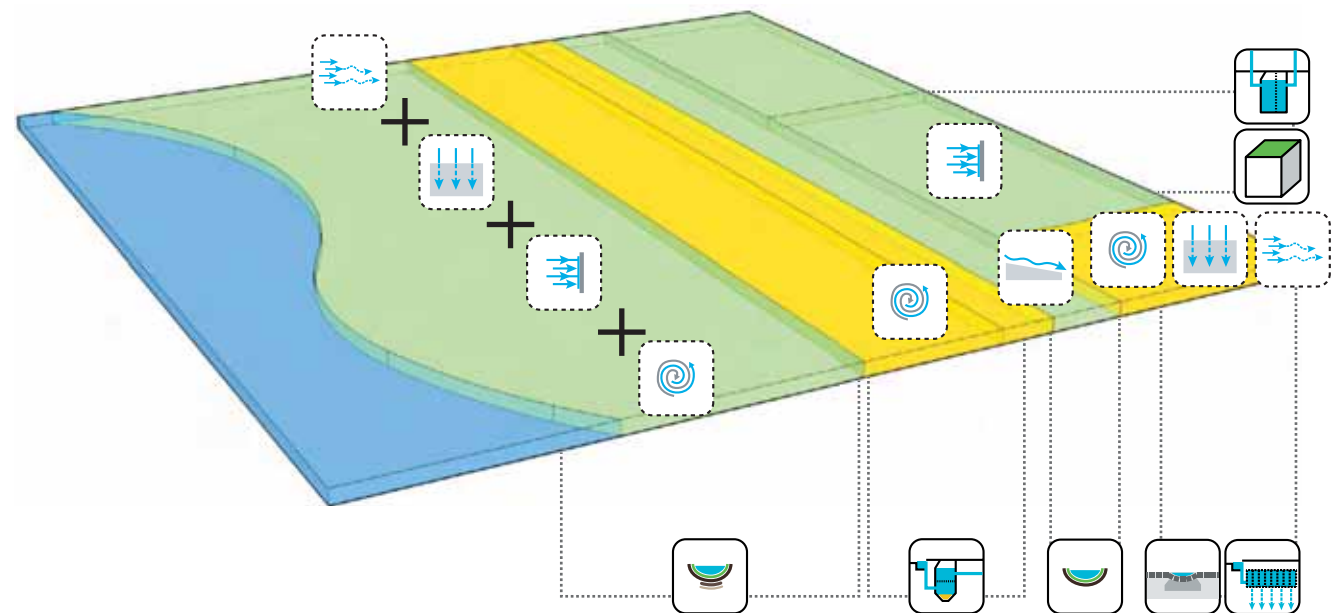
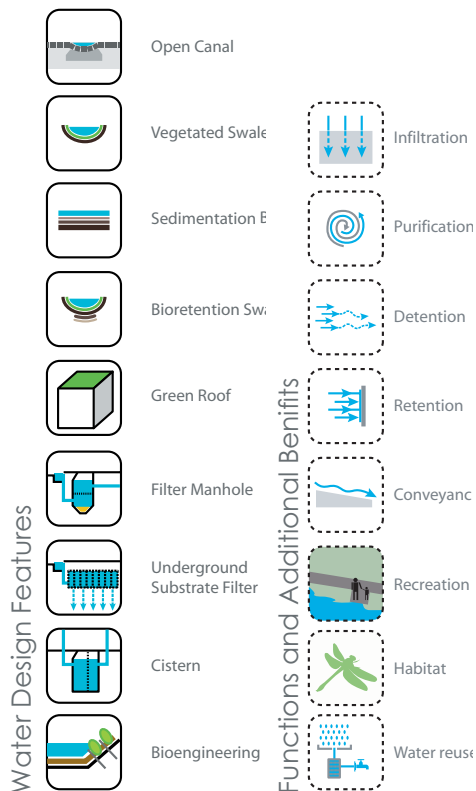


Type 1 is characteristic for its streets with planting strips, multi-storied buildings with water demand and large open spaces with the possibility of a decentralized stormwater treatment by cleaning water through its surface.

Installation of green roofs help to reduce storm water runoff. This runoff can be collected in an underground cistern. The planting strip along the street's edge can be reconstructed into vegetated swales. Swales collect and direct stormwater away from streets and parking lots as it removes particles with the soil and plant roots. It is fully separated from the combined sewage system.

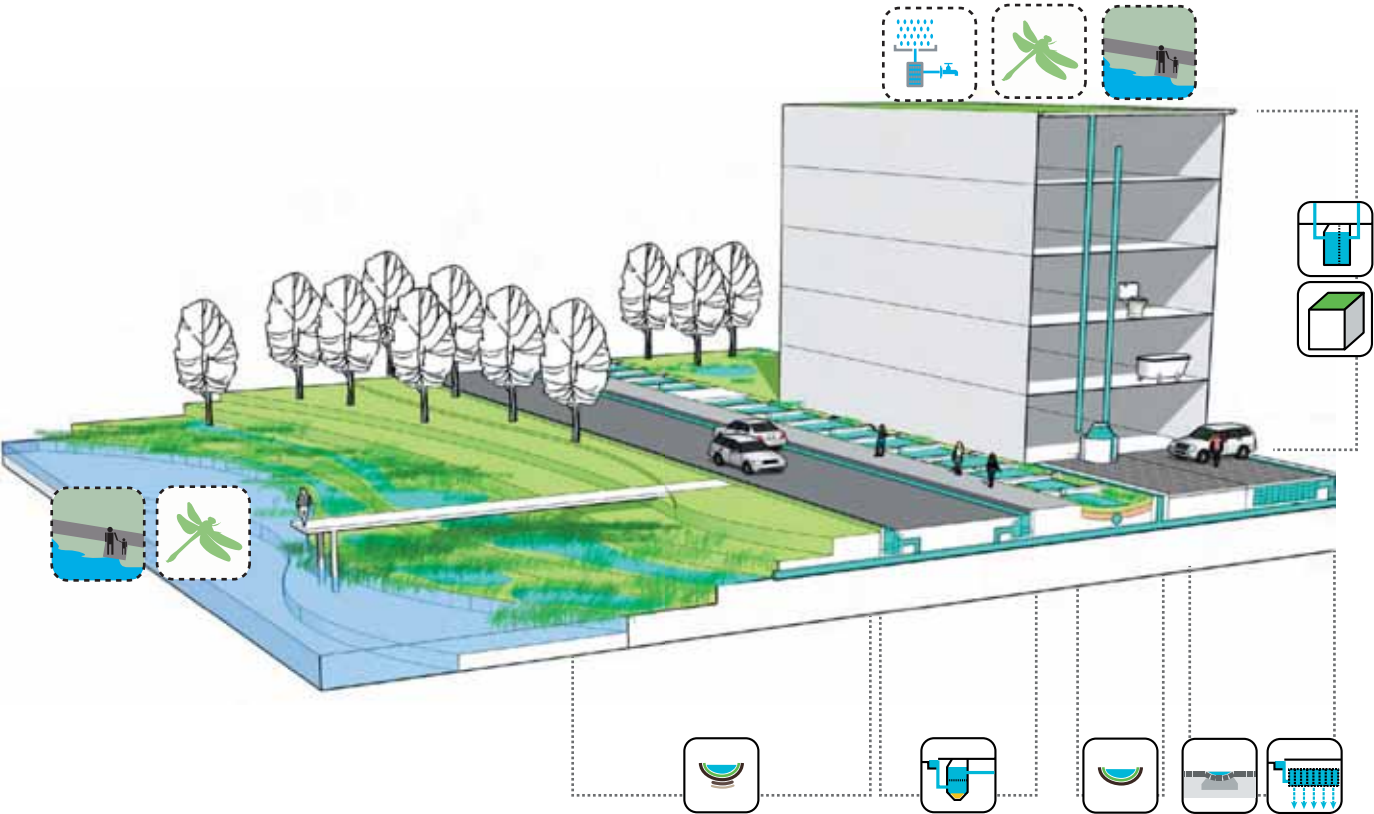
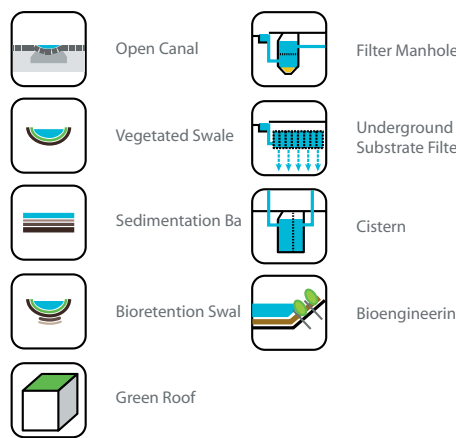
Additionally, collected water in the cistern can be reused to flush toilets, irrigate plants etc. Green roofs and bioretention swales also improve the micro-climate through evaporation, providing both cooling and a living place for fauna and flora.

The Green area along the river can be installed with bioretention swales which helps restore the stormwater, purifying and releasing it slowly into the river.



Possible Scenario

A possible scenario shows stormwater treatment tools integrated together with the landscape design. This combination supports not only stormwater functions, but also provides recreational areas for people and a habitat for flora and fauna.





## Sample Project: Lanferbach, Gelsenkirchen, Germany

- Restoration of a Creek, Stormwater-Management

The storm water which accumulates on streets, driveways and street-oriented rooftops now is collected into drainfields and open swales, where it is retained and precleaned through a series of purification stages, before it enters the Lanferbach. Since the storm water is now slowed down and allowed to seep directly into the ground it helps to raise the local groundwater level.

**Field of expertise:** River Restoration Project  
**Project Role:** Lead Designer, Landscape, Water Design, Stormwater Management  
**Client:** Emscher-genossenschaft  
Planning & Design: 1994-1998  
**Construction:** 1999  
**Entire Area:** 12 ha / 30 acres  
**Size:** 32.000 m<sup>2</sup> / 8 acres

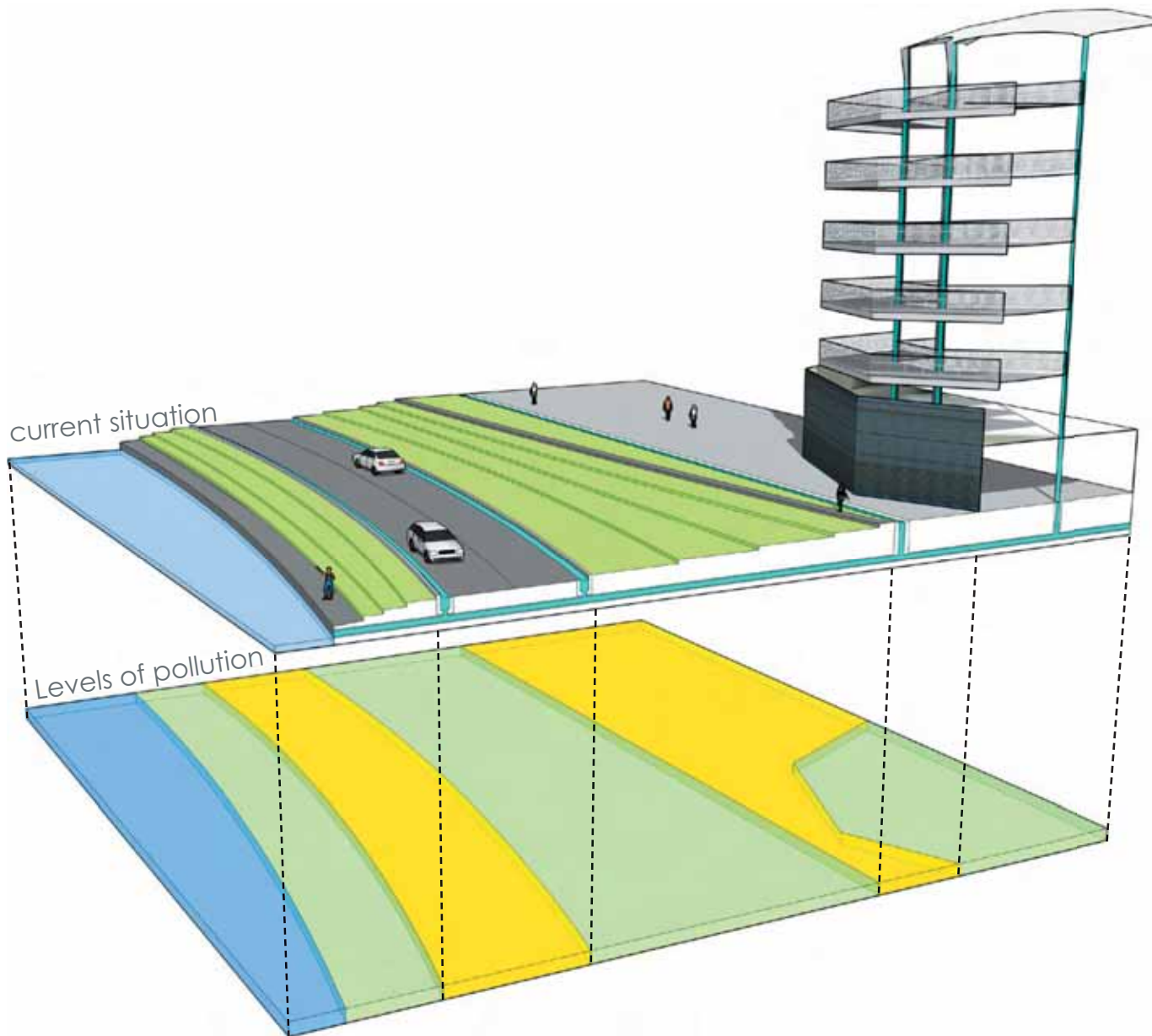


— Storm water from streets will be treated  
— Storm water from roofs will be piped into stream

# Analysis of current situation



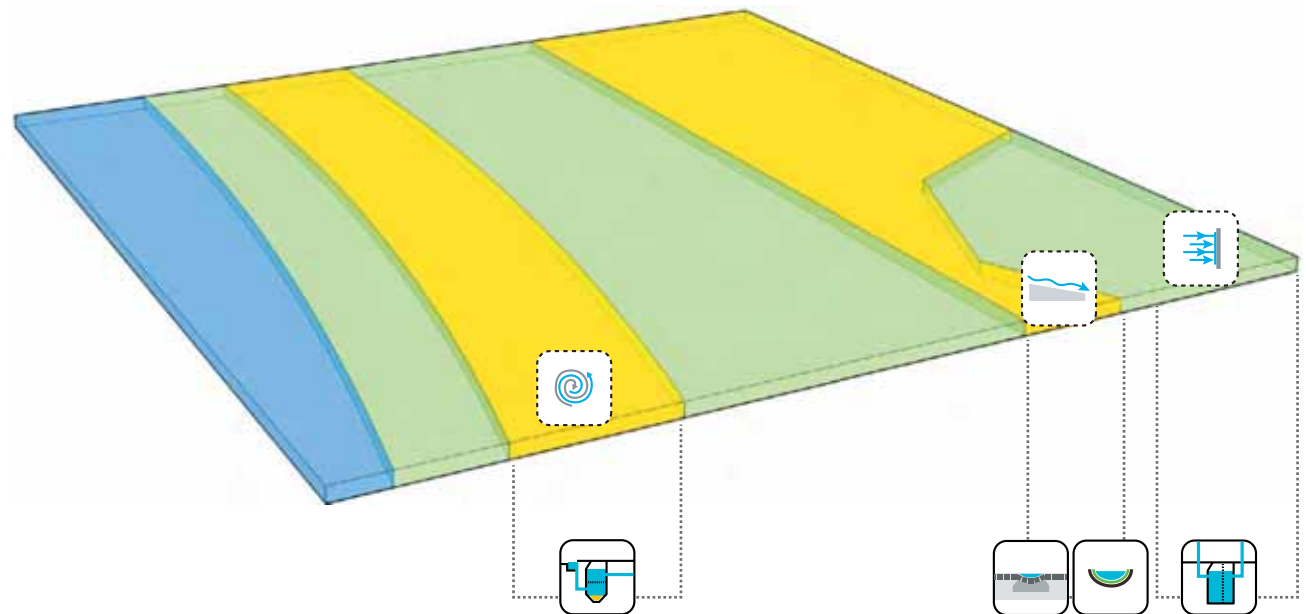
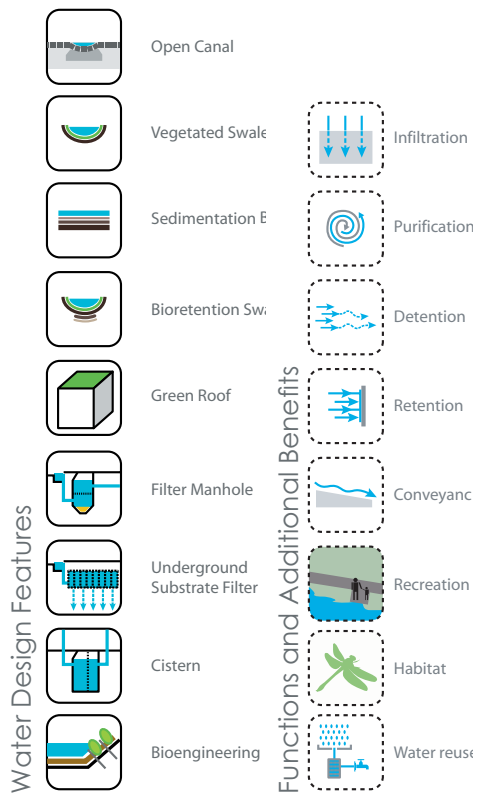
Street with Green + Multi-storied Building with Water Demands + Square + Green Areas



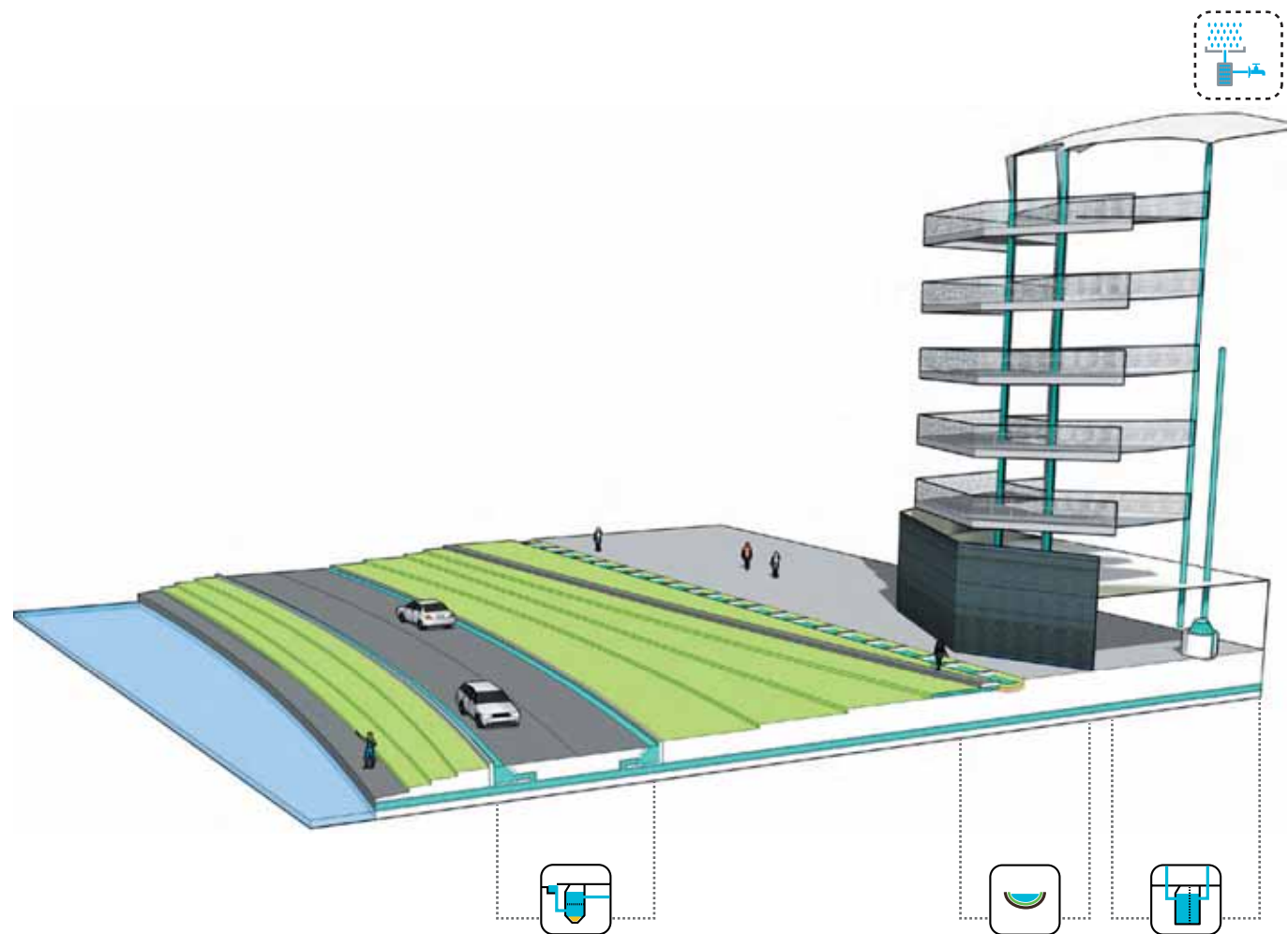
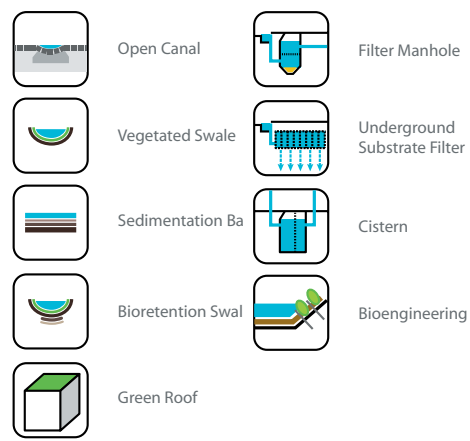
Levels of Storm Water Runoff Pollution (see page 91)

- environmentally inoffensive
- tolerable after Treatment Tools
- tolerable after Wastewater Treatment Plant

## Proposed Treatment



# Possible Scenario



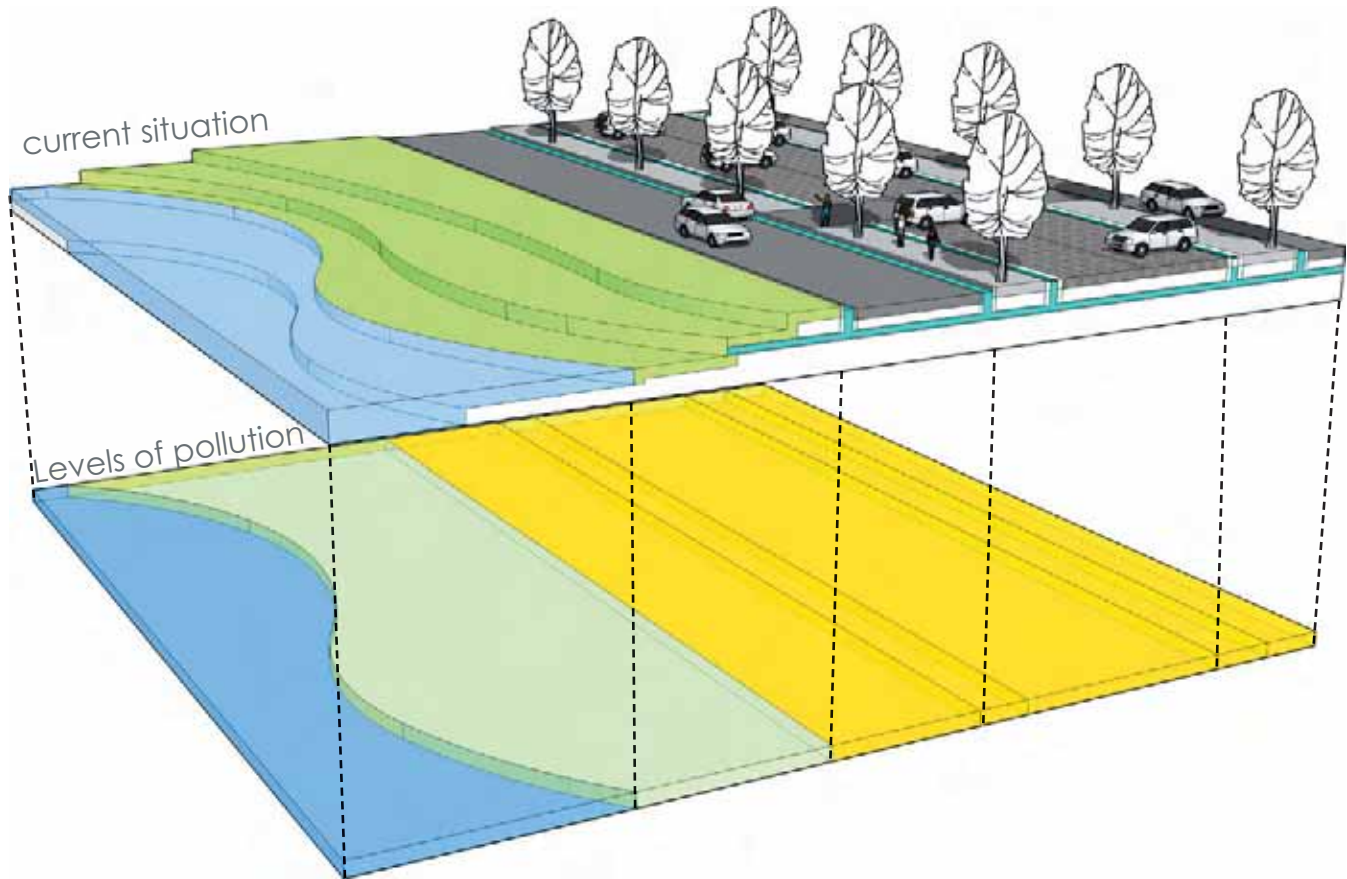




Analysis of current situation



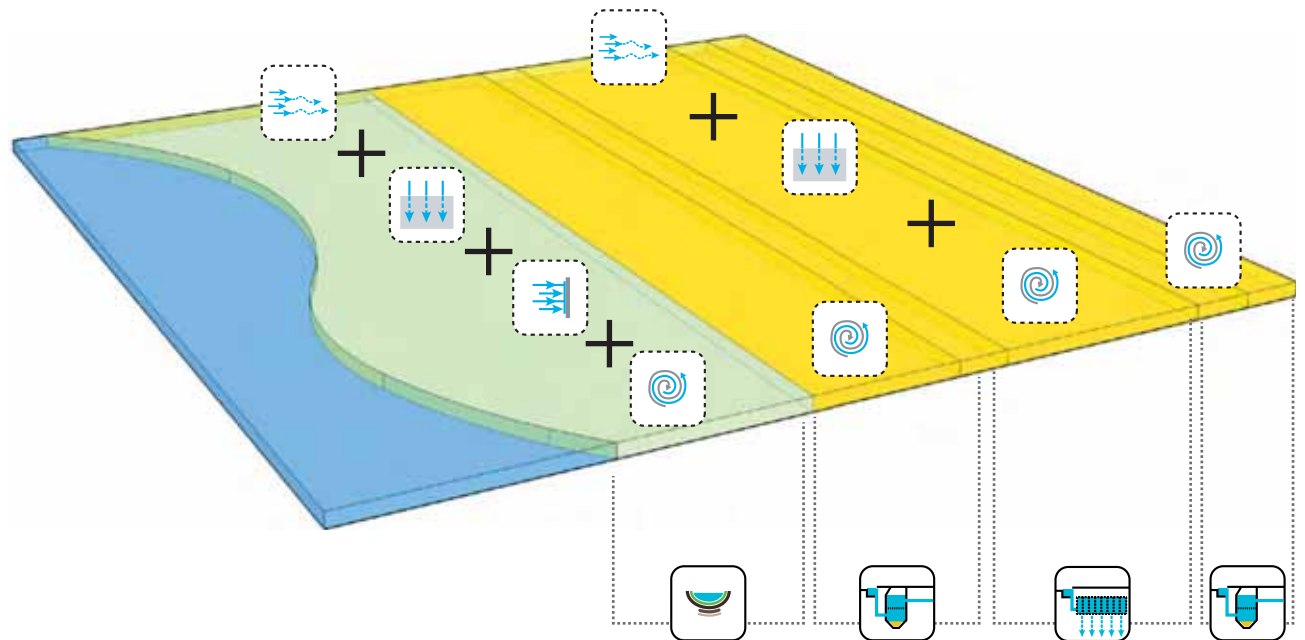
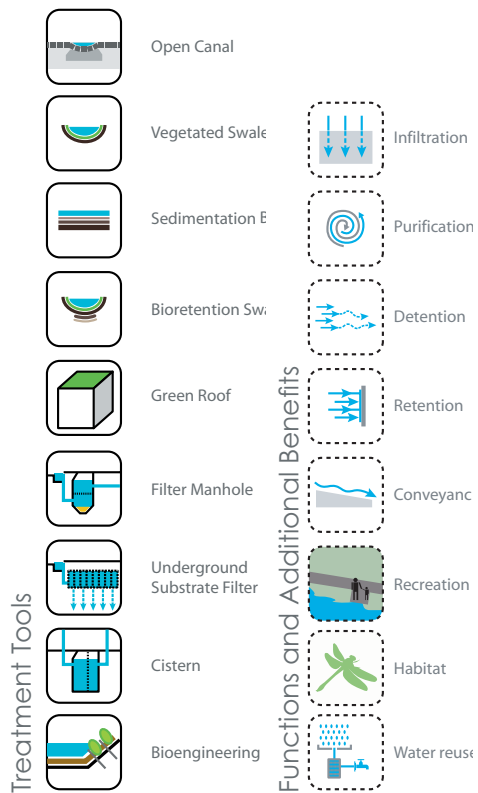
Street with Green + Parking Lots + Green Areas



Levels of Storm Water Runoff Pollution  
(see page 91)

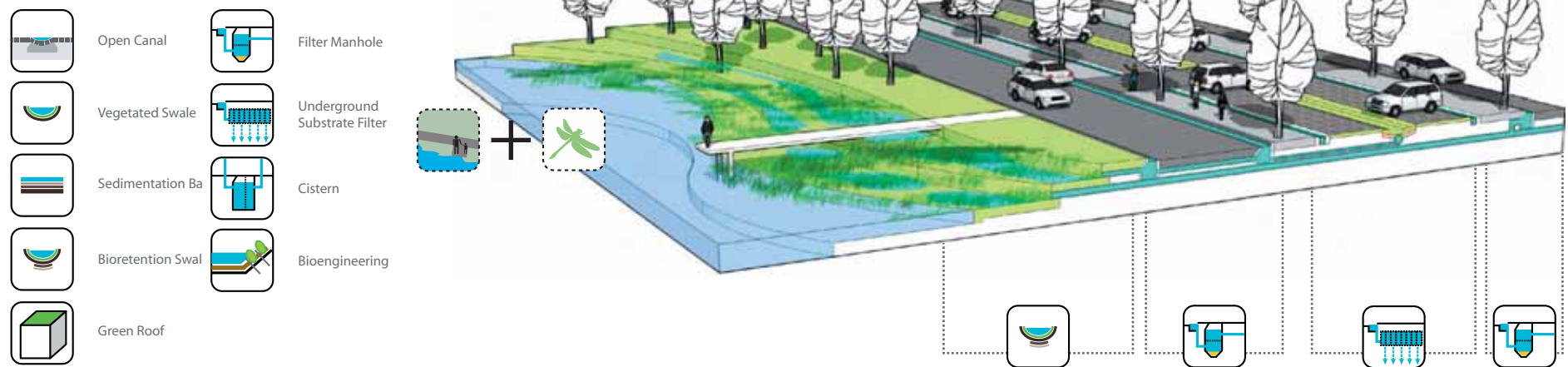
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## Proposed Treatment





# Possible Scenario

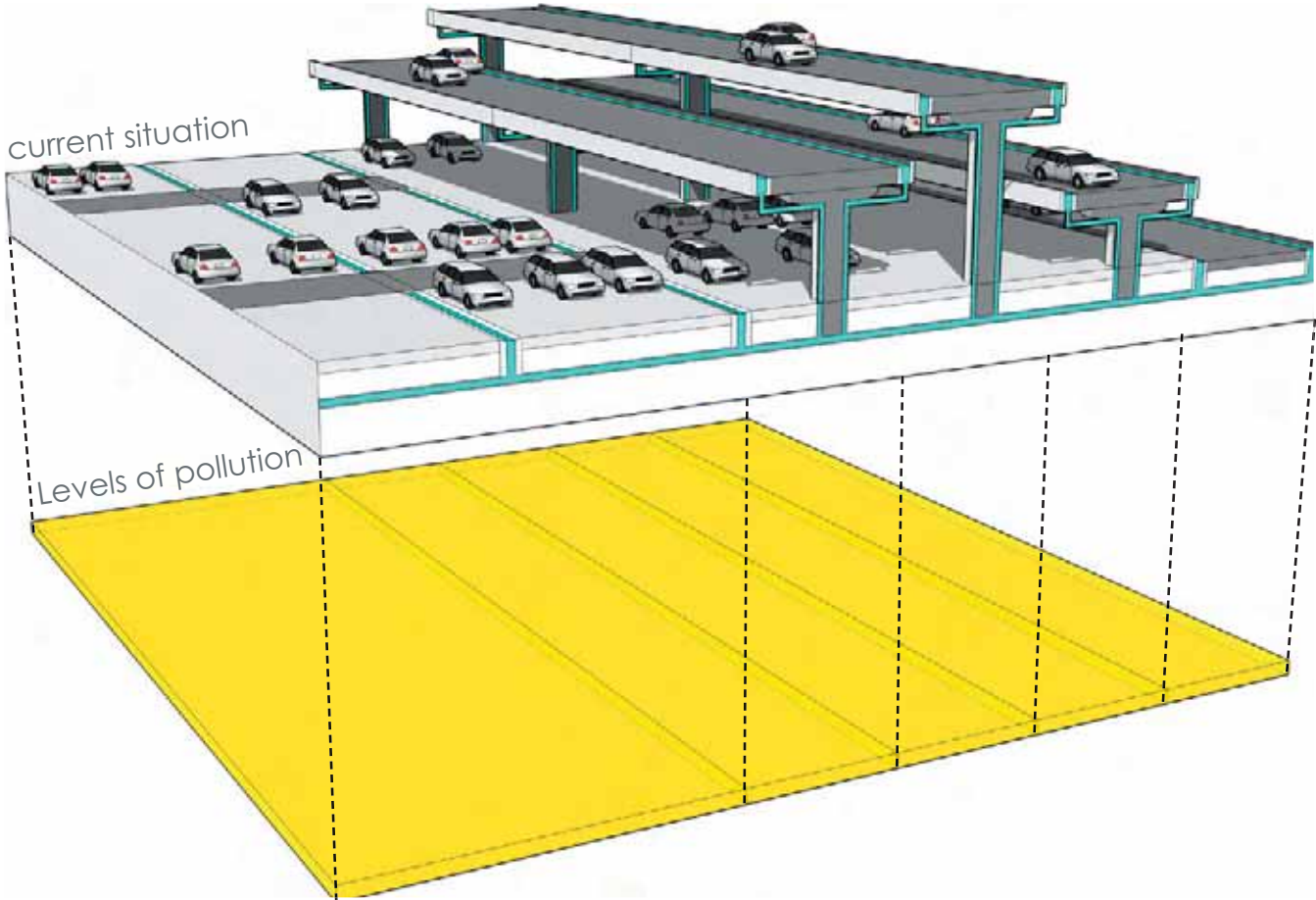




Analysis of current situation



Highway + Parking Lots

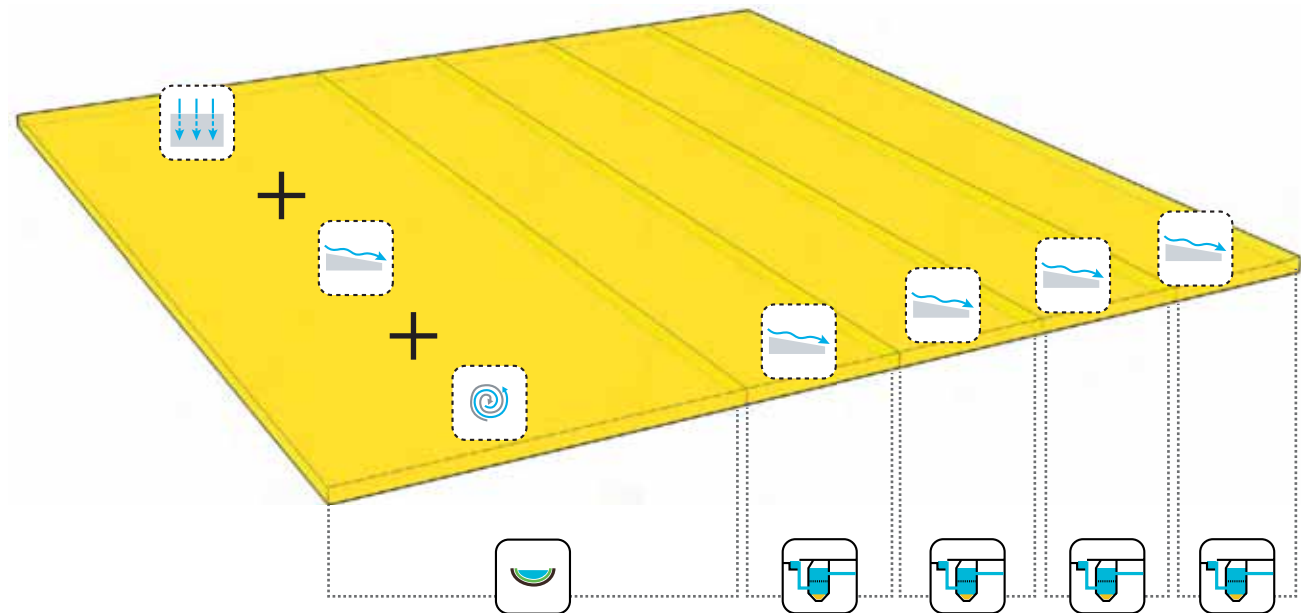
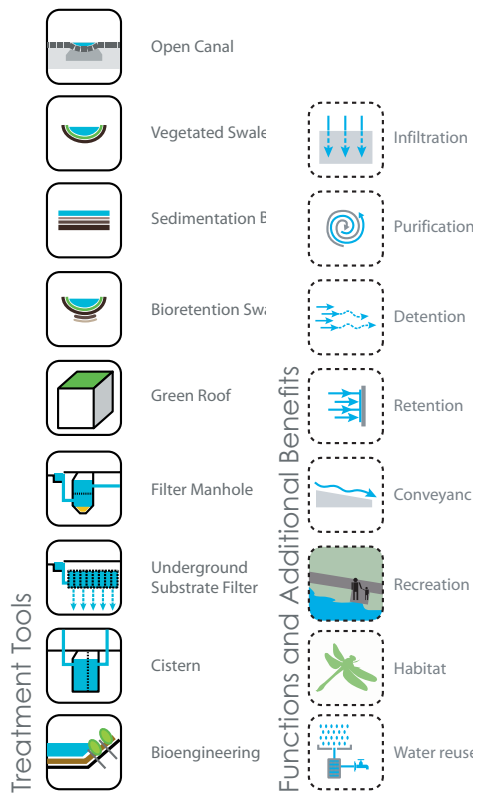


Levels of Storm Water Runoff Pollution  
(see page 91)

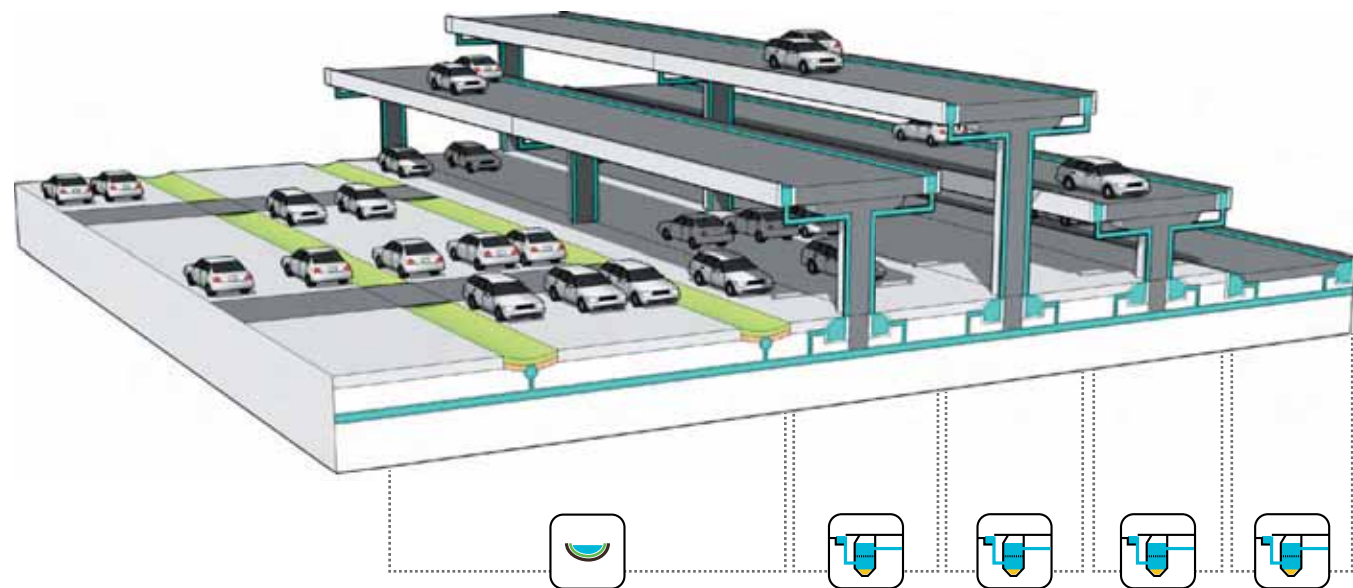
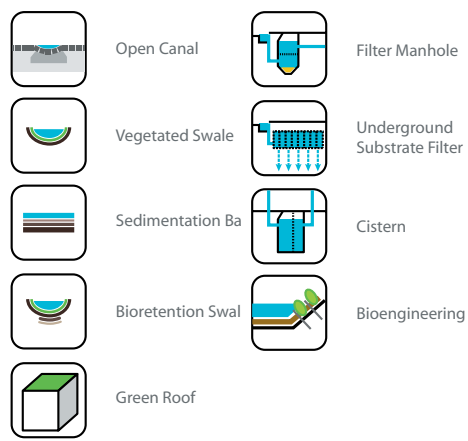
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- tolerable after Treatment Tools
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## Proposed Treatment



# Possible Scenario

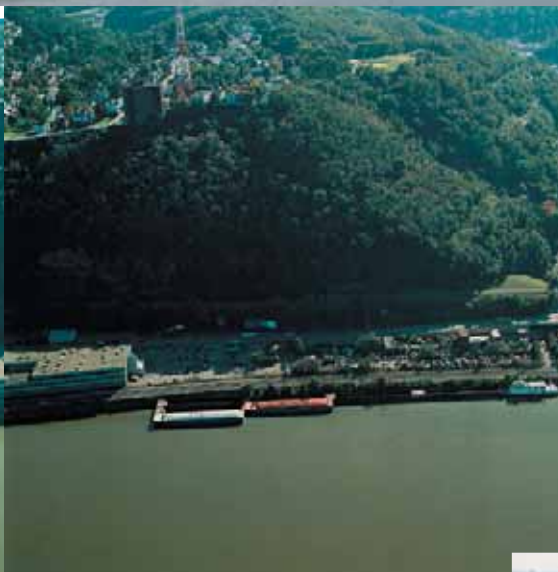












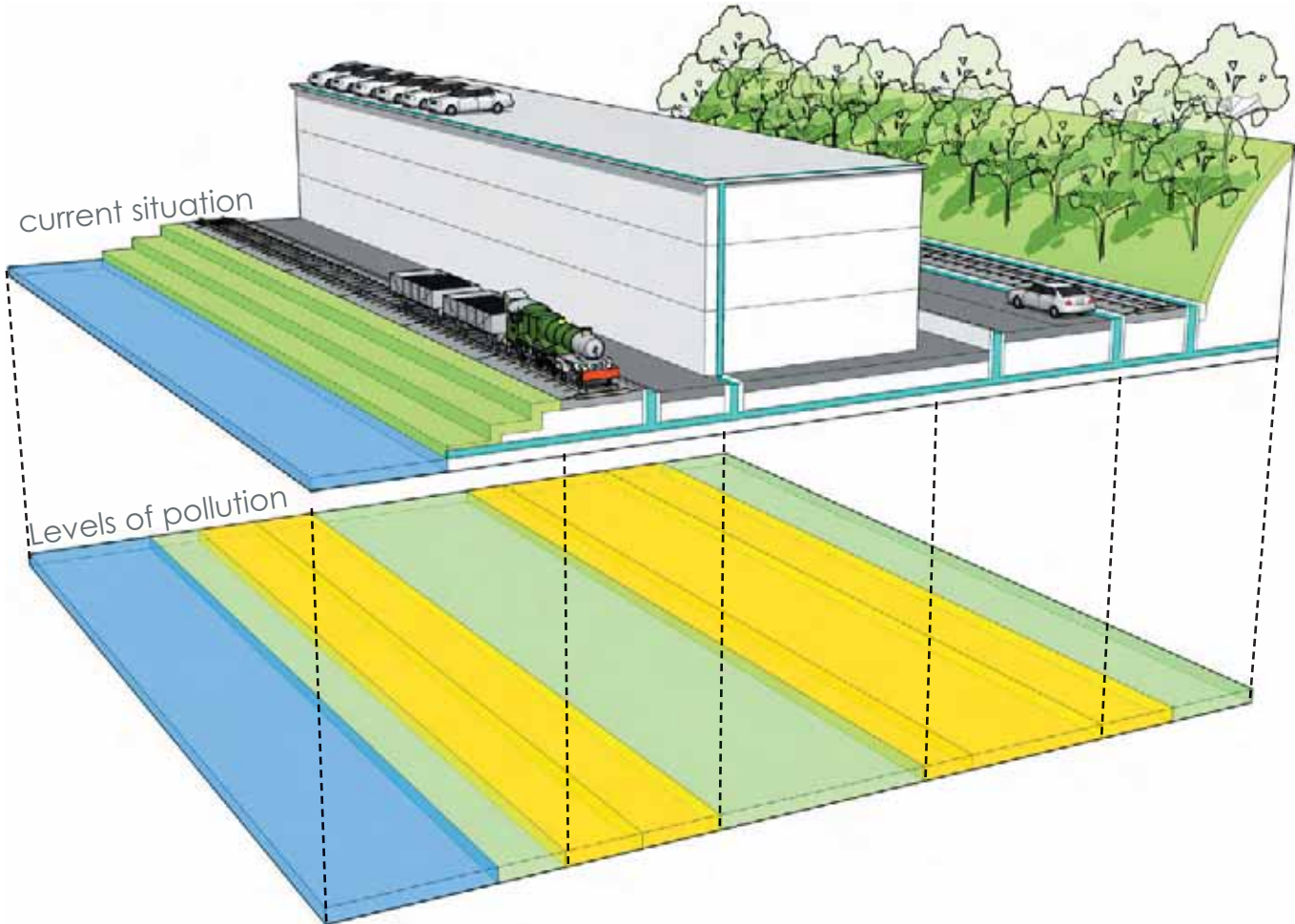
South Side of Three Rivers



Analysis of current situation



Street with unusable Green + Highway + Railway + Multi-storied Building with Water Demands + Green Areas

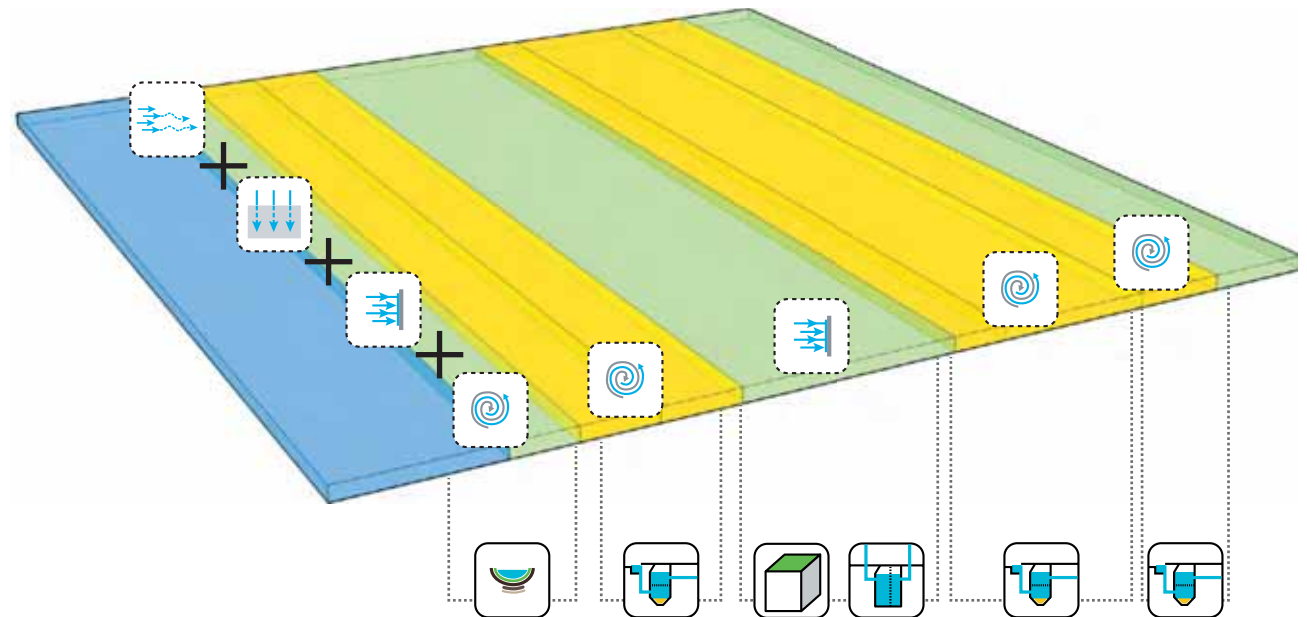
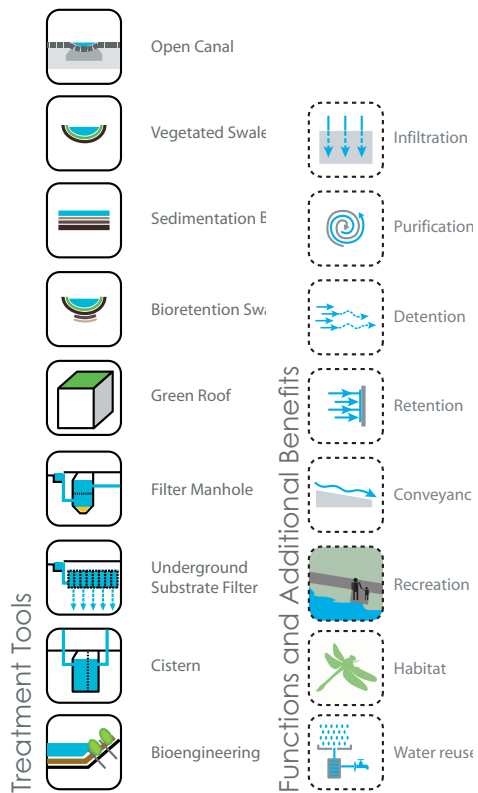


Levels of Storm Water Runoff Pollution (see page 91)

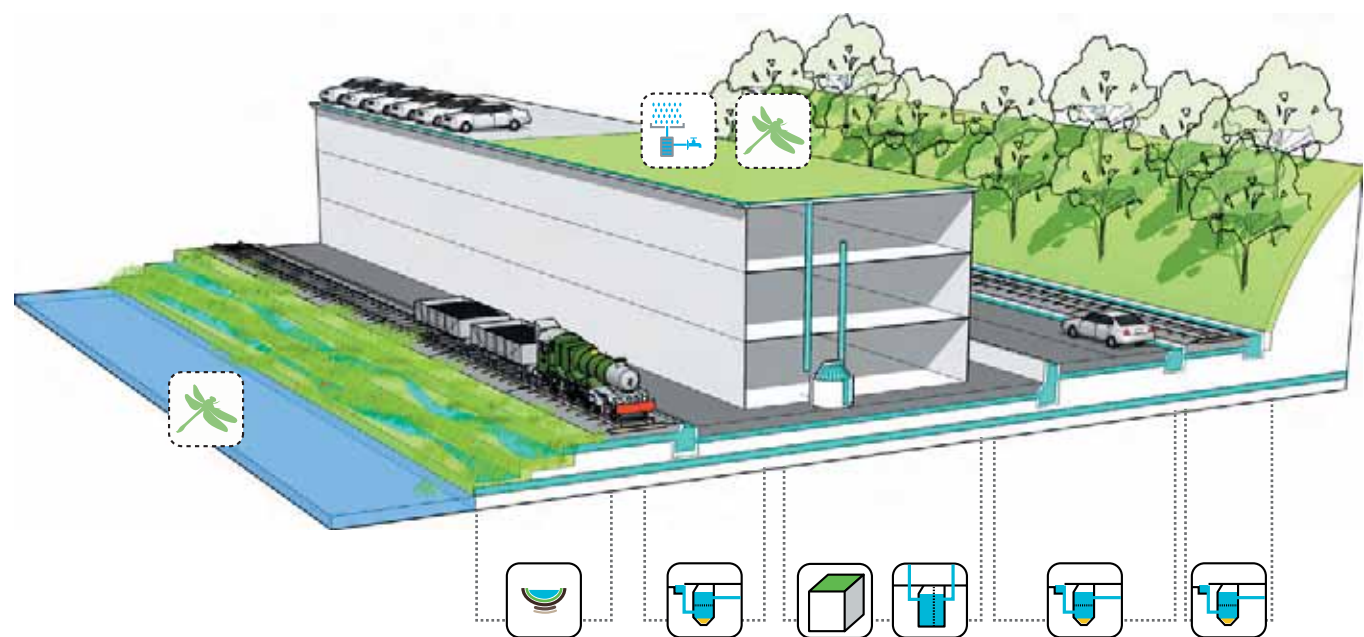
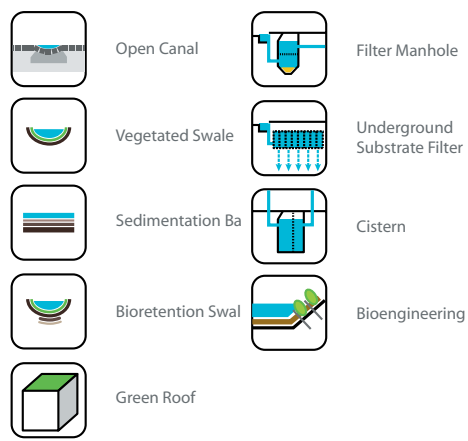
- environmentally inoffensive
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## Proposed Treatment



Possible Scenario



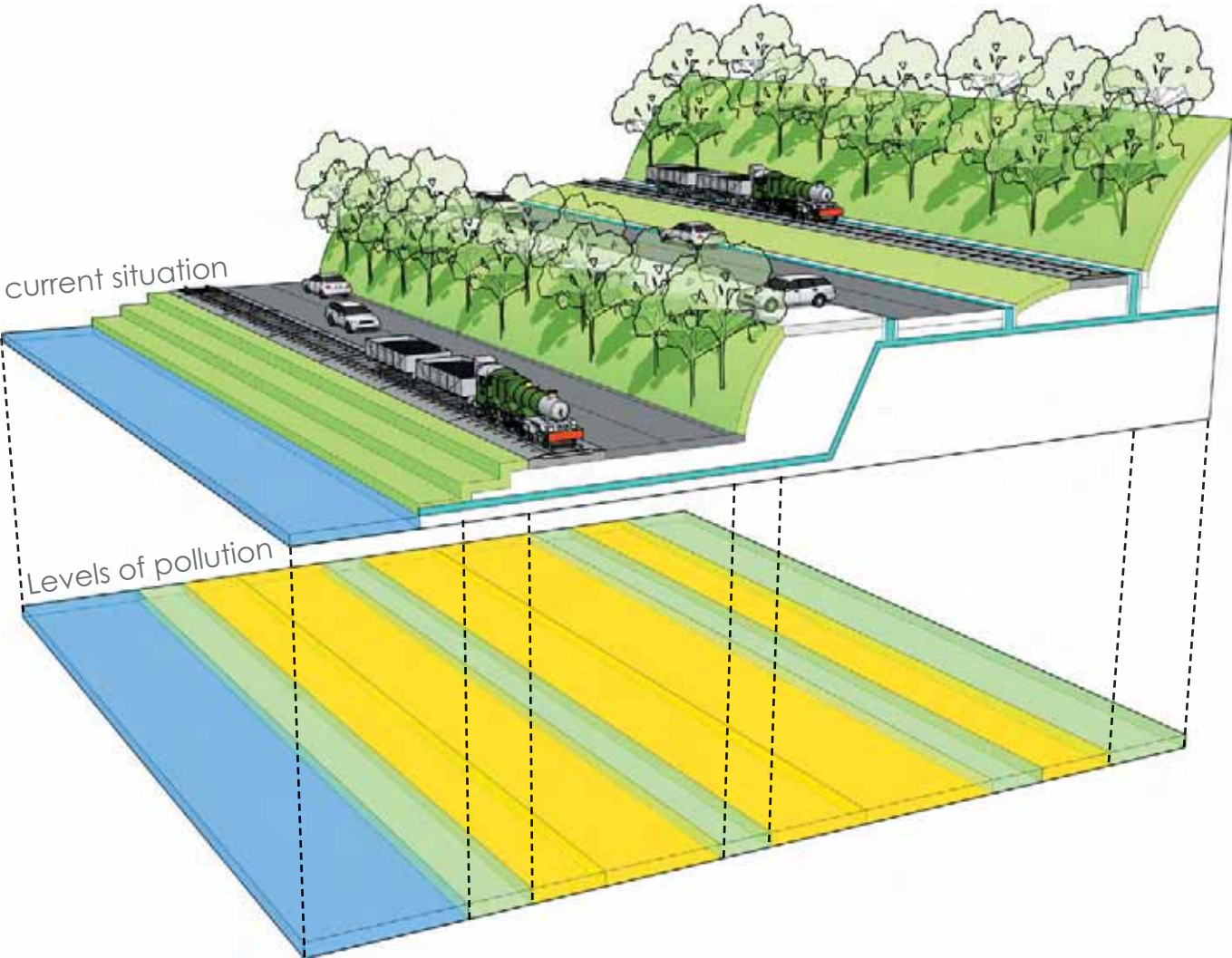




# Analysis of current situation



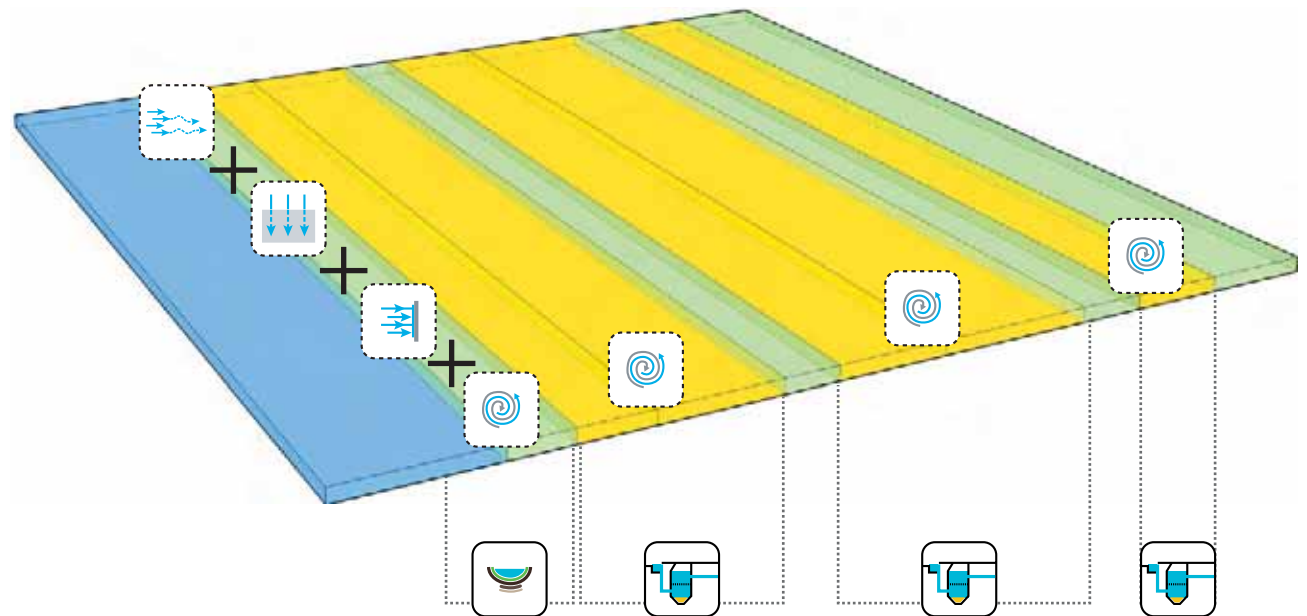
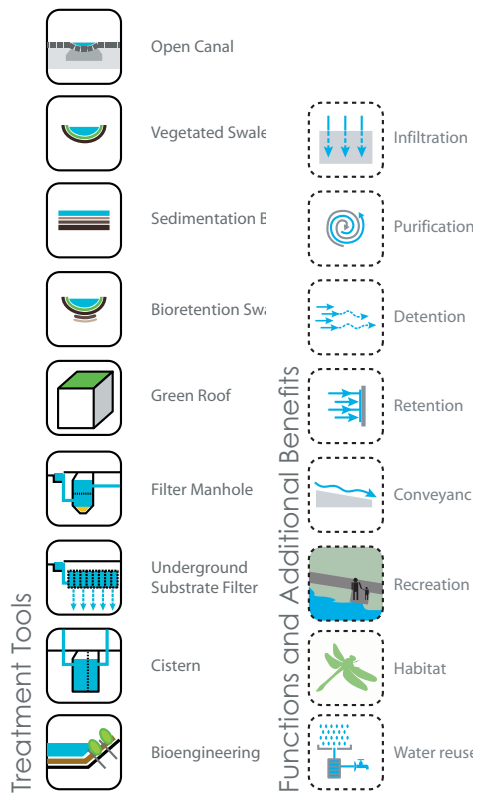
Street with unusable Green + Highway + Railway + Parking Lots + Green Areas



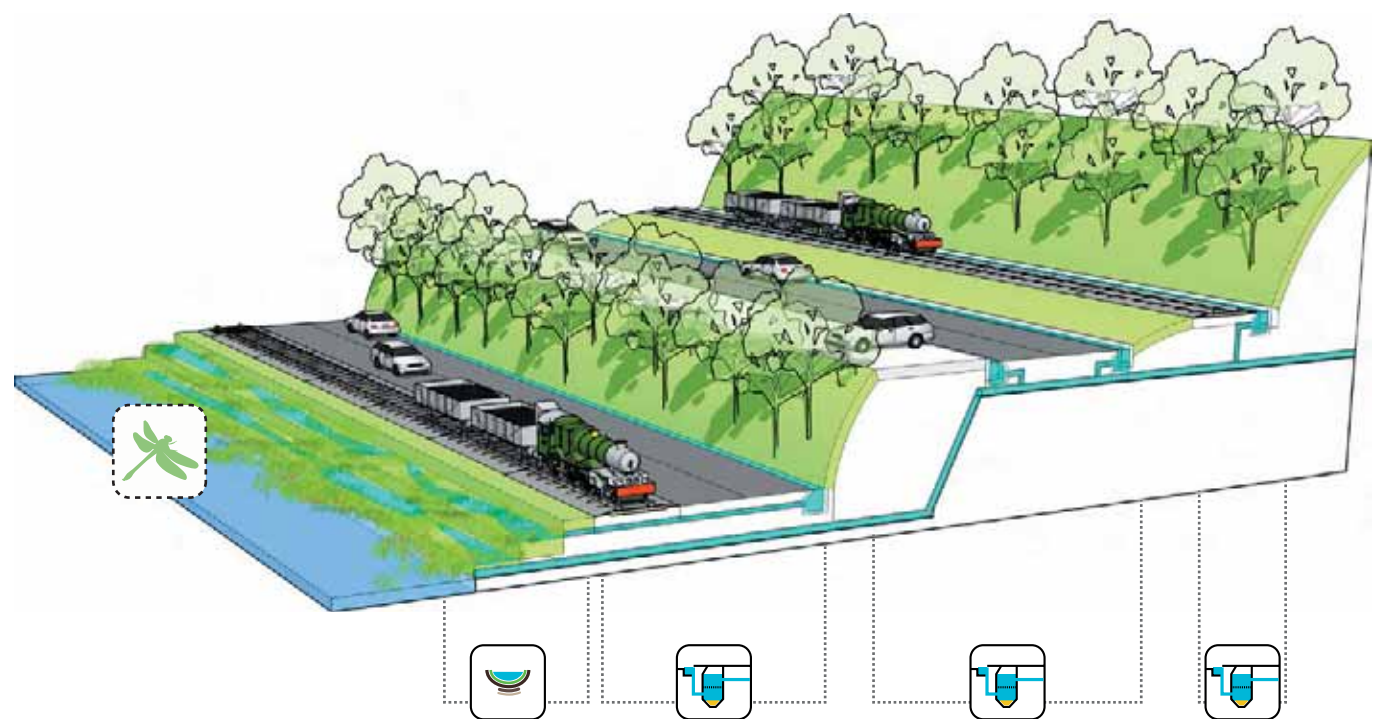
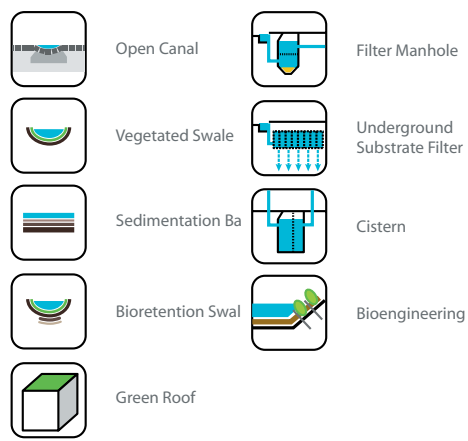
Levels of Storm Water Runoff Pollution (see page 91)

- environmentally inoffensive
- tolerable after Treatment Tools
- tolerable after Wastewater Treatment Plant

## Proposed Treatment



# Possible Scenario



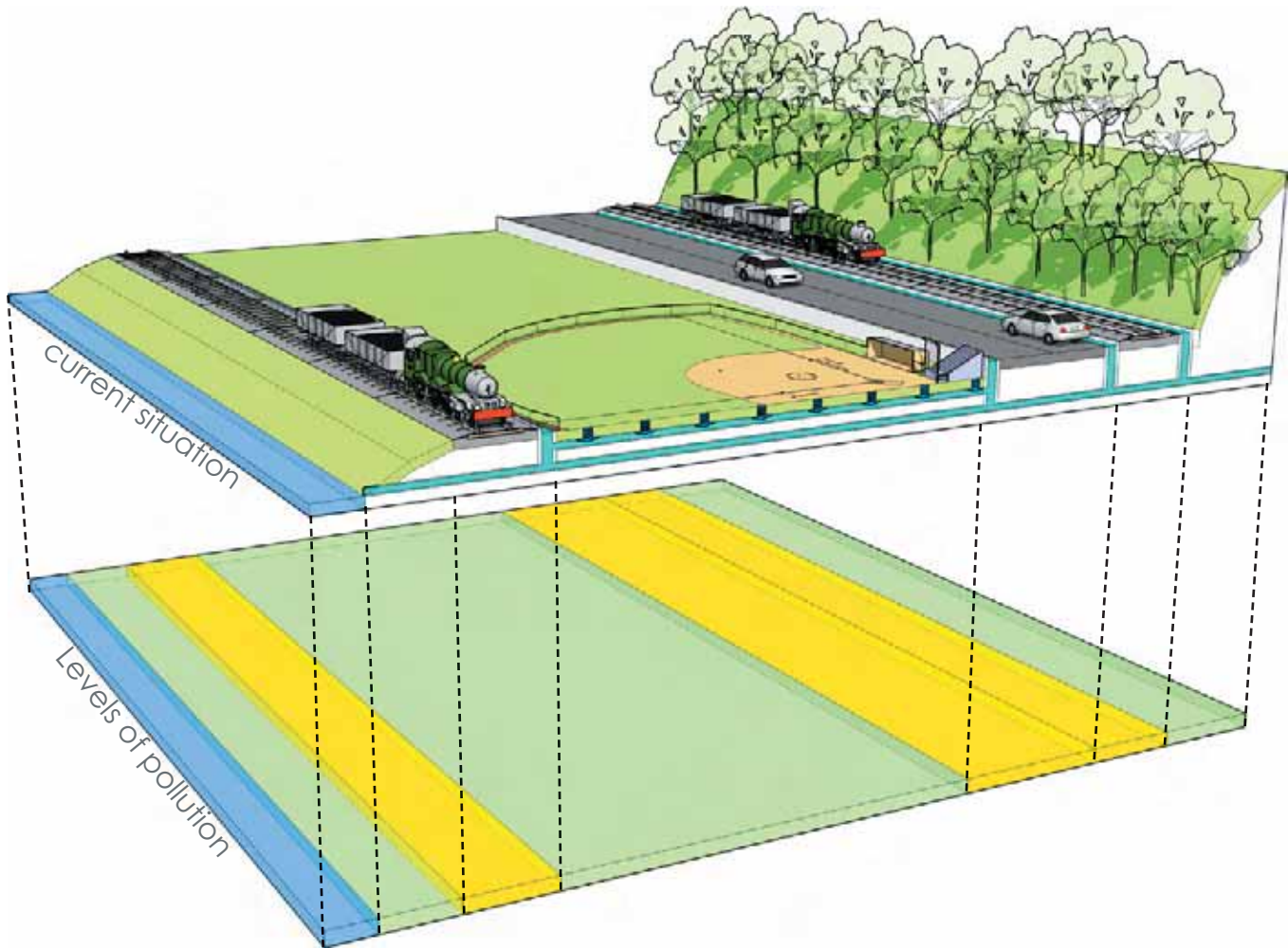




Analysis of current situation in Pittsburgh



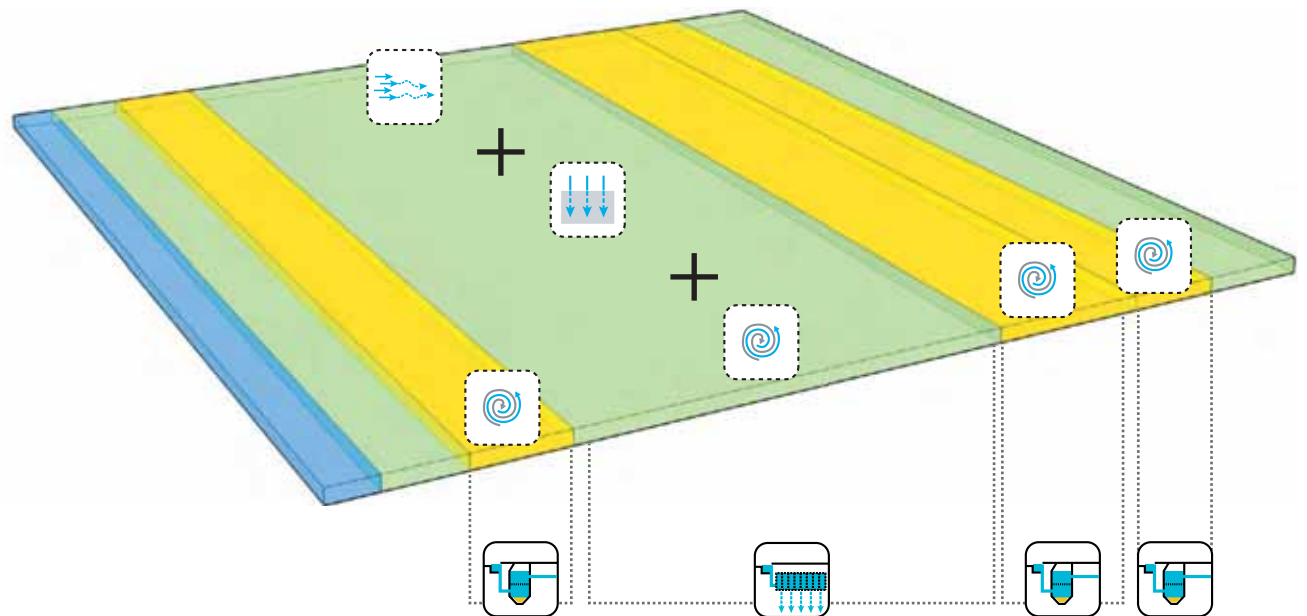
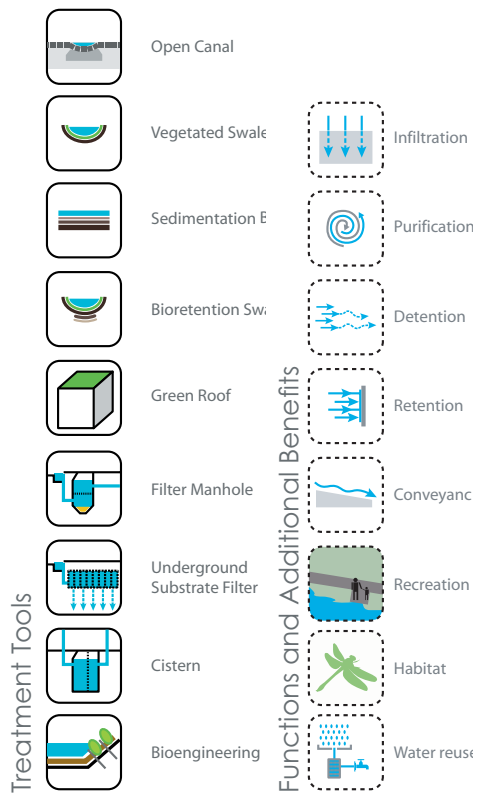
Street with unusable Green + Highway + Railway + Parking Lots + Sport Fields



Levels of Storm Water Runoff Pollution (see page 91)

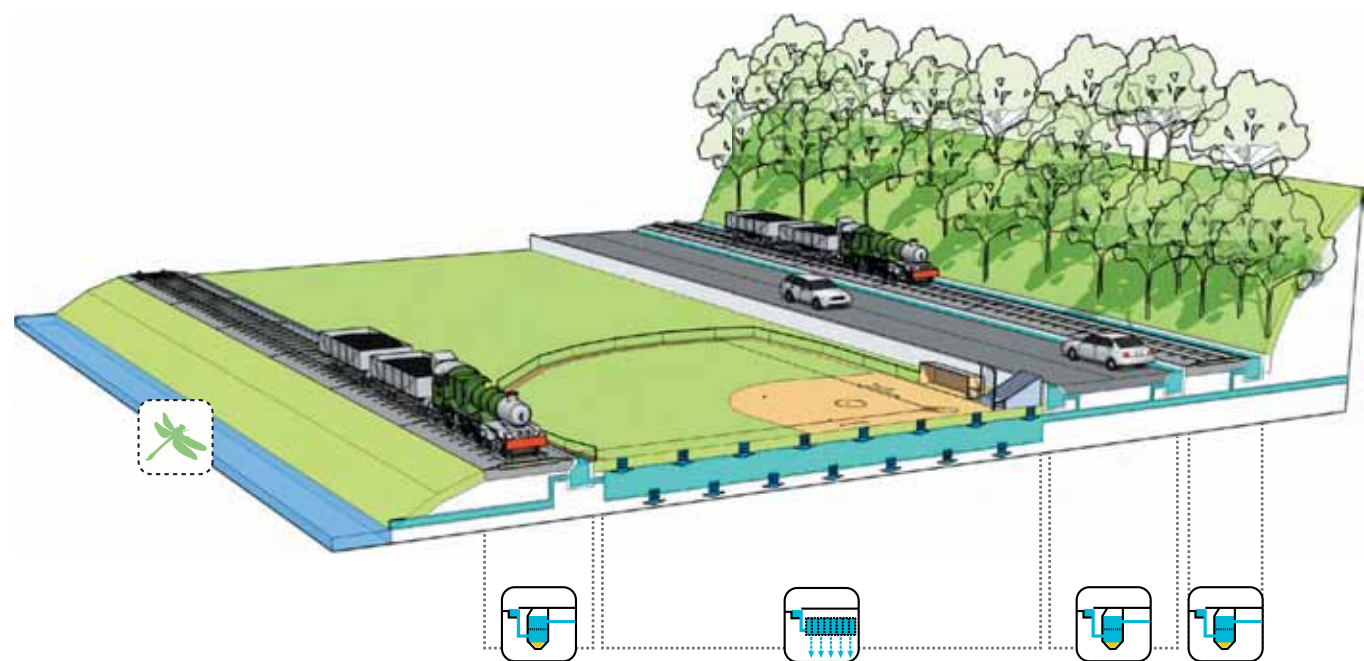
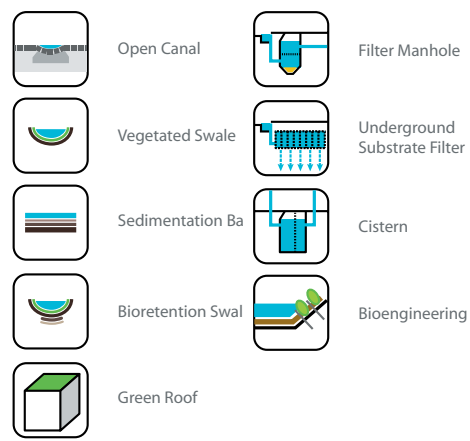
- environmentally inoffensive
- tolerable after Treatment Tools
- tolerable after Wastewater Treatment Plant

## Proposed Treatment



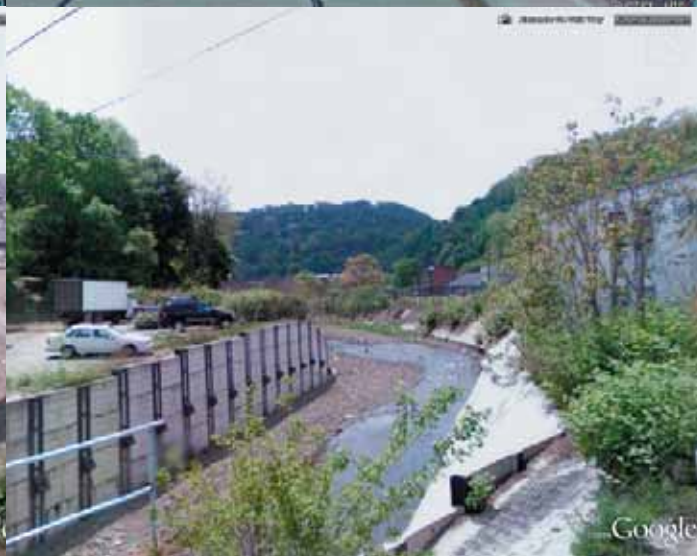


# Possible Scenario

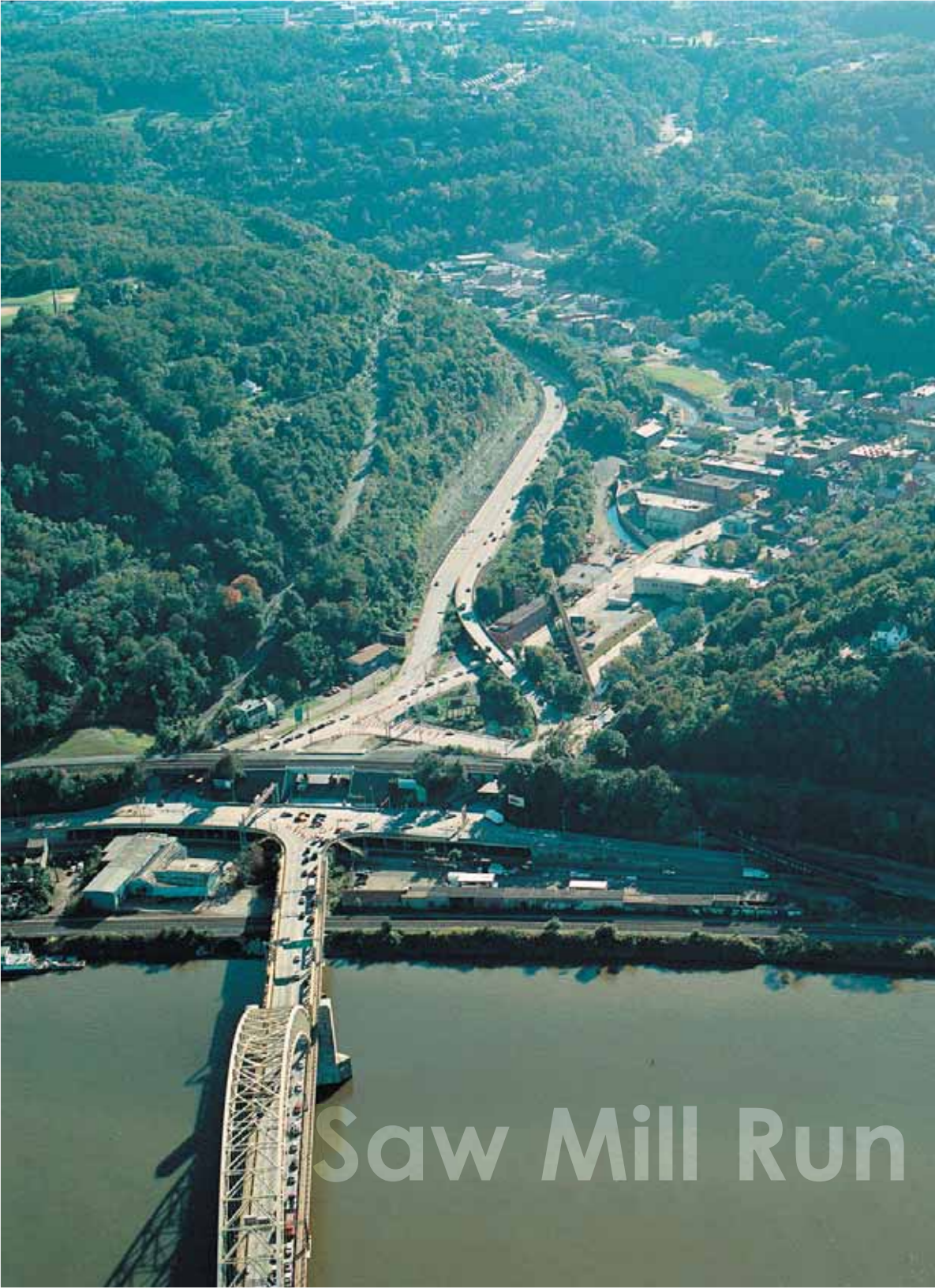










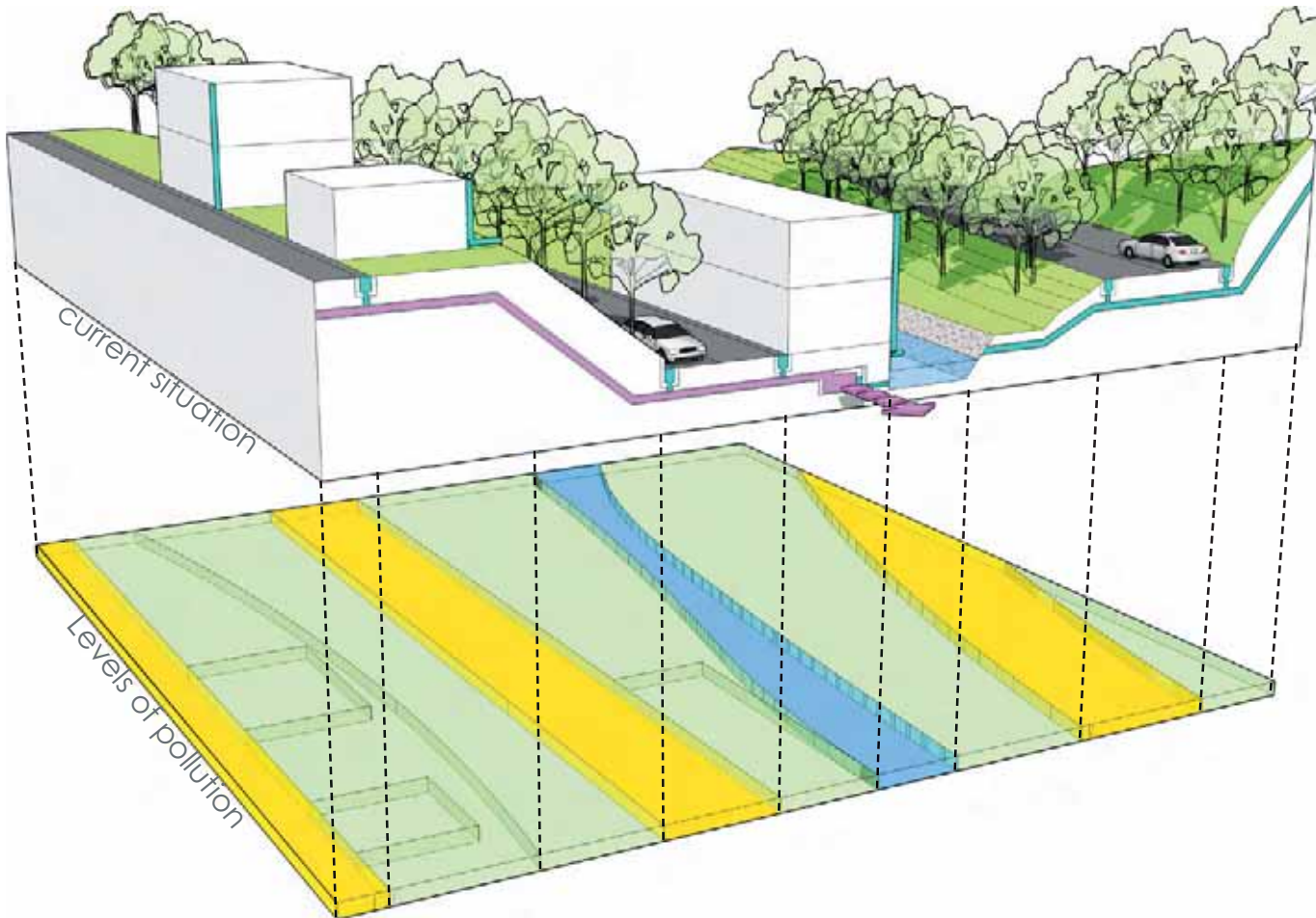




Analysis of current situation



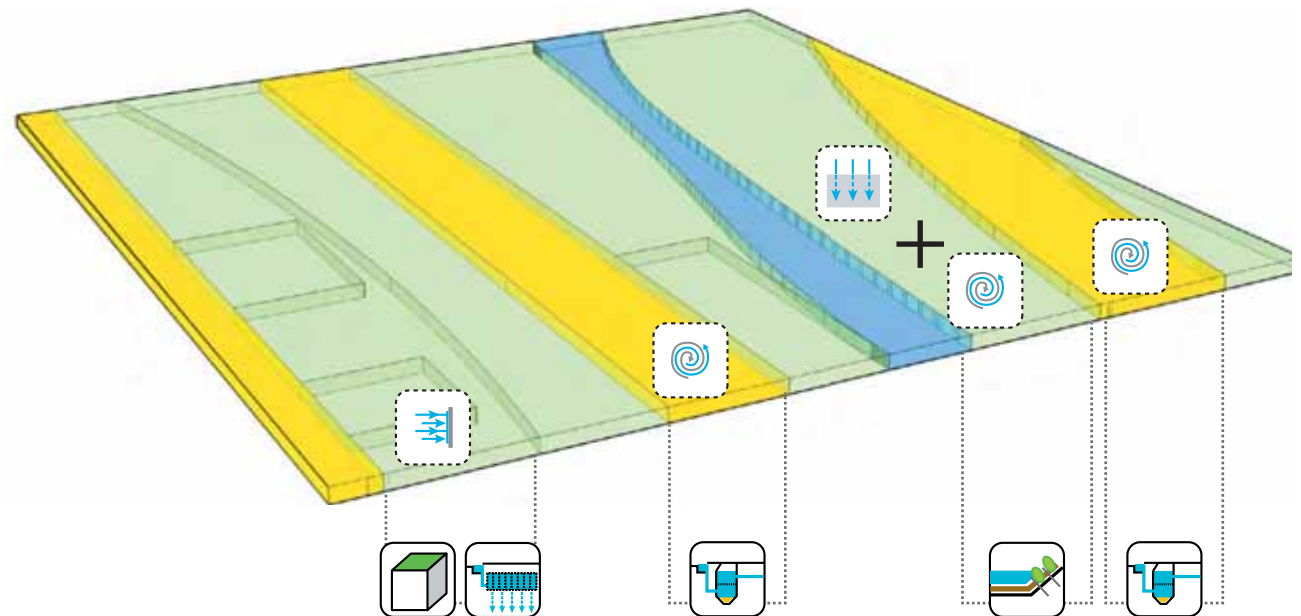
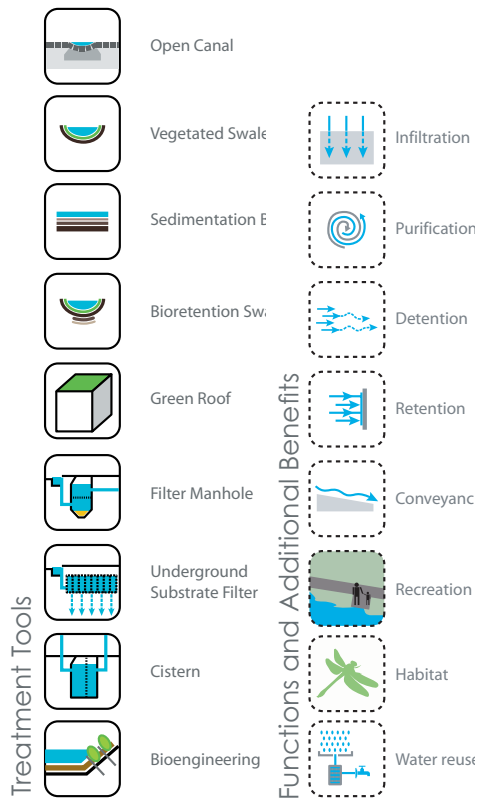
Situation Saw Mill Run



Levels of Storm Water Runoff Pollution










- environmentally inoffensive
- tolerable after Treatment Tools
- tolerable after Wastewater Treatment Plant

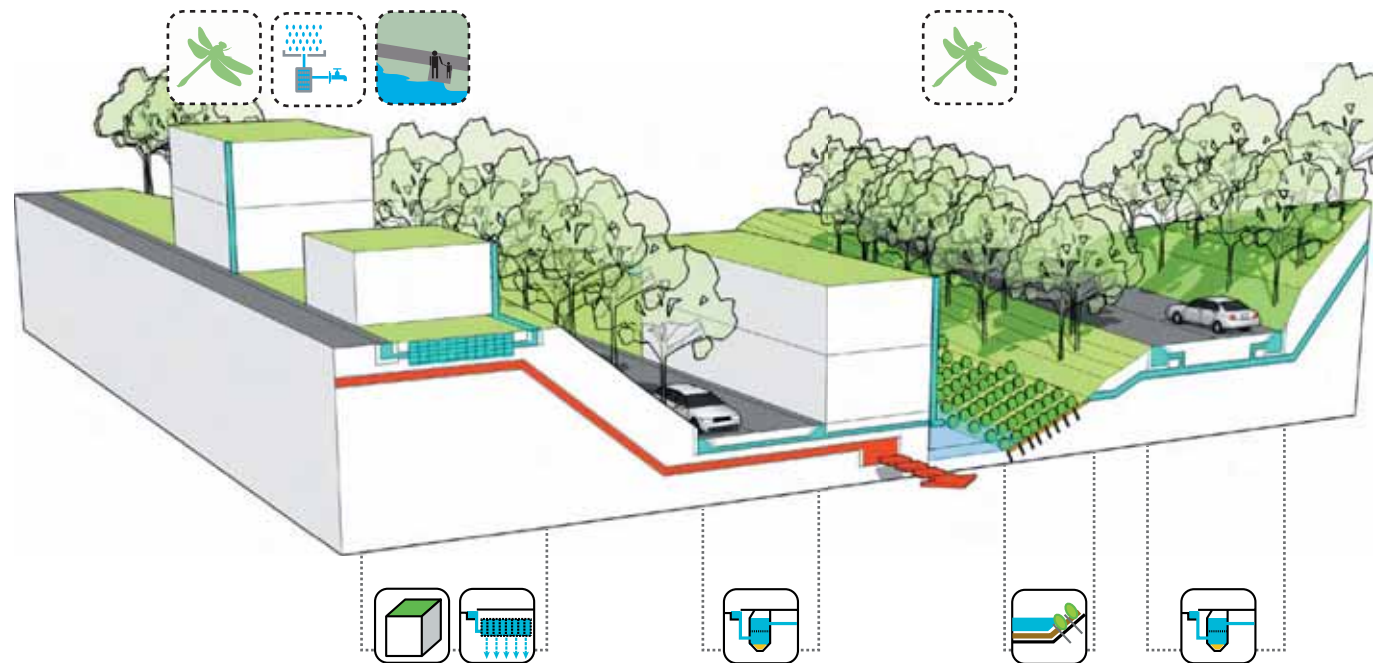
## Proposed Treatment





# Possible Scenario

- |   |                     |   |                              |
|---|---------------------|---|------------------------------|
|  | Open Canal          |  | Filter Manhole               |
|  | Vegetated Swale     |  | Underground Substrate Filter |
|  | Sedimentation Basin |  | Cistern                      |
|  | Bioretention Swale  |  | Bioengineering               |
|  | Green Roof          |   |                              |











## Introduction

In this section we will show an integrated solution of stormwater treatment tools with a decentralized stormwater treatment system to solve the area's stormwater predicaments.

The installed treatment tools are designed into an urban public park.

This is an urban public park which weaves people and nature together and teaches principles of sustainability.

The various property owners, as well as the people of Pittsburgh and the river itself, will all benefit.







## Analysis

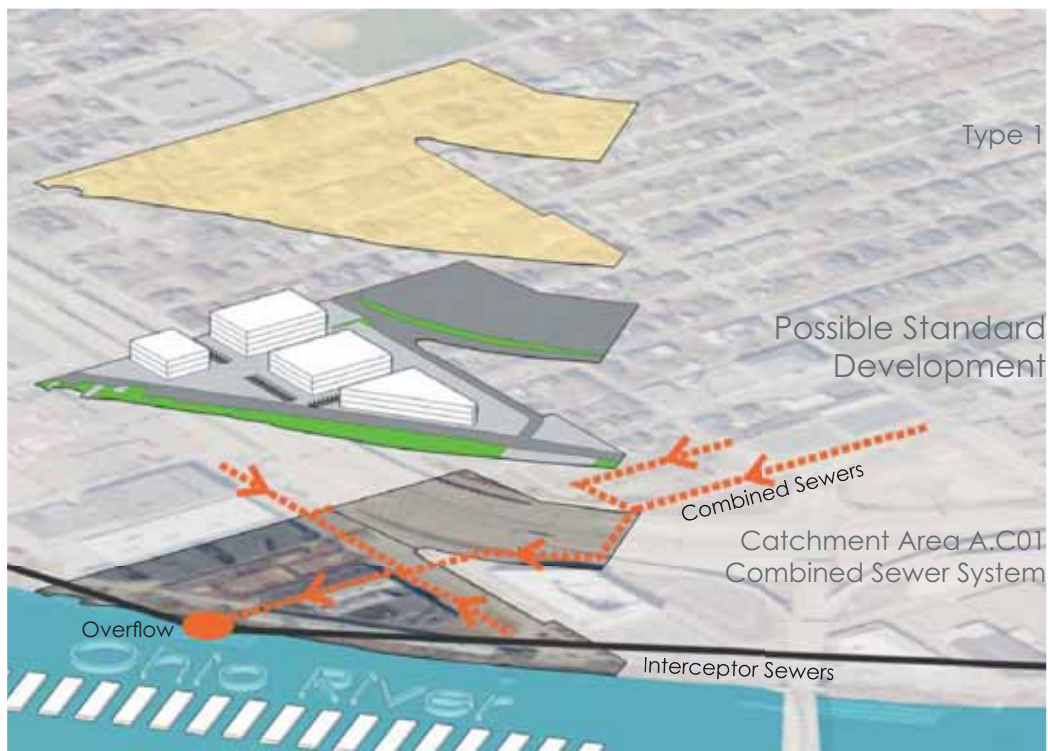
Catchment Area A.C.01, north of the Ohio River between North Ave, Chateau St. and Kroll Dr., was chosen because it shows general problems which are symptomatic of this project area. These problems include the sewage system, traffic dominating the surrounding area, high impermeable surface rate, and a high value of waterfront space for recreation use.

Analysis of the sewage system and its possible future development is illustrated in this section. To demonstrate the difference between standard development and sustainable development visual, a stormwater calculation with various levels and sustainable development with bioretention swales are shown. Later a scenario of sustainable development integrated into landscape design is proposed.

Already existant in this area is a combined sewage system which collects stormwater runoff and sanitary sewage in one pipe. The pipe is connected to an interceptor pipe, transporting sewage to the treatment plant. There is also a combined sewage overflow, diverting runoff and sewage into the river during very wet weather.

In its future development, this area could be planned as a commercial area with shopping malls, restaurants etc., capable of having high water demand.

According to our forecast, this area has the same situation of type 1 (See page 32-34).



Section VI. Sample Project Area A.C.01



## Catchment Area - A.C01

### Dimension

487,200 ft<sup>2</sup>

Impermeable Surface: 88 %

### Water balance

92 % discharge

3 % infiltration

5 % evaporation

**Outflow quality into river**  
Untreated without detention.



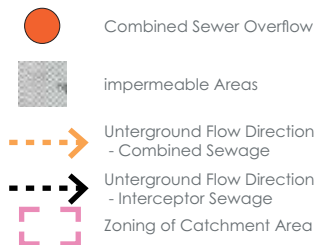
## Storm Water Calculation - Standard Development

Standard Development provides a high degree of hard covered surfaces with less maintenance effort for green areas.

The stormwater runoff will be directed to the river without any treatment and on the shortest way in pipes, non visible.

The new system will be a separate sewer system, but because of connection to the combined sewer system, the combined wastewater from the upper catchment flows without treatment into the river too.

The calculation of standard development of the catchment area A.C01 shows that the impermeable surface rate is nearly 90%. Because of continuation of using a combined sewage system, the combined wastewater flows without detention into the river through the overflow during the wet weather.





## Catchment Area - A.C01

### Dimension

481,800 ft<sup>2</sup>

Impermeable Surface: 77 %

Detention area: 38,410 ft<sup>2</sup>

Watermark (max.): 0.90 ft

Frequency n : 2 years

Detention Volume max.:  
34,478 ft<sup>3</sup>

### Water balance

70 % discharge

0 % infiltration

30 % evaporation

16 pieces of Filter Manhole  
(10,765 ft<sup>2</sup>/piece)

### Water Quality

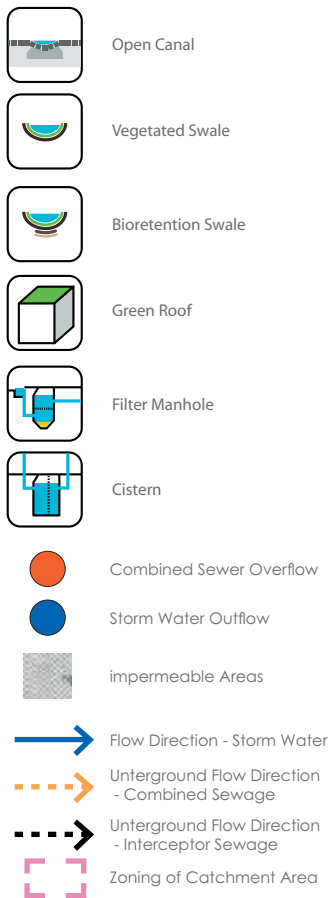
Reduced outflow/flowrate

70 % reduced of pollutant  
(heavy metals, sediments, floatable trash, organics)





## Storm Water Calculation - Sustainable Development



Sustainable development of the catchment area is constructed with a completely separated stormwater system to clean, detain, and use the water for landscape and household purposes.

Because of the highway's impervious surface and little to no green drainage areas, the stormwater from streets can be treated with filtered manholes. Sixteen filtered manholes are needed. The connected manholes then pipe cleaned stormwater into the river.

The streets, promenade, and parking lots with usable areas will have vegetated swales installed to remove sediments and convey storm water. The water is then collected in different bioretention swales, which lay along the riverbank of Ohio River.

Building roofs will be planted with vegetation. This will reduce the stormwater runoff and

keep temperatures down. The roof runoff is in cisterns, which store the stormwater for different uses, toilet flushing, irrigation, climatization and as landscape water. Overflows from the cistern are connected to the stormwater pipes.

Seventy percent of stormwater in this catchment area will be treated.

Our calculations show that through sustainable design the impermeable surface is reduced from 88% to 77%. The installed bioretention swales helps to store the stormwater with a return period of two years.



## Possible Scenario - Sustainable Development

The vegetated swales also work as a guide to break through the embankment and lead people to bioretention swales at the waterfront.

The bioretention swales can be designed into interesting recreation areas for people, offer a lesson in sustainable solutions for stormwater as well as a place to observe nature in the city.

Through purification of stormwater, the bioretention swales provide a nature-like habitat for local fauna and flora.

In its entirety, this sustainable development revitalizes valuable areas and connects people to the nature in an authentic way.





This master plan document contains stormwater guidelines specially tailored for the Ohio River Basin in the City of Pittsburgh. Based on a light screening of city codes and state regulations as well as years of storm water planning experience the design concepts in this document are ready for implementation.

The next step in the process should involve a wider public audience to give hope and realistic goals for sustainable development for a livable environment.

The consequent and creative public outreach should not only be limited to newsletters, a website or presentations. The flow of information should also include advanced training to the architects and engineers as well as for the public administration.

It was a good starting point to create a round table with the stakeholders of the riverfront. This will help to get the actors on board.

Construction and renovations should integrate the preschematic ideas to create a showcase for sustainable redevelopment. Quick steps should be undertaken for the north riverfront.

Possible Next Steps:

- Create a „Three River Demonstration“ project, apply for a federal program
- Lift the project up to the Government Level like an ecorestauration project
- Organize River Festival – Celebrate the river and launch the “Ohio Basin”
- Address the public's desire for a healthy, safety, and a friendly environment,
- Promote further educational events (congress, advanced training ...)
- City agencies start to change regulations along rivers
- Launch the idea of a sustainable spine with the first platinum rated bldg. at the river

The power of an active community will find solutions with the most synergetic power – we are sure. Let's go!







## Primary Functions of Stormwater Management System



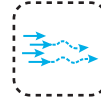
### **INFILTRATION:**

Infiltration, as a basic term, is the process by which water seeps into the ground. It is important to maintain a balanced level of infiltration. On the one hand, infiltration recharges groundwaters and aquifers. On the other hand, the higher the infiltration level, the lower the amount of runoff and water that can be collected. Infiltration has the added benefit of purification because water is progressively cleansed as it percolates through layers of sand. In many countries, water pumped from the ground is clean enough to be potable.



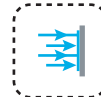
### **PURIFICATION:**

The process of purifying water can best be understood by categorizing the pollutants into various categories. These include (list of pollutants here). Each of these categories requires a different set of treatments, which is here simplified into screening, sedimentation, adhesion & filtration, biological uptake and chemical treatment.



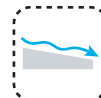
### **DETENTION:**

The regulation of rainfall discharge is necessary for easing the stresses on the downstream stormwater management system. One way of achieving it is by storing it temporarily in an on-site facility and releasing it intermittently later. The flow of water can also be slowed down through a variety of methods, such as draining it through vegetation, increasing the roughness and area or decreasing the gradient of the runoff surface, etc.



### **RETENTION:**

Water is retained permanently (in a cistern, basin or wetland) either for later use or until it is dissipated through plant absorption, evaporation or percolation into the ground.



### **CONVEYANCE:**

Conveyance, specifically to stormwater management, refers to the measure by which runoff water is transported and directed from the point of initial rainfall to final discharge. This is necessary to ensure that water is brought along the right channels to ensure minimum contamination and maximize effective runoff.

## Treatment Tools

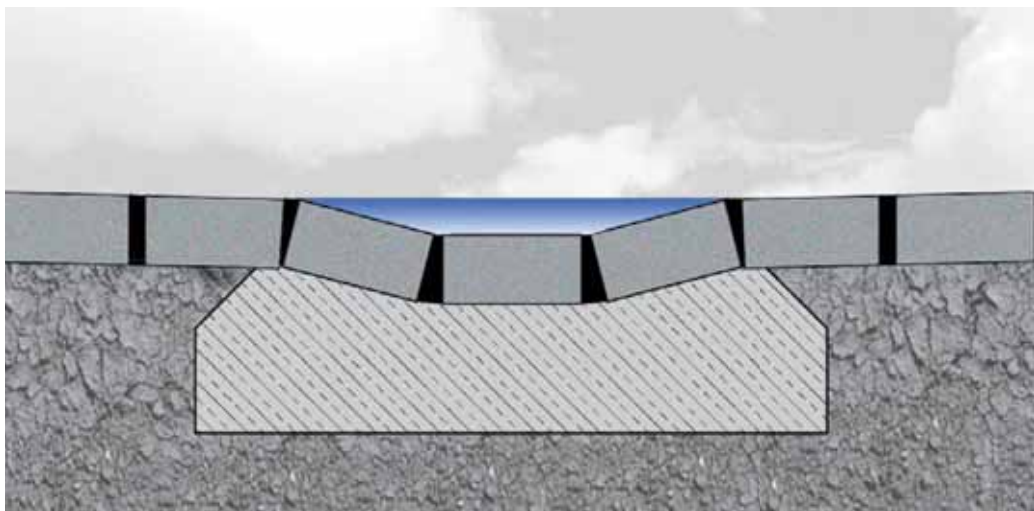


### OPEN CANAL:

Open Canals are used for surface stormwater drainage on roads and parking lots. There are different options for the placement of an open canal within the road section - on the sides, in the centre, or halfway between. Open Canals offer many advantages:

- visibility of the stormwater system, integrating roof runoff
- allow water to run into open surface stormwater treatment facilities
- easy maintenance, integrated in road cleaning
- offers aesthetic design options for the streetscape

The longitudinal and cross slope of road has to be modulated as a whole gradient design. The hydraulic capacity is limited due to its depth. Open canals need to be as shallow possible while meeting capacity requirements for convenient crossing by pedestrians or cyclists.



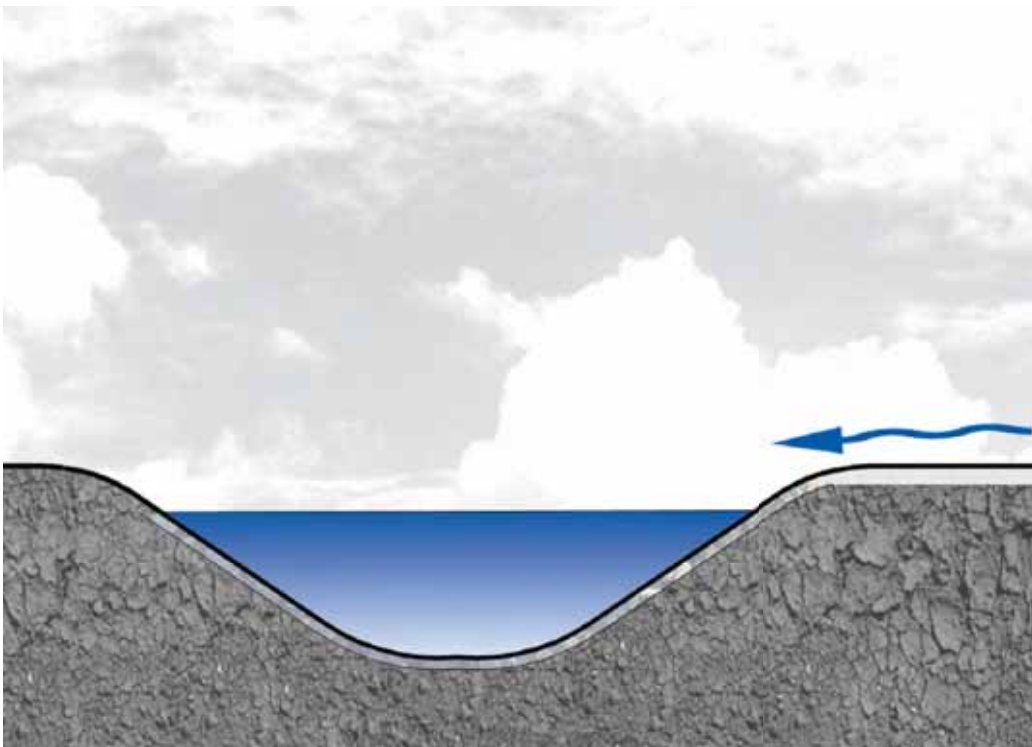
Pagana, Murten, Switzerland





### VEGETATED SWALES:

Vegetated swales are used to remove soil particles (sediments) and convey stormwater in lieu of or with underground pipe drainage systems. They can be used in combination with buffer strips and bioretention systems. Swales utilize overland flow and mild slopes to convey water slowly downstream. They protect waterways from damage by erosive flows from frequent storm events because swale flow velocities are slower than piped systems.



Kronsberg, Hannover, Germany



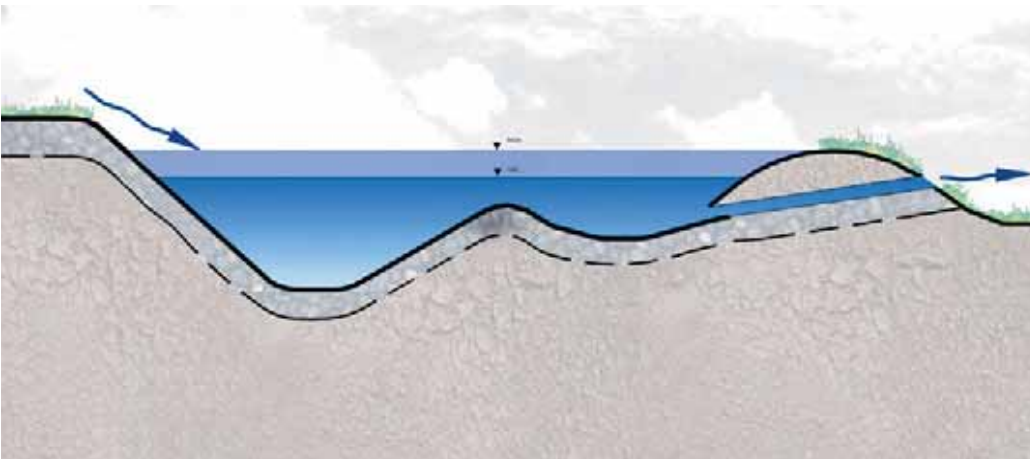


## Treatment Tools



### SEDIMENTATION BASIN:

One of important ways to improve stormwater quality is to reduce sediment loads. Sedimentation basins are used to remove (by settling) coarse to medium-sized sediments from the water column. Sedimentation basins can take various forms and can be used as permanent systems integrated into an urban design or temporary measures to control sediment discharge during construction. By providing temporary detention and reducing flow velocities, sedimentation basins promote settling of particles. They are designed to capture 70 to 90 percent of sediment above a target size (typically  $125\mu\text{m}$ ), whilst ensuring that the clean out frequency is consistent with the maintenance regime (typically annually to once every 3 years).



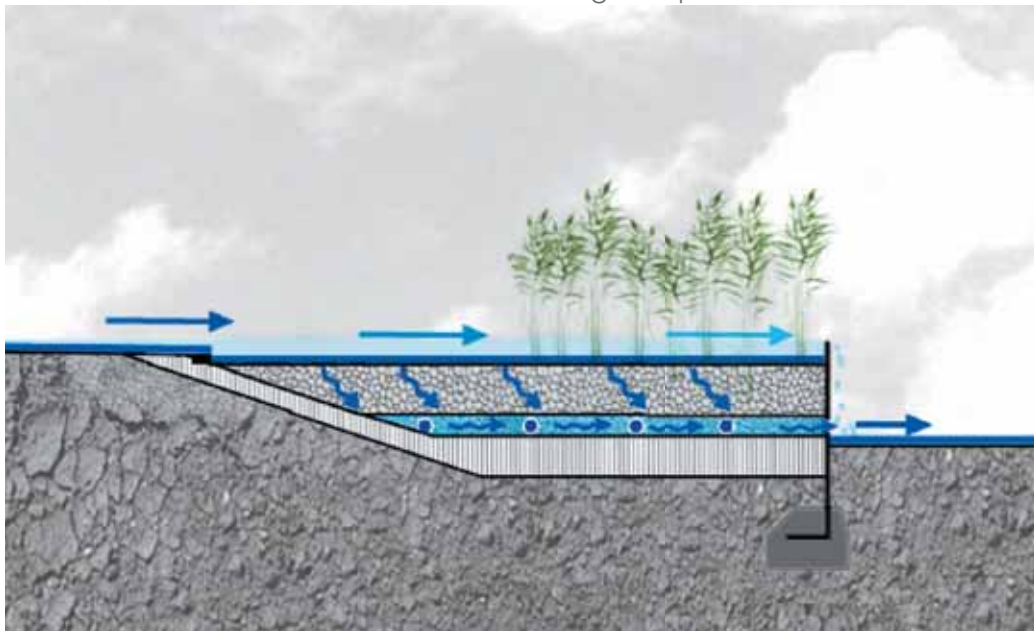
Sedimentation Basin, Solingen, Germany





## BIORETENTION SWALE:

Bioretention swales are retention or detention basins with a vegetated surface. There are different possibilities for construction as a plane or drawn out trenches or cascades. The swale consists on different construction elements to direct the inflow of stormwater, for the cleansing and drainage, to reduce the outlet and for emergency overflow. Runoff is cleansed as it percolates downwards. When the infiltration rate of the existing subsoil is not sufficient the water is collected by a drainage system (e.g. gravel, perforated pipes or geotextile) and conveyed to downstream waterways. A special build-up layer structure (subsoil drainage + storage + filter substrate) provides efficient treatment of storm water through fine filtration, extended detention and some biological uptake.



Reduced Outlet (Orifice) from Bioretention Swales



Kronsberg, Hannover, Germany



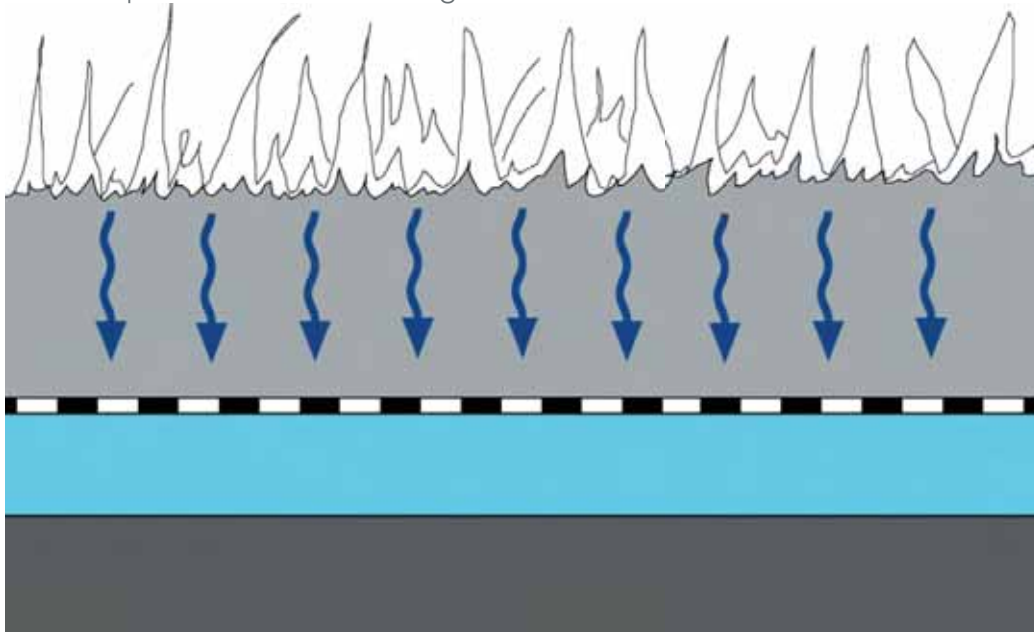
## Treatment Tools



### GREEN ROOFS:

A green roof is a roof that is planted partially or completely with vegetation and soil over a waterproofing membrane. Green roofs can be categorized from extensive (5-15cm) up to intensive (25-100cm), depending on the depth of planting medium and the amount of maintenance they need. Usually it includes additional layers such as substrates, drainage layer and root barrier.

Green roofs will reduce stormwater run off significantly, will keep temperatures down, particularly in urban areas and will also reduce heat loss and energy consumption in winter conditions. Ecological benefits, such as cooling the air and the production of oxygen. They help to regulate the moisture in the air, absorb dust and promote rainwater storage.



Scharnhäuser Park Ostfildern, Germany







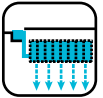
### **FILTER MANHOLE:**

Remove Pollutant and Sediments:

- suspended solids
- heavy metals
- nutrients (nitrogen and phosphorus)
- Organics (oil, grease, hydrocarbons, pesticides, fertilizer)
- floatable trash and debris

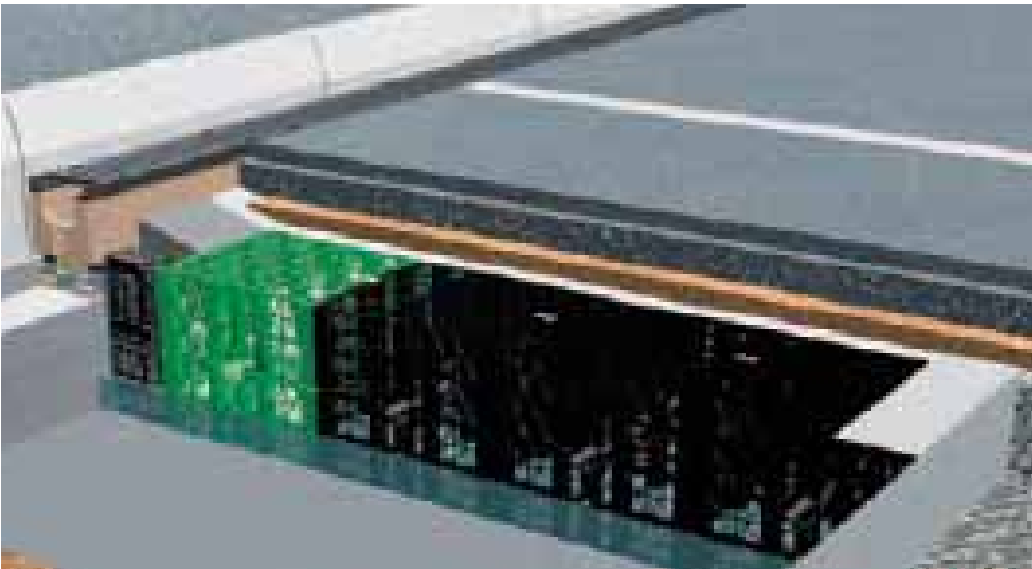
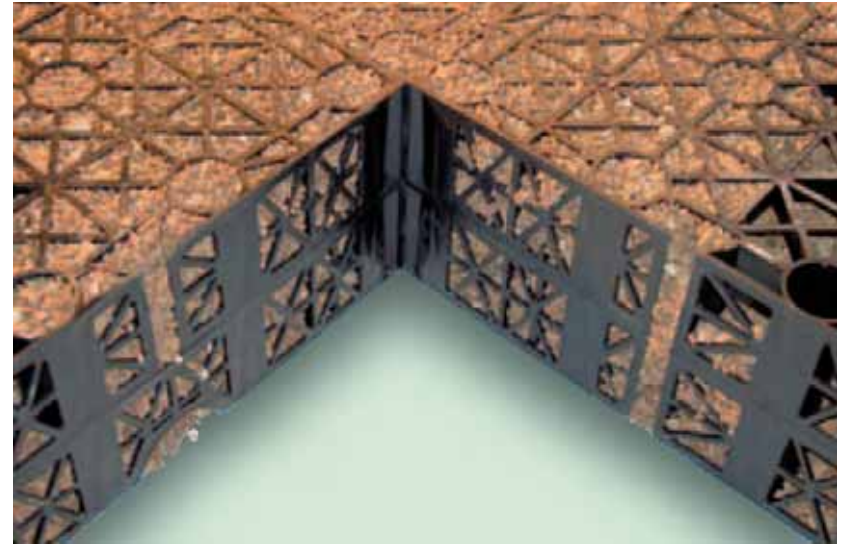


## Treatment Tools



### UNDERGROUND SUBSTRATE FILTER:

Underground substrate filter consists of a box with a grid structure to give a maximum static stability which is filled with mineral aggregate free of compression. The bio-filtrating aggregate facilitates the treatment of organic pollution by biotic and abiotic sorption, precipitation and complexation. There are several precast products that offer a complete System of grid boxes and aggregates.

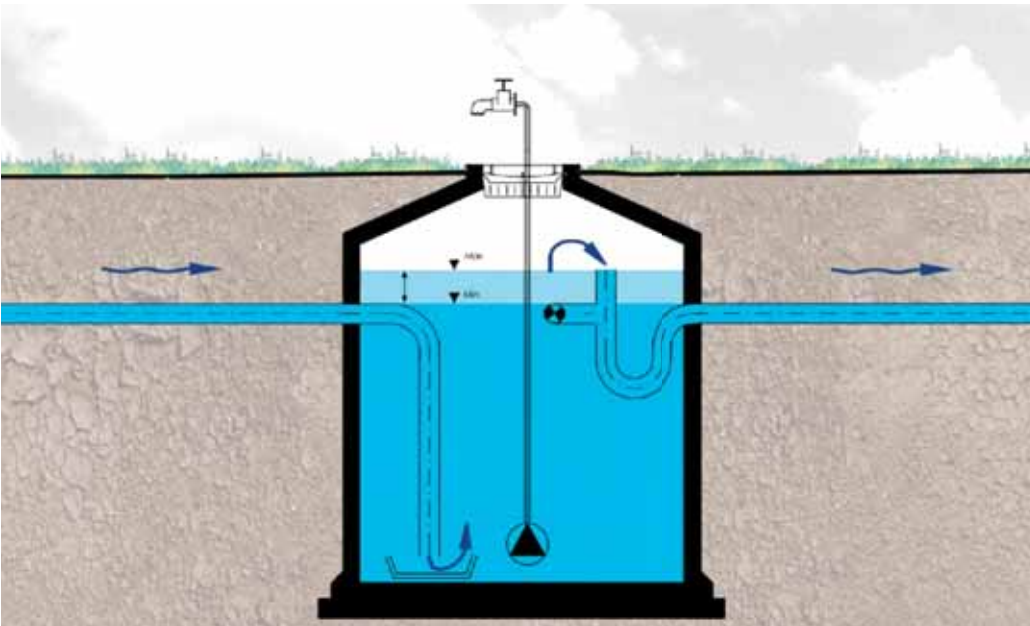




## CISTERN:

Cistern function mainly as rainwater storage and secondly for stormwater detention. The basic storage volume depends on the demand of rainwater use for toilet flush, irrigation, climatization or water features. To optimize the storage volume it is recommended to do a longterm simulation.

The detention volume has to be topped up, when the rainwater storage will be full. With a reduced outflow valve or pump the detention buffer will be emptied after each storm event. Besides an emergency overflow is demanded. The reduced outflow and the overflow must be pumped into the public stormwater system.



Competence Center DaimlerChrysler Sindelfingen, Germany



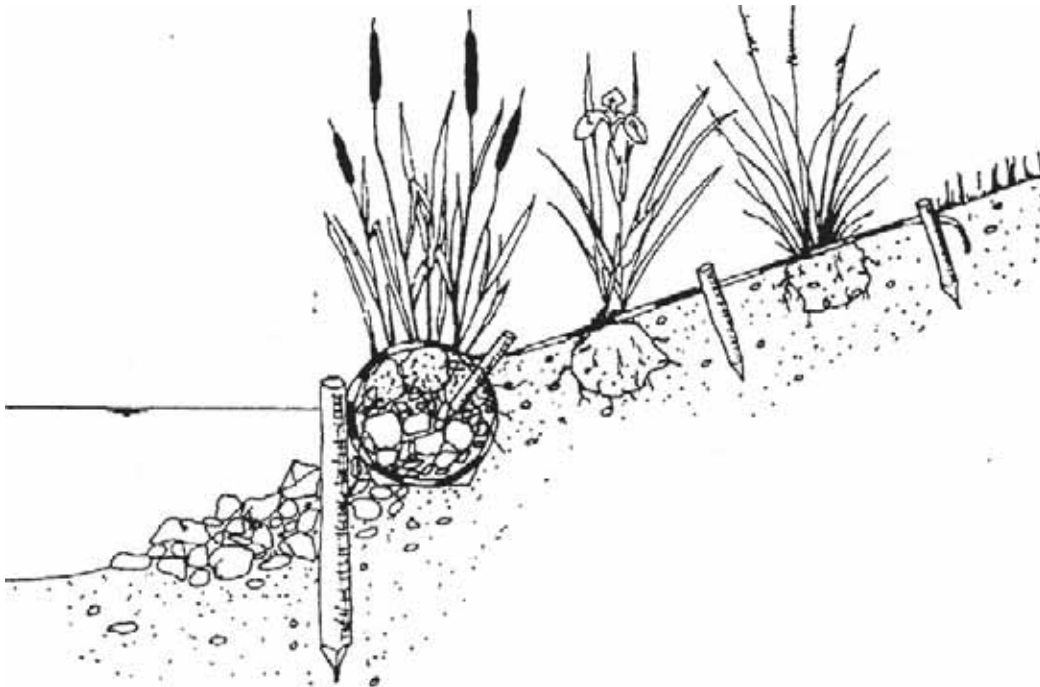


## Treatment Tools



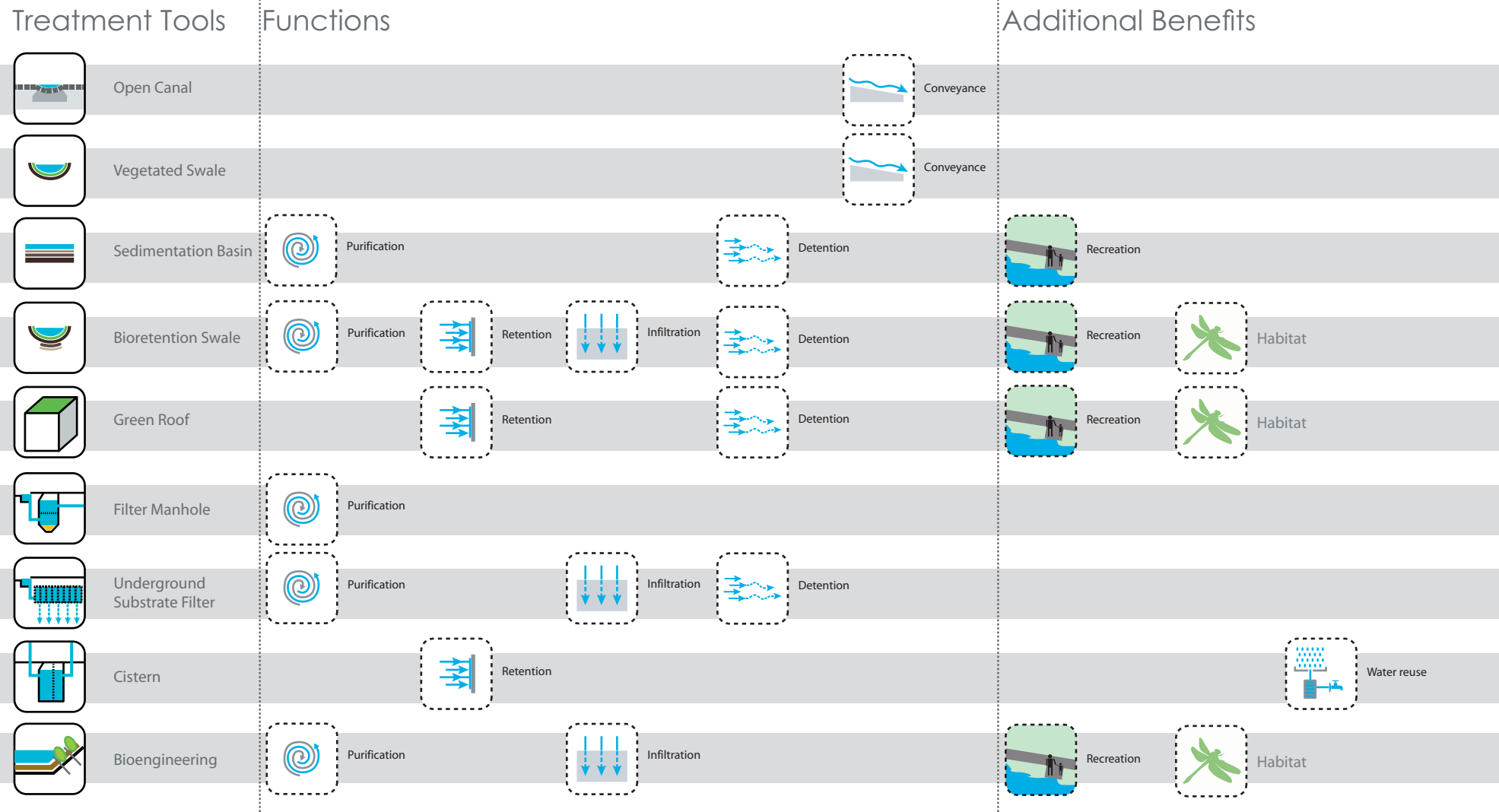
### BIOENGINEERING:

Bioengineering seeks to harness the inherent qualities and capabilities of organic matter (plants, seeds, branches, roots etc.) for the purpose of structural integrity, be it in a natural environment (such as stabilizing a river embankment) or a constructed space (retaining walls supporting roads and buildings). Bioengineering aspires to come as close as possible to nature not only in the use of materials but also in the methods of construction. Bioengineering techniques can be employed to replace traditional civil engineering applications, but more often than not, they are used in combination as a complement to each other.



Bishan Park, Singapore

## Treatment Tools Functions and additional Benefits



Infiltration systems can be considered 100 percent effective at removing pollutants in the fraction of water that is infiltrated, since the pollutants found in this volume are not discharged directly to surface waters.

Table 4-1. Median Event Mean Concentrations for Urban Land Uses

Pollutant	Units	Residential		Mixed		Commercial		Open/ Non-Urban	
		Median	COV	Median	COV	Median	COV	Median	COV
BOD	mg/l	10	0.41	7.8	0.52	9.3	0.31	--	--
COD	mg/l	73	0.55	65	0.58	57	0.39	40	0.78
TSS	mg/l	101	0.96	67	1.14	69	0.85	70	2.92
Total Lead	µg/l	144	0.75	114	1.35	104	0.68	30	1.52
Total Copper	µg/l	33	0.99	27	1.32	29	0.81	--	--
Total Zinc	µg/l	135	0.84	154	0.78	226	1.07	195	0.66
Total Kjeldahl Nitrogen	µg/l	1900	0.73	1288	0.50	1179	0.43	965	1.00
Nitrate + Nitrite	µg/l	736	0.83	558	0.67	572	0.48	543	0.91
Total Phosphorus	µg/l	383	0.69	263	0.75	201	0.67	121	1.66

Table 4-4. Comparison of Water Quality Parameters in Urban Runoff with Domestic Wastewater (mg/l)

Constituent	Urban Runoff		Domestic Wastewater		
	Separate Sewers		Before Treatment		After Secondary
	Range	Typical	Range	Typical	Typical
COD	200-275	75	250-1,000	500	80
TSS	20-2,890	150	100-350	200	20
Total P	0.02-4.30	0.36	4-15	8	2
Total N	0.4-20.0	2	20-85	40	30
Lead	0.01-1.20	0.18	0.02-0.94	0.10	0.05
Copper	0.01-0.40	0.05	0.03-1.19	0.22	0.03
Zinc	0.01-2.90	0.02	0.02-7.68	0.28	0.08
Fecal Coliform per 100 ml	400-50,000		10 <sup>6</sup> -10 <sup>8</sup>		200

Source: Bastian, 1997

A comparison of the concentration of water quality parameters in urban runoff with the concentrations in domestic wastewater is shown in Table 4-4.

Table 4-3. Typical Pollutant Loadings from Runoff by Urban Land Use (lbs/acre-yr)

Land Use	TSS	TP	TKN	NH <sub>3</sub> -N	NO <sub>3</sub> +NO <sub>2</sub> -N	BOD	COD	Pb	Zn	Cu
Commercial	1000	1.5	6.7	1.9	3.1	62	420	2.7	2.1	0.4
Parking Lot	400	0.7	5.1	2	2.9	47	270	0.8	0.8	0.04
HDR	420	1	4.2	0.8	2	27	170	0.8	0.7	0.03
MDR	190	0.5	2.5	0.5	1.4	13	72	0.2	0.2	0.14
LDR	10	0.04	0.03	0.02	0.1	NA	NA	0.01	0.04	0.01
Freeway	880	0.9	7.9	1.5	4.2	NA	NA	4.5	2.1	0.37
Industrial	860	1.3	3.8	0.2	1.3	NA	NA	2.4	7.3	0.5
Park	3	0.03	1.5	NA	0.3	NA	2	0	NA	NA
Construction	6000	80	NA	NA	NA	NA	NA	NA	NA	NA

HDR: High Density Residential, MDR: Medium Density Residential, LDR: Low Density Residential  
NA: Not available; insufficient data to characterize loadings  
Source: Horner et al, 1994

The concentrations of pollutants found in urban runoff are directly related to degree of development within the watershed. This trend is shown in Table 4-3, a compilation of typical pollutant loadings from different urban land uses.

Table 5-7. Structural BMP Expected Pollutant Removal Efficiency

BMP Type	Typical Pollutant Removal (percent)				
	Suspended Solids	Nitrogen	Phosphorus	Pathogens	Metals
Dry Detention Basins	30 - 65	15 - 45	15 - 45	< 30	15 - 45
Retention Basins	50 - 80	30 - 65	30 - 65	< 30	50 - 80
Constructed Wetlands	50 - 80	< 30	15 - 45	< 30	50 - 80
Infiltration Basins	50 - 80	50 - 80	50 - 80	65 - 100	50 - 80
Infiltration Trenches/ Dry Wells	50 - 80	50 - 80	15 - 45	65 - 100	50 - 80
Porous Pavement	65 - 100	65 - 100	30 - 65	65 - 100	65 - 100
Grassed Swales	30 - 65	15 - 45	15 - 45	< 30	15 - 45
Vegetated Filter Strips	50 - 80	50 - 80	50 - 80	< 30	30 - 65
Surface Sand Filters	50 - 80	< 30	50 - 80	< 30	50 - 80
Other Media Filters	65 - 100	15 - 45	< 30	< 30	50 - 80

Source: Adapted from US EPA, 1993c.

Table 5-7 presents expected pollutant removal efficiencies for various BMP types (US EPA, 1993c). The values found in this table give an indication of the expected overall pollutant removal efficiency for a properly sited, designed, sized, constructed and maintained BMP.





## Levels of Storm Water Runoff Pollution

Before storm water falls on the surface, it is nearly unpolluted. After landing, it flows and takes in materials in both dissolved and undissolved forms from the surfaces on its flow path to the river or groundwater.

According to the different kind of dissolved and undissolved materials, the stormwater will be polluted differently. The chart below shows the levels of storm water runoff pollution from different runoff areas. It also shows whether it should be treated or not.

Levels of Storm Water Runoff Pollution		Runoff Areas
environmentally inoffensive		Roofs, excepting uncoated metal roofs(Lead, Copper and Zinc); Bicycle-, Foot Path, Streets
tolerable after Treatment Tools		Roofs with uncoated metal. Roofs in commercial- and industry area with significant air pollution
tolerable after Treatment Tools		Court areas, automobile parking lots
tolerable after Treatment Tools		Airport
tolerable after Wastewater Treatment Plant		Court Areas and Streets in commercial and industry Areas with significant Air Pollution
tolerable after Wastewater Treatment Plant		Special areas, e.g. Parking Lots for trucks, Gas Stations









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