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Abstract

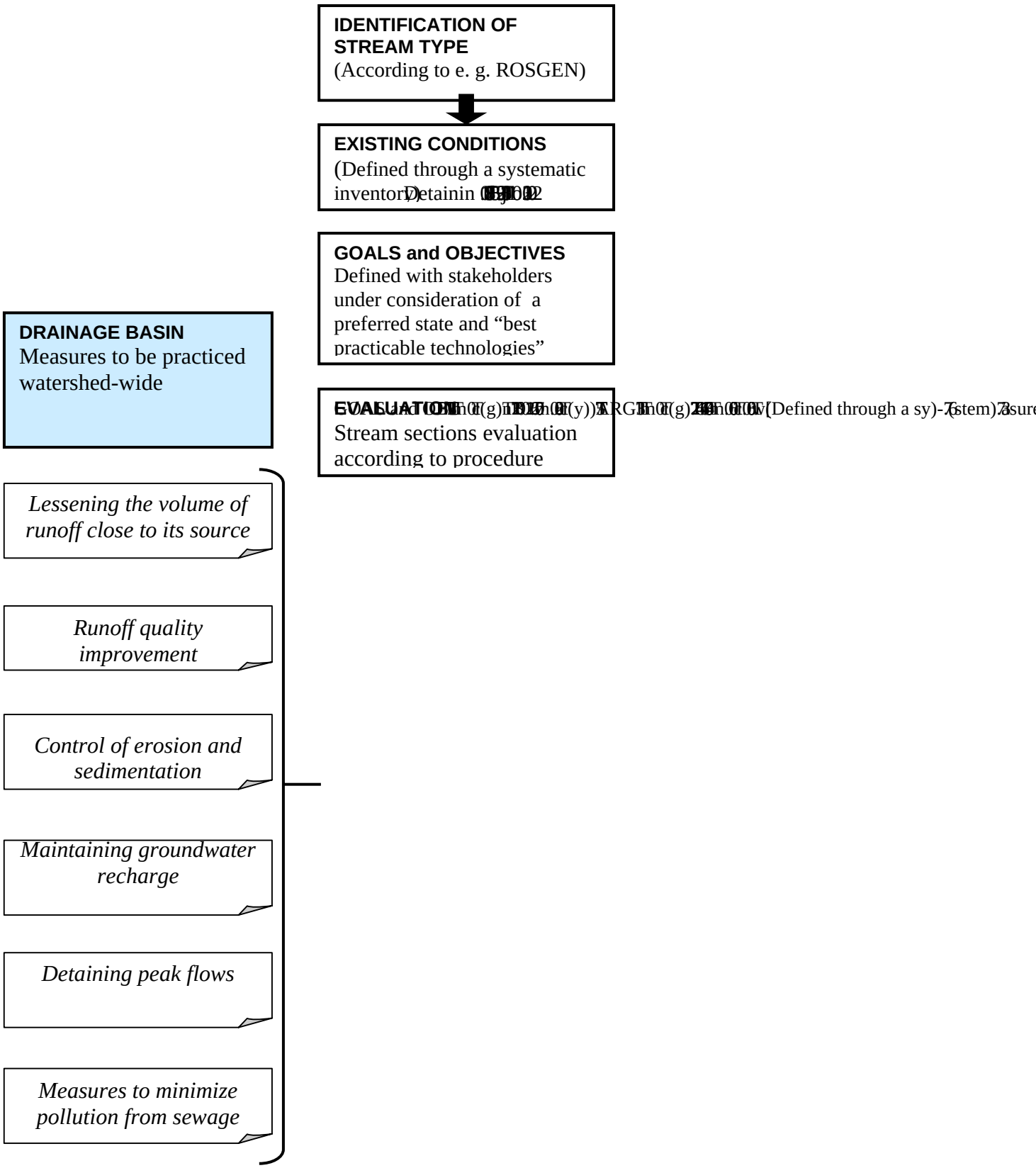
This manual consist of selected technical measures for urban stream rehabilitation measures, which can be become a component of urban river enhancement projects, dealing with river channels, banks as well riparian areas. Techniques presented can be integrated into urban settings to prevent or reduce problems affecting water resources. Techniques presented here improve the hydro-morphological condition of rivers and the runoff that drains into them. Urban runoff control, also called “sustainable urban drainage” is being seen as a component of urban river basin enhancement. Techniques are divided into groups related to certain aspects, such as control of the amount and quality of runoff, or channel rehabilitation. Fact sheets contain construction guidelines, maintenance aspects, advantages, disadvantages, an illustration sketch, photos and references and suggested reading.For each technique individually covered are description, application, advantages and disadvantages, maintenance. They are designed to provide an overview for professionals, decision makers, non-governmental organizations and the general public.

1 Planning Procedures for re-naturalizing flow regimes

The Implementation of the EU Water Framework Directive (WFD) is expected to improve water quality and the ecologic conditions of rivers within Europe. As a result, rivers with improved water quality will flow through cities increasing the attractiveness of waterfront property for public uses, aid real estate development, and in turn help to shape the city of tomorrow. Cities that have classified their rivers as “heavily modified waterbodies” need to meet provisions of the WFD and achieve a “good ecological potential” for their urban rivers. The “Excisting Case Studies” work package of URBEM shows how selected cities in Europe and abroad have achieved good ecological conditions by combining water resources management and city planning, hence improving the quality of life. These examples may achieve the status of “best practicable technology” to guide cities how to achieve good ecological potential.

URBEM teams conducting case studies learned that the regeneration and re-naturalization of flow regimes takes much more than the mere installation of measures. Many of the successful installations in Toronto, Canada, Washington DC and in Europe presented in case studies were found to be the result of a planning process that was started more than 10 years ago and was aided by planning procedures such as those for “Natural Channel Systems: An Approach to Management and Design“ issued by the State

Figure 1 - Procedure chart for renaturalizing flow regimes



1.6 Selection of measures

All the previous steps are required to be taken before a first selection of potential

2.1 Measures to lessen the volume of runoff close to its source

On natural terrain 40% of precipitation avapotranspirates and up to 50% infiltrates. In urban areas similar results can be achieved through vegetated roof covers and through surfaces that infiltrate runoff. Both can be retro-fitted to existing roofs and parking lots. Measures are as follows

Porous Paving Modular

Modular pavers can be made of either concrete blocks and brick, or plastic grids. They provide a surface of up to 75% permeable gravel or soil and thus allow water to gradually infiltrate. Below the filter course or bedding layer, a choker course is installed.

Porous Paving Asphalt

A permeable paving system that consists of a top course of an aggregate mix of bituminous asphalt paving material. In the asphalt openings are created by exclusion of fines in the mix. Underneath is a gravel layer that acts as a temporary reservoir, permitting the slow-rate percolation of rainwater into the soil.

Vegetated Roof Covers

Here a veneer of living vegetation is installed on top of a conventional flat or sloping roof. Depth of the growing medium layer determines the choice of

Grassed Swales

Grassed swales are linear areas of grass, generally designed to convey runoff from one location to another. The main purpose of the swale, in addition to conveyance, is to trap suspended solids.

Constructed Wetlands

These facilities treat runoff by utilizing the water-quality enhancement processes of sedimentation, filtration, adsorption, extended retention, as well as biological processes. Control of an adequate water level is essential.

Bio Retention

A bioretention system is a multifunctional landscaped area that provides for the retention of a design storm and for water-quality improvement. They contain a soil aggregate of 3 feet depth and are drained underneath by a layer of crushed stone with an optional drain pipe. The surface is vegetated and improves water quality through infiltration and evapo-transpiration. They also offer owners site enhancement benefits.

2.3 Measures to control erosion and sedimentation

Sheet erosion and streambank erosion are sources of sedimentation and a form of water pollution. Sediments abrade and coat aquatic organisms and clog the gills of fish and aquatic invertebrates, By the sediment blanketing the stream bottom, it is reducing the juvenile fish survival rate, impairing fish spawning grounds, and inhibiting photosynthesis of aquatic vegetation and its oxygen production. Furthermore, pollutants tend to cling to sediments and their deposits and re-suspension in urban drainage ways during flood events are a severe problem. Wherever a soil cover is removed steps need to be taken to control erosion.

Management of Construction Sites and Traffic

Minimizing erosion during construction activities results in the reduction of one of the major sources of sediments. It not only results in faster reestablishment of vegetation, but also in an enhanced appearance. On all the sites susceptible to erosion attention should be paid to the layout of construction roads.

Temporary Runoff Diversions and Chutes

Temporary flow diversion structures (such as gutters, drains, dikes, berms, swales, and graded pavement) are used to collect and divert stormwater to prevent the contamination of runoff and receiving water. Stormwater that is potentially contaminated can be directed to a treatment facility.

Silt Fence and Trap Devices

Silt fences are temporary structures used to prevent or minimize transport of sediment in stormwater runoff that is leaving a construction site. They consist of a linear filter barrier constructed of synthetic filter fabric (geo-fabric), posts, and depending upon the strength of the fabric used, wire fencing for support.

Sediment Basins

A sediment basin is formed by a barrier across a drainage way, forming an impoundment that functions as a sediment basin. The size of the basin is calculated to store expected sediment yields of disturbed sites. Once a site is stabilized the basin may be put to another use.

Hydroseeding and Chemical Stabilization

Hydroseeders are truck-mounted and enable the forced application of a slurry of seed, water, fertilizer, soil conditioner and a fiber mulch. Steep areas, and areas of vast scale, may be seeded and fertilized economically in just one operation. Chemical soil stabilizers may also be added to the slurry to help prevent seed loss and erosion during germination.

Cover Crops, Temporary Mulches

This measure is used to protect temporarily disturbed areas from erosion with a quick growing annual crop and/or mulch. Cover crops may be used to improve soil conditions for permanent crop by discing residue of cover crop into the soil. Temporary mulches of shredded straw may be applied through a power blower.

2.4 Measures to maintain groundwater recharge

Over 80 percent of the dry weather base flow of streams comes from groundwater. In urban areas impervious cover is reducing groundwater recharge. This particularly affects small tributary streams where severe conditions are encountered during low flow periods in the summer. Some streams fall dry at times and others have a reduced permanent flow

has been widely accepted as a means of guarding against increased peak rates of discharge and prolonged flooding. Detention facilities temporarily hold water and provide for a delayed discharge.

Dry Pond Detention Basins

These basins consist of a dry depression in the ground designed to temporarily detain and slowly release stormwater runoff at a predetermined rate. Shallow basins can be maintained with a cover of grass and may permit multiple uses.

Wet Pond Detention Basins

A permanent pool of water is the distinct characteristic of a wet detention basin. It provides the multi-purpose benefits of wildlife and recreation. Water quality should be maintained and the pool should be integrated into urban uses through carefull design.

2.6 Measures to minimize pollution from sewage

Combined sewers that carry both sanitary sewage and stormwater runoff during rainfall events service most of our cities. Most sewage treatment plants have been sized to treat only dry weather flows of sewage. During storm events the combined sewer overflow (CSO's) lighten the load on treatment plants by discharging untreated sewage into local streams. Most CSO's are located in heavily populated urban centers and are universily considered to be an urban problem. The concept of CSO's is that stormwater was expected to dilute the sanitary flow, but was then found to have a considerable pollution load of its own. Effective measures described here are source control and off-line storage.

Combined Sewer Source Control

Source control reduces the quantity of pollutants entering the system. This

measures that use a combination of living plant material and mechanical means to achieve specific engineering functions (Schiechtl 1994). As an ancient technique soil-bioengineering was revived and further developed in Austria and Germany and is now is also being advocated by government agencies in the US and Canada (USDA, 2003). On urban rivers soil-bioengineering is highly suited for reconstruction, stabilization,

Fibre Rolls and Reed Rolls

Cylindrical, earth filled coconut fiber rolls, approximately 6m in length and 30 cm in diameter. They are staked into place at the foot of the streambank. Rolls have a life expectancy of 6 to 10 years. Vegetation is planted behind rolls secures the streambank. Biologs of steel netting are filled with a mix of earth, gravel and reed rhizomes containing herbaceous plants that sprout through the netting and secure the bank with their roots.

Riprap and Vegetated Riprap

Rock rip-rap is a lining of stream banks with stone that dissipates the energy of flowing water and minimizes scouring problems. Live cuttings of at least 4 cm diameter are placed or inserted deep enough to reach groundwater to aid sprouting.

Live Cribwalls

Chambers of interlocking logs are filled with alternating layers of soil and live branches creating a nearly vertical wall with a slight incline. Live cribwalls are usually more than 2 m high. Construction starts with rock filled chambers below water level, and with logs secured with reinforcing bars. Cribwalls may be covered with vegetation in a single growing season.

Live Slope Gratings, Timber Framing

Similar to a cribwall, a live slope grating is a lattice-like arrangement of vertical and horizontal timbers laid to the surface of a steep slope. Openings in the structure are filled with backfill material and live branch cuttings are placed in a manner similar to brush layering. On the toe of the slope a trench of approximately 1 m depth is established to secure the grating against slippage.

Vegetated Rock Gabions

Gabions are rectangular wire baskets made of heavily galvanized or coated wire mesh. They are filled with small to medium sized rock and soil. Gabions are laced together to form terraces or a wall. Placing live branches between each layer of rock filled baskets incorporates vegetation.

Rootwad and Boulder Revetment

In deeper streams tree trunks can be buried into the streambank at a 90 degrees angle to the streamflow with their rootwads exposed underwater. The logs are weighed down with boulders 1.5 times the diameter of the trunk. Exposed roots slow the flow of water, trap sediments, and create in-stream habitat structure for fish spawning and rearing. Log rootwads and boulder revetments can be used as a secured foundation for further soil-bioengineering installations.

3.4 Stabilization of upper streambanks through surface protection measures

Water laws in most countries make it a point to define a stream to include riparian areas that are subject to frequent and periodic flooding. The floodplain may be divided into an open floodway of high velocity flows and to an adjacent flood fringe area subject to ponding. Flood events are usually measured according to their 2, 5, 10, 20, 50 and 100 year frequency of occurrence. Vegetation on the floodplain can be divided into the reed bank zone, the softwood zone and the hardwood zone. Vegetated floodplains play a vital role in stream hydromorphology, water quality, water temperature and aquatic life. It is essential that vegetation be established and maintained in these areas, using the following techniques.

Seeding Grass and Legumes

These measures are used on sites not susceptible to serious erosion. Seeding with a mixture of grass and legumes will give a quick, effective, and cheap soil protection. Sod may be used when a cover is required in a short period of time.

Live Stakes and Dormant Posts

Cuttings from living branches (4.5 cm diameter minimum) that are inserted into the ground will root and leaf out. They are an alternative to planting rooted stock.

Hedge Layers, Brush Layers, Hedgebrush Layers

When providing for a long-term plant community, brush layers of cuttings are combined with rooted nursery stock plants. A hedge brush layer stabilizes cuts and fills and can be used to protect steep slopes. Hedge layers, rooted nursery stock of hedge plants, are placed horizontally into cuts made on steep slopes with the ends

Lunker Structures

A crib wall of logs and rocks are embedded into the toe of the stream bank, creating a fore bay that extends over the water. Lunker structures combine toe streambank protection to curb bank erosion. They also serve as shelter to aquatic life.

3.6 Safety and flood damage control

Enhancement of urban rivers brings social responsibilities. It is the clean water in urban rivers that will attract people who would want to experience them. These beloved riverfronts have the aesthetic qualities of tranquillity, peace, a cooling effect as well as beauty. In turn through this demand, water also has an upgrading effect on real-estate value. Waterfront property has been reported to sell at a 50% higher price than units that are removed from the water, and units that have a water view but no frontage sell for 20 to 30 % higher, depending on proximity (Tourbier 1992). Cities have recognized this and are marketing abandoned harbours and related derelict industrial sites for waterfront development.

A problem that needs to be addressed though are public health and safety concerns, particularly flood damage. Continuous increases in paved surfaces have led to more frequent flooding events throughout Europe. Cities that improve the attractiveness of rivers also must assume a responsibility not to place people in harms way. At the least, authorities must be held accountable for arranging the flood proofing of sewer lines, oil-tanks and below ground garages as well as organizing adequate emergency access and flood warning systems for residents. This requires mapping the extent of an “open floodway district” and “flood fringe areas”, as well as legislative passage of building codes for flood proofing. Possible measures are listed below:

Flood Proofing and Water Pollution Control

New buildings that have been permitted to be constructed on the floodplains should be built on stilts in order to avoid the reduction of flood storage capacities. Existing structures should be flood proofed to include provisions for intentional flooding of spaces below flood stages to balance internal and external pressure. Openings and doors should be reinforced. Structures should be equipped to be flood resistant hence having sufficient strength to withstand the pressure and the impacts of floating debris.

3.7 Technique Fact Sheets

The technique fact sheets that follow permit a review of measures according to their purpose, application, construction guidelines, maintenance, advantages, disadvantages, including an illustration sketch, photos and references and suggested reading. Techniques are presented in the following groups:

1. Lessening the volume of runoff close to its source
2. Runoff quality improvement
3. Control of erosion and sedimentation
4. Maintaining groundwater research
5. Detaining peak flow
6. Minimizing pollution from sewage
7. Channel rehabilitation through transverse structures
8. Channel rehabilitation through parallel structures
9. Point protection and stabilization of streambanks
10. Stabilization of upper streambanks and floodplain areas
11. In-stream habitat improvement
12. Flood damage control

This manual and its technique fact sheets should give planners of river rehabilitation projects data to select and design measures that in their combination, then constitute river enhancement schemes. A comprehensive approach has been taken to not only present measures that are being taken on the banks of a river but also to include those taken in the urban catchment area and beyond, to ensure that water as a resource is being protected. “Blue- green technologies“ can be used as a term to describe the many land based measures that not only help to achieve the “good ecological condition” called for by the EU Water Framework Directive but also provide for enhancement of banks of a river, its tributary streams and riparian areas. Fig. 2 below shows an overview of all individual technique fact sheets arranged in groups.

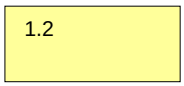
Group No	Group of measures
1.1	Lessening the volume of runoff close to its source

Measure name	Sy
Porous Paving Modular	Rasengittersteine

G

1.1	Lessening the volume of runoff close to its source

Porous Paving Modular	Rasengittersteine


1.2

Group No	Group of measures
1.2	Lessening the volume of runoff close to its source

Measure name	Synonym
Porous Paving Asphalt	Poröser Asphalt

A two-part maintenance program of quarte6hDy ef2c-0pef2ctthe/ va

Group No	Group of measures
1.3	Lessening the volume of runoff close to its source

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Vegetated Roof Covers	Dachbegrünung

Group No

1.3

Group of measures

Lessening the volume of runoff close to its source

Measure name

Vegetated Roof Covers

Synonym

Dachbegrünung

Maintenance

The key to low-maintenance designs is the selection of plants that can thrive under the severe growing conditions without the need for routine irrigation or fertilisation. It takes 1 to 2 years for the VCR foliage layer to become fully established. During this time periodic watering and fertilisation are generally recommended. Once the cover is established, many roofs require little or no routine maintenance.

Advantages

Large reductions in cumulative annual runoff volume are readily achieved by using VCR. This is particularly important in highly urbanized areas, where runoff is correlated with flushing of pollutants into receiving streams and water bodies.
VCRs are generally more effective in controlling runoff peak rates produced by rainfall events equal or smaller than 2-year storm. An evaluation will frequently show that most stormwater impacts are associated with small storms, whose impact include transport of road pollutants, chronic overflows of combined sewer systems, stream bank erosion in receiving streams, and nuisance flooding on roads and pedestrian walkways.

Disadvantages

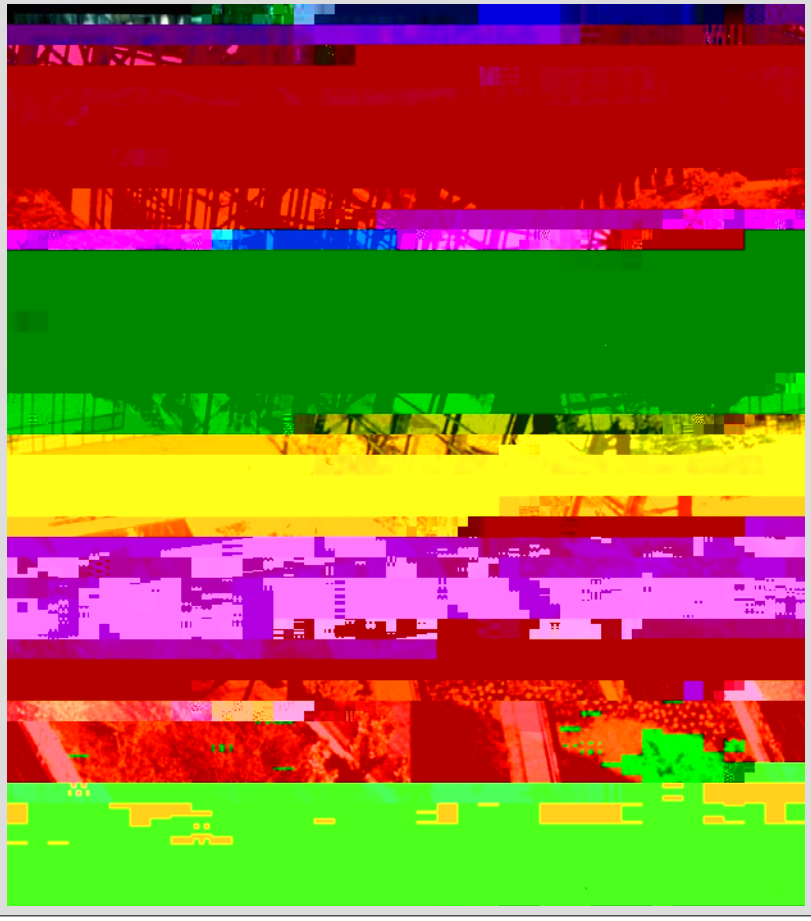
Examples

Installation through Optigrün,
Krauchenwies – Göggingen, DE

References and suggested reading

Tourbier, J.T.: Blue-Green Technologies. Integrated Practices to Manage Stormwater as an Asset. Great Swamp Watershed Ass.; Madison, N.J. 2002;

Example Photos



Group No	Group of measures
2.1	Runoff quality improvement

Measure name	Synonym
Wet Ponds with Extended Detention	Teiche mit langer Rückhaltung

Maintenance

Debris, potential algal growth, and sediment deposits need to be addressed through maintenance. The wet pond should be inspected at least once a year during a storm. Accumulations of debris around the riser should be removed on a regular basis. The permanent pool volume must be restored by dredging accumulated sediments. It is recommended that ponds contain a forebay (10 % of the total pond volume) to trap sediments to be removed in 10 year intervals.

Group No	Group of measures
2.2	Runoff quality improvement

Measure name	Synonym
Oil Grit Separators	Leichtstoff Abscheider/Feststoffabscheider

Oil/Grit Separators are multi-chambered structures designed to remove course sediment and oils from stormwater prior to delivery to a storm drain network. Separators are often used as pre-treatment for infiltration BMP’s such as Porous A

2.2	Runoff quality improvement

Oil Grit Separators	Leichtstoff Abscheider/Feststoffabscheider

Group No	Group of measures
2.3	Runoff quality improvement

Measure name	Synonym
Sand Filters and Peat-Sand Filters	Torfmullfilter/Sandfilter

Sand filters improve runoff quality at most sites, such as infill development, downtown areas, parking lots, gas stations, and other highway-orientated commercial

2.3	Runoff quality improvement

Sand Filters and Peat-Sand Filters	Torfmullfilter/Sandfilter

Group No	Group of measures
2.4	Runoff quality improvement

Measure name	Synonym
Constructed Wetlands	Feuchtbiotope

These facilities treat runoff by utilizing the water-quality enhancement processes of sedimentation, filtration, adsorption, extended retention, as well as biological processes. Control of an adequate water level is essential.

This facility may be constructed on sites where a permanent pool of water can be maintained. It can be achieved when groundwater is intercepted, or

Group No	Group of measures
2.4	Runoff quality improvement

Measure name	Synonym
Constructed Wetlands	Feuchtbiotope

Maintenance

Stormwater wetlands should be inspected twice a year for three years after construction and once a year thereafter for species distribution and survival, water elevations, condition of the outlet, and sediment accumulation. Sediments in the forebay should be removed every three to five years. Access areas and the embankment should be mowed twice a year to discourage the growth of woody vegetation.

Constructed wetlands can be designed to be a visually pleasing natural element in the landscape. They are space efficient since they can be placed within conventional stormwater detention basins. Constructed stormwater wetland design requires a good understanding of hydrology and wetland ecology.

Example Photos

Group No	Group of measures
2.6	Runoff quality improvement

Measure name	Synonym
Vegetated Filter Strips	Bewachsene Filterstreifen

Sheet flow must be maintained if a vegetated filter strip is to be effective. Maintenance must insure that gullying does not occur. Following severe storms,

Group No	Group of measures
2.7	Runoff quality improvement

Measure name	Synonym
Bio Retention	Rückhalt mit biologischer Aufwertung

Purpose	Applications
Bioretention areas are planted areas of deep absorptive soils that improve runoff quality and recharge the groundwater. They can also significantly increase the time of concentration and reduce the total volume of runoff and so reduce flood peaks. Shallow depressions (natural or man-made) are filled with a free draining soil mix (with under-drainage if necessary) to form a sponge-like lens capable of retaining and infiltrating runoff. The areas are landscaped.	Bioretention should be used in upstream areas as close as possible to the source of runoff. The areas can be beautifully landscaped and can be located in private gardens or public open space. Bioretention should not be used where the water table is less than 2 m below the surface or on slopes greater than 20%. Nor should they be used where mature trees (such as beech) are intolerant of periods of inundation, however brief. Bioretention beds can be used manage water from rooftops and other impermeable areas and greywater from residential uses.

Bioretention essentially mimics the hydrological function of natural woodland. The quality of stormwater is greatly improved and secondary benefits include the absorption of a large proportion of precipitation and the enhancement of infiltration and groundwater recharge. Bioretention systems can be used on-line or off-line. On-line systems are located in grass swales or other linear conveyance systems where space permits. Small check dams can be used to create shallow depressions to retain stormwater (see also Measure 4.1 Vegetated Infiltration Swales with Check Dams). These depressions can extend (by excavation if desired) beyond the regular parallel boundaries of the swale. Off-line bioretention areas are located to receive runoff directly from impervious surfaces and roof drains or can be diverted from a storm drain. They may also receive residential greywater. Natural depressions in the terrain are selected or shallow depressions 1-1.5 m deep are dug. On the base is placed a 15cm layer of crushed stone which is covered with a filter fabric/root barrier. Above this is placed 1m of free draining soil mix. This soil mix should have a pH between 6.0 and 7.0 to maximise pollutant removal by microbial activity, and should have an organic content of at least 3%. Any concentrated flow should be spread over the bed with a level spreader. Underdrainage with a perforated pipe system in the crushed stone layer is optional. Bioretention areas are planted with species that are tolerant of occasional brief periods of inundation. If runoff contains a large amount of coarse sediment that can q7o-n.8(h) wiof inun.74faces and roof dra7 Tw[y conc

2.7	

Bio Retention

Group No	Group of measures
3.1	Control of erosion and sedimentation

Measure name	Synonym
Cover Crops, Temporary Mulches	Decksaaten, Mulchen

This measure is applicable on all sites which are disturbed over a full growing season and where it

Group No		
3.1	Control of erosion and sedimentation	

Cover Crops, Temporary Mulches	Decksaaten, Mulchen

Group No	Group of measures
3.2	Control of erosion and sedimentation

Measure name	Synonym
Temporary Runoff Diversions and Chutes	Temporäre Umleitungen

Purpose	Applications
Temporary flow diversion structures (such as gutters, drains, dikes, berms, swales, and graded pavement) are used to collect and divert storm water to prevent the contamination of runoff and receiving water. Storm water that is potentially contaminated can be directed to a treatment facility.	This measure is used to protect temporarily disturbed areas from erosion by diverting erosive flows away from susceptible areas. It is also used to divert unpolluted stormwater around a disturbed site where it is likely to pick up sediments and other pollutants.

A **diversion,** also called **Interceptor Dike,** consists of a channel and a berm. It is normally created by a cut and fill, though temporary diversions may be created by placing a well-compacted earth berm on a slope. This will withstand slight storms and will divert runoff where washouts could cause serious problems. Diversions are designed to convey runoff along the contour at safe flow velocities. Channels that are constructed on cut can convey runoff at greater velocities than channels constructed wholly or in part on fill. Temporary diversions are designed by calculating peak runoff for a design storm of two-year frequency for roads and playing fields and five-year frequency storms for building sites. A freeboard is usually not required. The side slope of a temporary diversion that is frequently passed by construction traffic should not exceed 4.1. The cross section may be parabolic, trapezoidal or tempor

Group No

3.2

Group of measures

Control of erosion and sedimentation

Measure name

Temporary Runoff Diversions and Chutes

Synonym

Temporäre Umleitungen

Maintenance

All temporary measures should be inspected for washouts regularly and should be promptly repaired

Advantages

Temporary diversions protect areas where final grading has been completed from erosion by overland flow, permitting vegetation to root for final soil stabilization.

Temporary diversions may be used to prevent runoff entering partially completed storm drainage systems.

The amount of re-grading and repair is minimized.

Disadvantages

Diversions may actually cause an increase of infiltration into fill slopes, resulting in slumping and instability problems.

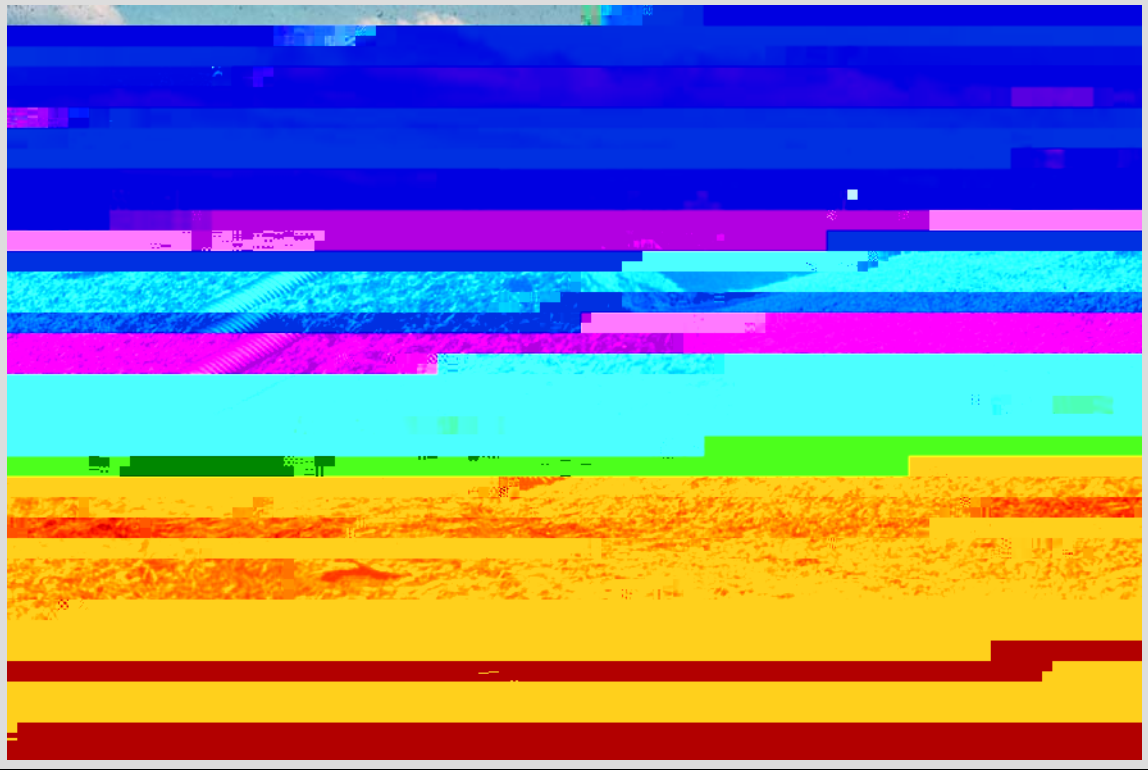
Additional costs are often high enough a deterrent to take a gamble on the weather, rather than to incur costs.

Examples

The photograph below shows a flexible downdrain used in contract work for the Delaware Department of Transportation, USA.

Tourbier, J. Toby; Westmacott, Richard: Water Resources Protection Technology. A Handbook of

Example Photos



Group No	Group of measures
3.3	Control of erosion and sedimentation

Measure name	Synonym
Silt Fence and Trap Devices	Feststoff Filterzeune

Straw bales were once used to form a linear barrier to trap sediment in runoff from construction sites. Bales continue to be used but silt fences made of synthetic geotextile are now more common. These are temporary structures that consist of a linear barrier of synthetic filter fabric supported by posts and if needed, wire fencing for support.

Silt fences are used on the downslope boundaries of all construction sites where earth disturbing activities are planned. In many areas they are required under erosion and sediment control ordinances.
Silt fences are not reliable where boundaries cross drainage swales that carry large volumes of concentrated stormwater. At these points sediment basins will be more effective (Measure 3.4).
Silt barriers or fences are also used within construction sites to prevent drainage structures

3.3

Silt Fence and Trap Devices

Group No	Group of measures
3.4	**Control of erosion and sedimentation**

Measure name	Synonym
Sediment Basins	Feststoff Absetzbecken

Purp

A sediment basin is formed by a barrier across a drainage way, causing the impoundment of stormwater giving larger sediment (usually more than 10 microns) sufficient time to be precipitated. Once a site is stabilized, sediment basins may be removed or retrofitted for another use.	Sediment basins are effective in precipitating suspended sediment in runoff that has begun to accumulate in gulleys and drainage ways before it is allowed to leave construction sites. They are often used in combination with silt fences (Measure 3.3) which are most effective in controlling sediments in sheet runoff.

Group No

3.4

Group of measures

Control of erosion and sedimentation

Measure name

Sediment Basins

Synonym

Feststoff Absetzbecken

Maintenance

Sediment basins should be designed to allow some accumulation of sediment without loss of the desired effectivness. Most sediment will be carried by a few large storms and following such storms ,basins should be inspected to make sure accumulations of sediments do not exceed the space allocated. If removal is required a backhoe with a wide bucket will usually be used.
It may be necessary to fence the installation to prevent potential danger to trespassers.

Advantages

There has been considerable experiece using sediment basins.
Sediment basins are very effective in removing larger sediments from concentrated flows of stormwater.
Basins can often be sited in existing drainge ways with a small earth dam. If necessary capacity can be increased by excavation.

Disadvantages

Sediment basins usually require clean-out after large storms.
Residual mud left in an empty basin is unsightly. Mud also smothers existing stream life in the basin.
Sediment basins are rarely adaptable for use after construction is complete, although they are sometimes retrofitted for runoff detention.

Examples

Examples

Example Photos

References and suggested reading

WRPT Sheet 2:11

Group No	Group of measures
3.5	**Control of erosion and sedimentation**

Measure name	Synonym
Hydroseeding and Chemical Stabilization	Hydroansaat, Chemische Stabilisatoren

Hydroseeders use a pressure spray to apply a slurry of seed, water, fertilizer, soil conditioner and mulch in one process. Rough and steep areas that are difficult to access with farm machinery may be seeded and fertilized economically. Chemical binders may be added to the slurry to help keep the seed and mulch in place during germination and to reduce water loss and erosion.

Hydroseeding is becoming increasingly common as the service becomes more available at reasonable

Group No

3.5

Group of measures

Control of erosion and sedimentation

Measure name

Hydroseeding and Chemical Stabilization

Synonym

Hydroansaat, Chemische Stabilisatoren

Maintenance

No maintenance is required but reapplication may be necessary if seeding fails. Even if hyroseeding is used, correct timing and careful choice of species is essential to ensure successful germination and growth

Advantages

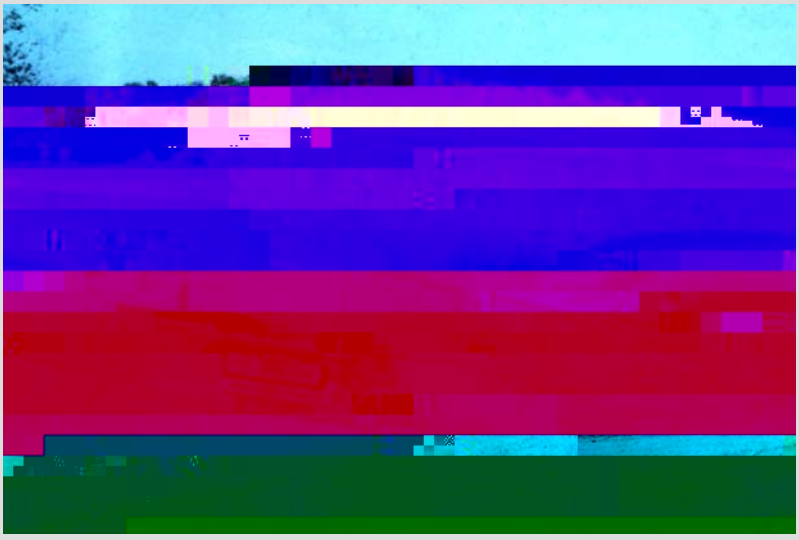
Hyroseeding can be used on sites inaccessible for standard farm equipment
The use of mulch and chemical binders in the slurry increases germination rates on all sites.
The application of seed, mulch, fertilizer, soil conditioners and binders all in one slurry makes this an efficient and fast process which will often easily justify additional cost.

Disadvantages

Hydroseeding can be expensive especially for jobs carried out in small increments.
Although spray equipment has a long reach, the tanker
must have access to within about 60 m of the farthest point to be seeded.
Hydroseeding is usually subcontracted which may make scheduling difficult.

Example Photos

Hydroseeding of a streambank. Source: In S... Principals, Processes, and Practices (10/98). By the Federal Interagency Stream Restoration Wo...



Group No	Group of measures
3.6	**Control of erosion and sedimentation**

Measure name	Synonym
Management of Construction Sites and Traffic	Bauverkehr

Construction activities are one of the most serious sources of soil erosion and sediment pollution. Construction sites should be managed to minimize the period during which the

Group No	Group of measures
4.1	**Maintaining groundwater recharge**

Measure name	Synonym
Vegetated infiltration Swales with Check Dams	Infiltrationsrinnen

A constructed open-channel drainage way used to

4.1	**Maintaining groundwater recharge**

Vegetated infiltration Swales with Check Dams

Group No	Group of measures
4.2	**Maintaining groundwater recharge**

Measure name	Synonym
Infiltration Basins	Sickerbecken

Purpose	A
A water impoundment made by excavation or construction of an embankment to intercept runoff and to maintain or increase natural groundwater recharge by infiltration through the bed and sides of a pond or basin. It is sized to hold and infiltrate the runoff from a design storm (e.g. a two year frequency storm).	Infiltration basins are most effectively used in watersheds of 5-20 acres. The infiltration rate of soils under infiltration basins should be 0.52 inches per hour or greater. The seasonal high water table and bedrock should be at least 2 to 4 feet from the bottom of the basin. Infiltration basins should not be used in limestone and other karst-sensitive areas where sinkhole formation is common due to high potential for groundwater contamination. Infiltration areas should be set back at least 100 feet from any water-supply well, as well as at least 10 feet down gradient from any

Group No

4.2

Group of measures

Maintaining groundwater recharge

Measure name

Infiltration Basins

Synonym

Sickerbecken

Maintenance

Infiltration basins should be inspected at least once a year and after every heavy storm. Eroded areas should be replanted and the source of the problem corrected. Sediments should be removed from basin floors that are clogged. The basin should then be plowed, disked, organic material worked in, and replanted to restore percolation rates.

Advantages

Infiltration basins preserve the natural water table of a site and can provide complete control of peak flows from the design storm. They also provide total trapping of design storm particulates and partial removal of nutrients. If they are not properly maintained, they can clog, breed mosquitoes, and become an eyesore.

Disadvantages

Examples

Examples

References and suggested reading

Tourbier & Walmsley, Inc.: London Grove Township Stormwater Management Guidance Manual. London Grove Township Board of Supervisors, Philadelphia 1996;

Example Photos

Photos

Group No	Group of measures
4.3	**Maintaining groundwater recharge**

Measure name	Synonym
Seepage Beds	Sickerflächen

Seepage beds are extensive multi use areas that are excavated to a shallow depth and filled with crushed stone. Their purpose is to cause the infiltration of stormwater which has been collected from elsewhere on site. The areas may be surfaced with porous paving, mowed grass or meadow depending on the intended use.

Group No

4.3

Group of measures

Maintaining groundwater recharge

Measure name

Seepage Beds

Synonym

Sickerflächen

Maintenance

Maintaining the infiltration capacity of the seepage bed is the essential of a maintenance program. The most likely problem will be clogging caused by sediment in the inflow water. This problem should be minimized by installing sediment control measures upstream of the seepage bed and insuring their regular cleanout. The infiltration capacity of porous pavement must be maintained by regular vacuum sweeping. Reduced infiltration of vegetated areas may be caused by sediment and also by compaction. In both cases infiltration capacity can be restored by cultivation and reseeding.

Photos

Group No

4.4

Group of measures

Maintaining groundwater recharge

Measure name

Gravel Filled Trenches

Synonym

Rigolen

Purpose

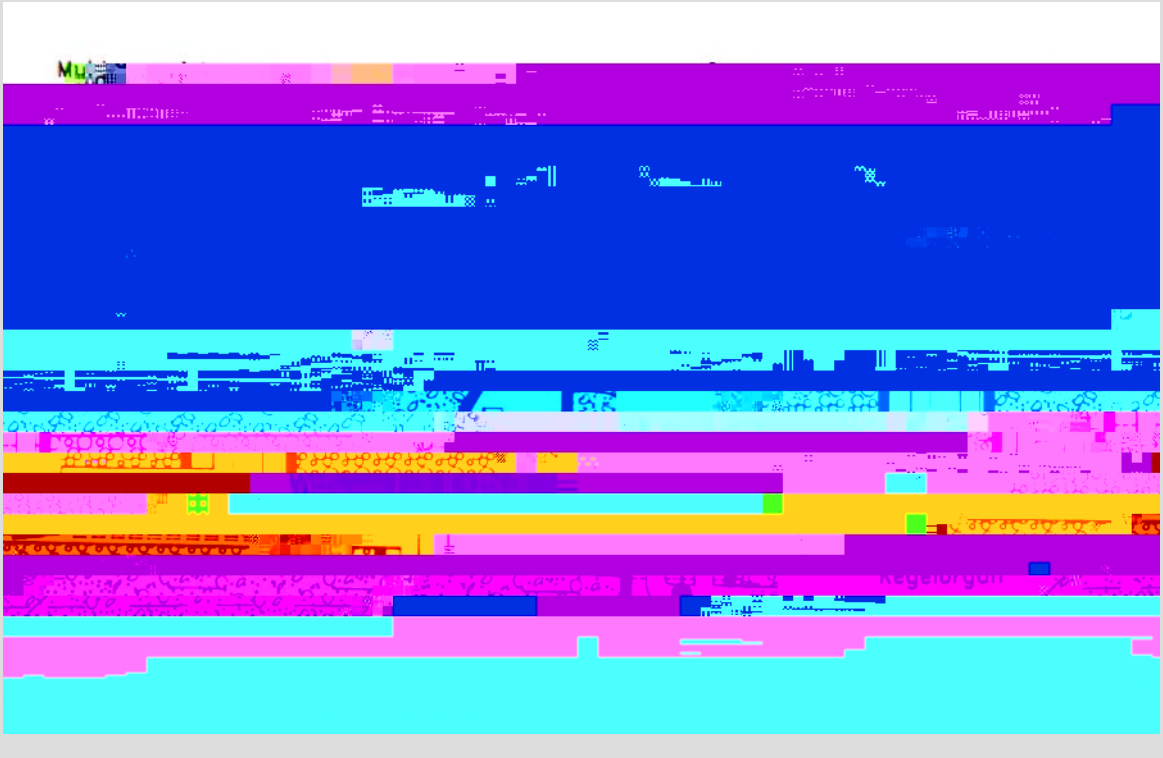
Gravel filled trenches (with optional underdrainage) are infiltration and pollutant removal devices installed close to runoff-generating surfaces. They also reduce peak flows although this is not their primary purpose. Trenches remove both soluble and particulate pollutants through interaction with soil.

Applications

Gravel filled trenches can be used in a variety of urban and suburban situations to receive runoff generated by parking lots, median strips, swales, and rooftops.
Soil should be well drained, have a favourable cation-exchange rate, and an infiltration rate of 0.5 inches per hour or greater. The water table and bedrock should be at least 2 to 4 feet below the bottom of the trench during all seasons. Their low surface area to volume ratio makes trenches useful in areas where space is limited.

Descrip

Stormwater entering trenches is stored within the void volume of the gravel and moves gradually into the subsoil.
Trenches are typically 3 to 8 feet deep and designed to drain within three days. The infiltration rate of the soil, depth to bedrock, and the level of the water table will determine the trench depth.
The sides of trenches are lined with filter fabric and when the trench is filled, 6" of sand is first placed on the bottom. Gravel or crushed stone should be 1.5 to 3 inches in size. If there is a vegetated surface over the trench, gravel should be covered with filter fabric before placing the topsoil. Metal gratings or a perforated concrete slabs may also be used above the gravel to pass overland flow into the trench. These should be set with a 6 inch void beneath and filter fabric on top of the gravel. In sloping terrain trenches at various levels may be connected by distribution pipes with overflow valves. To avoid clogging with sediments, trenches should not be installed until all contributing areas have been stabilized.
Simple monitoring wells, consisting of vertical perforated plastic pipes, should be installed in each gravel filled trench to check infiltration rates after storms and to observe how fast sediments accumulate.
Runoff quality improvement is considerable: (1) suspended sediment removal: 80-100%, (2) total phosphorus removal 40-60%, (3) total nitrogen removal 40-60%, (4) oxygen removal 60-80%, (5) trace metal removal 80-100%, and (6) bacterial removal 60-80%.



Group No

4.4

Group of measures

Maintaining groundwater recharge

Measure name

Gravel Filled Trenches

Synonym

Rigolen

Maintenance

Monitoring wells should be examined quarterly and following every large storm. When sediment accumulation causes the draining time to exceed three days, the trench should be dug up and remade. When the inflow is through a grating and there is accumulation of sediment on the filter fabric, the fabric should be lifted and replaced.

Advantages

Gravel filled trenches provide good to excellent pollutant removal for small drainage areas or infill developments. They make efficient use of limited space through their low surface area to volume ratio.

Disadvantages

Gravel filled trenches require regular maintenance to prevent premature clogging. Digging up and replacing a badly performing trench can be disruptive and expensive.

Examples

Examples

Example Photos

Photos

References and sugges g-0.0427 0.0427 TD(s)Tj0.75294 g0.547 -0.0427 TD(g-0.040.5983 3427 0.)Tj0.75294 g0.5983 -s

Tourbier & Walmsley, Inc.: London Grove Township Stormwater Management Guidance Manual. London Grove Township Board of Supervisors, Philadelphia 1996;

4.5

Wells and Gravity Shafts

Group No

4.5

Group of measures

Maintaining groundwater recharge

Measure name

Wells and Gravity Shafts

Synonym

Sickerschächte

Maintenance

Clogging is generally the worst problem affecting the performance of recharge wells. The only effective means of perpetuating the life of a well is to remove silt by filtration before the stormwater enters the well. However filters will only remove sediments 25 microns or larger (WRPT sheet 2:7). Filters can be cleaned by reverse flushing or can be replaced.
A sediment basin with the necessary storage volume to allow sufficient time for sediments to settle can be used. But the required size is very large to remove smaller sediments (measure 3.4). In the case of backfilled wells, the cone of porous material protecting its mouth is intended to filter sediments from the stormwater.

Recharge wells require less space than any other recharge measure.

Example Photos

Photos

Group No

4.6

Group of measures

Maintaining groundwater recharge

Measure name

Infiltration Berms

Synonym

Sicker Berme

Purpose

Infiltration terraces are constructed across a slope with a berm along the downslope edge to impound runoff on the terrace. This allows the runoff to infiltrate. They vary in width and spacing. They are usually sized to hold and infiltrate the runoff from a two year design storm. Similar to depression storage found in nature, infiltration berms can be designed to blend harmoniously into the landscape.

Applications

Infiltration terraces are well suited for rolling topography with long slopes and permeable soils. This measure was traditionally used in agriculture, but can be applied to urban development sites if the terraces are planned as part of the open space network. They can be very compatible in developments where vehicular access and structures are designed to run parallel to the contours.

Description

Infiltration berms are shallow embankments designed to impound water on terraces constructed parallel to the contours on a sloping site. The terrace and the berm are built level to intercept surface flow. The width of terraces may vary depending on the steepness of slope. Side slopes of berms should not be steeper than 3:1 and the crests of berms should be level with a minimum width of 5 feet. Topsoil should be stripped from terrace areas before they are graded. During grading, great care should be taken to avoid the compaction of the base of the terrace. The berm however may be compacted. Sod may be used to protect the top and the downslope of the berm. Otherwise topsoil should be spread over the terrace and berm, harrowed and seeded. Where possible berms should not be constructed on areas of fill, but when this is not possible the whole area and the berms must be thoroughly compacted.

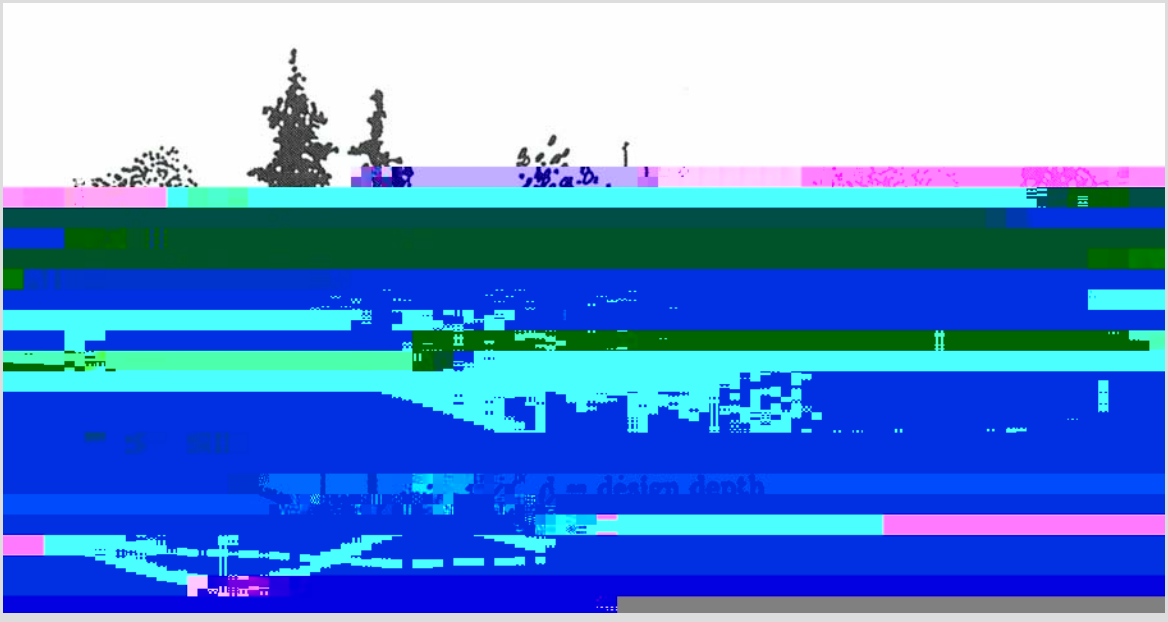
Terraces may be kept in woody vegetation, herbaceous vegetation or in grass, but berms are best kept in grass, mowed regularly. Woody vegetation on the terraces will help to keep the soil structure open and thus provide a self sustaining infiltration system that requires little long-term maintenance.

To enhance infiltration, one or more infiltration trenches (see Measure 4.4) filled with crushed stone wrapped in filter fabric may be constructed running along the length of each terrace. Infiltration trenches may contain (optional) a 10cm perforated pipe to improve subgrade distribution of water.

All terrace systems must be designed with an emergency spillway capable of handling stormwater flows in excess of the design storm.

The crest of the berm is a ideal location for pathways but access to the base of terrace should be discouraged as the resulting compaction will decrease infiltration.

Illustration /Sketch



Group No

4.6

Group of measures

Maintaining groundwater recharge

Measure name

Infiltration Berms

Synonym

Sicker Berme

Maintenance

All silt that accumulates on the terraces during and after construction should be removed. The berms should be mowed regularly and should be inspected after storms. Any erosion gullies should be repaired immediately. If the rate of infiltration of the terraces falls below the required rate, they can be retrofitted with infiltration trenches running along the terrace. However if woody vegetation is established on the terrace a series of infiltration pits installed with a post hole auger (measure 4.5) should be used. These will cause much less disturbance than the installation of an infiltration trench.

Ad

Infiltration terraces can effectively infiltrate runoff from a two year storm which will maintain pre-development infiltration rates and the natural baseflow of streams.
This measure will blend well in the landsape if planned in advance.
This measure is simple and requires very little maintenance.

Infiltration terraces require careful grading to be effective and their location is determined by the contours on site. A development therefore must be planned around the terraces which may impose constraints that are not acceptable. It may be difficult or impossible to incorporate the long linear horizontal open spaces that result in the design of a development.
In very dense developments, terraces may become severely compacted with a resulting loss of effectiveness.

Example Photos

Photos

Group No	Group of measures
5.2	**Detaining peak flows**

Measure name	Synonym
Dry Pond Detention Basins	Trockene Rückhaltebecken

Dry pond detention basins provide temporary storage of runoff to reduce peak flows. After a storm, stormwater is released at a predetermined rate until the basin is completely empty. The spillway is normally designed to allow complete release of impounded water within 12 hours. Very shallow basins can be maintained with a cover of grass to permit other uses during dry weather.
Dry pond detention basins will also give minor improvement in the quality of runoff and reduce sedimentation but these are secondary benefits. They will also increase infiltration to the ground water which may not be desirable if stormwater is badly polluted.

Dry detention basins do not have the visual appeal of wet basins and do not enhance adjacent property values.
Because dry detention basins are usually more than 1m deep and they pose a potential safety hazard and fencing may be necessary. This can be visually displeasing.
On sites where impoundments can be large but not deep enough to cause a safety hazard, multi use

5.2	

Dry Pond Detention Basins

Group No	Group of measures
6.1	**Minimizing pollution from sewage**

Measure name	Synonym
Combined Sewer Source Control	Mischkanalisation – Überflüsse

MaintenanceS

Maintenance requirements for all measures referred to here are discussed under each measure contained in this document and referred too by sheet number.

Group No	Group of measures
7.1	**Channel rehabilitation through transverse structures**

Measure name	Synonym
Sills or Weirs with Plunge Pool	Sohlgurt - Rundholzschwelle

Sills or weirs less than 30 cm high built across a stream will create a shallow pool upstream which will gradually fill with sediment. Or the upstream pool can be backfilled with rock and gravel to increase spawning habitat. In both cases a plunge pool will tend to form below the structure. The pool will be broad and shallow if flow is across the whole length of the sill, or smaller and deeper if spillway flow is concentrated to one point. Sills will tend to lessen scouring of the channel bed by dissipating energy in the plunge pool. This measure increases the diversity of habitat in

Group No	Group of measures
7.4	**Channel rehabilitation through transverse structures**

Measure name	Synonym
Rough Bed Channels	Rauhe Rampe, seiitlich gerümmte Sohlrampe

Roughening the bed of a stream channel will dissipate much of the energy in the streamflow without altering the gradient. Rock must be of sufficient size to resist any movement during high flows.
Live materials can be inserted between rock near the banks.
This measure can also increase spawning areas for some fish species especially when gravel is included with the rock during installation. Rou0 -1.1467 TD-0.0012 0-0.0427 TD( )Tj0 g--dovement during high

Group No

8.1

Group of measures

Channel rehabilitation through parallel structures

Measure name

Fibre Rolls and Reed Rolls

Synonym

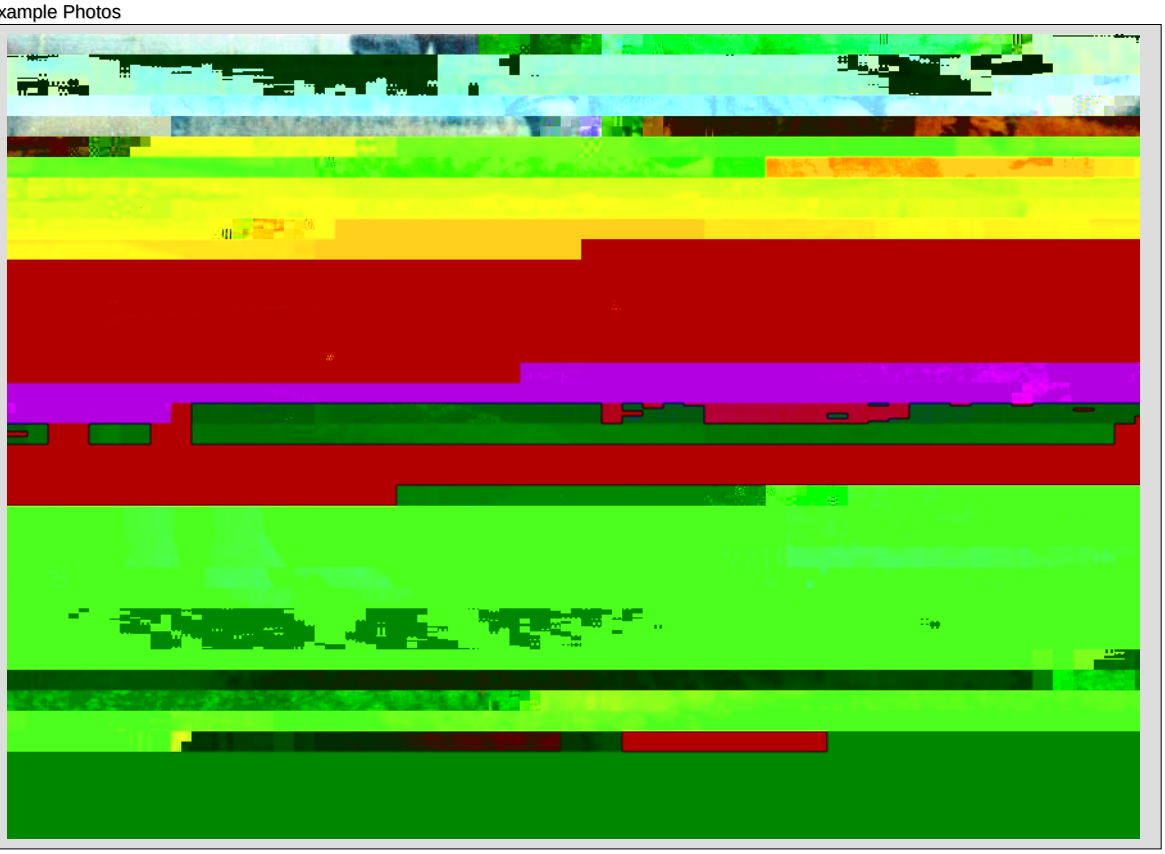
Röhrichtwalze

Maintenance

After a manufactured roll disintegrates some repair work may be needed, but if aquatic plants were included during installation it should be self-healing. Reed rolls normally require no maintenace except in cases where they were placed on a brush, riprap or gabion footing in which case some damage from slumping may occur. A technique appropriate to the specific type of damage must be selected to make repairs if they are necessary. If live stakes were used to secure the roll in place, the willow growth may require regular coppicing to prevent shade killing the aquatic plants.

The expense of manufactured rolls is offset by the ease and speed of installation.
Both manufactured rolls and reed rolls give immediate protection following installation.
If reed clups are available on site this is a very cost effective measure, t

Example Photos



Group No	Group of measures
8.2	**Channel rehabilitation through parallel structures**

Measure name	Synonym
Live piling revetments, Live barriers	Lebende Ufer Lahnung, Lebende Barre

Purpose	Applications
To protect and stabilize zones along the shore of rivers and other bodies of water against wave action. To create a “stillwater zone” as a habitat for microorganisms, submerged and emergent aquatic vegetation and aquatic fauna (salamanders, fish, water birds).	Where water surfaces are large enough to result in wave action that can cause shoreline erosion. Also on rivers where boat traffic can generate damaging waves that can also adversely affect stands of emergent aquatic vegetation.

Both, live piling revetments and live barriers create protected stillwater zones. Live piling revetments consist of brush packing and fascines between a double row of wooden posts (see Drawing).

Group No	Group of measures
8.3	**Channel rehabilitation through parallel structures**

Measure name	Synonym
Terraced Streambanks	Terrassierung

To create a stepped streambank above or below water stabilized by vegetation. The risers can be retained by walls, pilings or cribwork. If it is desired to stabilise a steep bank beneath the water along a deep channel, pilings can be driven parallel to an existing structure, backfilled with soil

Group No	Group of measures
8.4	**Channel rehabilitation through parallel structures**

Measure name	Synonym
Branch Packing	Packwerk

To repair and stabilize eroding streambanks using layers of live branches and compacted soil. USDA (1996, p.16-19 and scrh 36) recommend the measure for slumps and holes ranging from about 0.7-1.3m in height and depth. As the live branches form roots and begin to grow, the structure traps sediment which fills any voids while roots spread throughout the backfill and into the bank to form a unified mass.
For more extensive stabilization projects where the streambank can be regraded to a gentle slope, brush mattresses are effective (see measure 9.7).

This measure is usually used to repair or stabilize small localized erosion damage rather than extensive lengthsn

Group No	Group of measures
8.4	**Channel rehabilitation through parallel structures**

Measure name	Synonym
Branch Packing	Packwerk

8.5	**Channel rehabilitation through parallel structures**

Riprap and Vegetated Riprap	

8.6

Jacks, Jack Fields, and Tetrahedrons

Group No	Group of measures
9.1	**Point protection and stabilization of streambanks**

M

Brush Packing	Ausbuschung, Runsenausbuschung

Group No

9.1

Group of measures

Point protection and stabilization of streambanks

Measure name

Brush Packing

Synonym

Ausbuschung, Runsenausbuschung

Maintenance

Brushlayers are susceptible to damage before the vegetation is well established. Maintenace may be required during this period. Damage repair will be much easier if most of the vegetation has rooted in which case vigorous shoots can be bent over and pegged down on damaged areas. This technique allows the repair to be made during the same growing season, rather than waiting until the next dormant season. After establishment of vegetation the maintenance priority is to keep it vigorous and effective. Periodic coppicing will help to prevent the willow shading out adjacent plants.

This is a low cost measure if plenty of suitable live material is available locally.

Example Photos

Photos

9.2	**Point protection and stabilization of streambanks**

Live Willow Deflectors	

Group №		
9.2	**Point protection and stabilization of streambanks**	
Live Willow Deflectors	Lebende Weidenkämme – Buschbau Traverse	

Gro

9.3	**Point protection and stabilization of streambanks**

Live Slope Gratings, Timber Framing	Lebende Hangroste

Group No

9.3

Group of measures

Point protection and stabilization of streambanks

Measure name

Live Slope Gratings, Timber Framing

Synonym

Lebende Hangroste

Maintenance

If properly installed the measure should provide maintenance free protection for the slope. The measure will generally be used only on slopes that are too steep to mow and the long term protection will be given by woody vegetation and or groundcovers. Some management of the woody species may be required if shading is excessive. Periodic coppicing of species such as willow and dogwood may be needed.

Advantages

Good protection from erosion is provided by the timber framework.

Disadvantages

Installation requires extensive and precise grading.
The measure is expensive to install and there are other options (brush mattresses, measure 9.7) that give similar results at lower cost and without so much grading.
The measure cannot withstand high velocity streamflows and is suitable for use only on the upper stream bank.

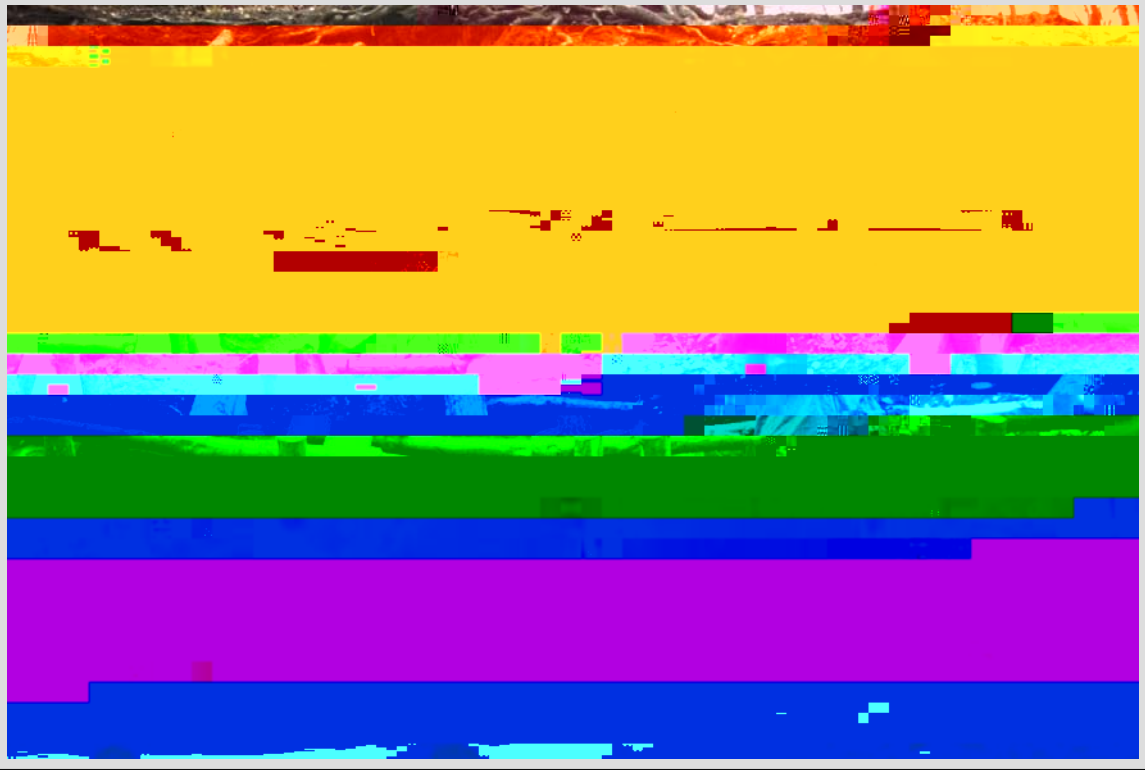
Examples

Photo: Demonstration
at the „Landesgartenschau Sachsen“
in Lichtenstein, Germany

References and suggested reading

SCRH 26
T&W Sheet 2:15

Example Photos



Group No	Group of measures
9.4	**Point protection and stabilization of streambanks**

Measure name	Synonym
Wing Deflectors	Buhnen

Wing deflectors divert erosive currents away from an eroding streambank. This can result in deepening the channel opposite and create a pool and improve fish habitat. If a series of deflectors are used they will promote deposition of sediment between the structures. Deflectors may be used todirect flow to the center of the stream causing it to deepen its channel and to establish its course. Deflectors may be only one log in height or can be constructed of cribwork upto 4 logs in height.	This is a measure appropriate only on small streams (lessD(0.04tto establish its course.)Tj0 -1.1467 TD-0.0016 T

Group No	Group of measures
9.4	**Point protection and stabilization of streambanks**

Measure name	Synonym
Wing Deflectors	Buhnen

Deflectors are not high cost structures designed to solve major problems but rather to make minor adjustments to correct minor erosion problems or to improve habitat. The stream's behaviour should be constantly observed by the manager. constaremo. Tadj31.4d by to correct min12(he streahe ma(modified. If sedi)Tj is.build0.g

Group No	Group of measures
9.5	**Point protection and stabilization of streambanks**

Measure name	Sy
Rootwad and Boulder Revetment	Wurzelkneul und Steinverkleidung

9.5

Rootwad and Boulder Revetment

9.6	**Point protection and stabilization of streambanks**

Whole Tree Revetment

Group No	Group of measures
9.7	**Point protection and stabilization of streambanks**

Measure name	Synonym
Brush Mattresses	Weiden Spreitlage

Purpose	Applications
A thick layer of live branches staked and wired down to protect gently sloping streambanks from erosion. The measure is sometimes used in combination with fascines (see measure 8.4) and live stakes (see measure 10.4). A brush mattress gives temporary mechanical protection during establishment and, after rooting the branches give long term protection.	Most useful where the streambank can be graded to a uniform 3(h):1(v) slope. The measure can be used on fast flowing streams above normal streamflow level and extend to above the bankful level. A plentiful local source of suitable willow branches is a great advantage.

Brush mattresses are thick layers of live branch cuttings 1.50 m to 3 m. long and about 2cm in diameter placed to cover and protect streambanks. Banks should be graded to a uniform slope of about 3:1. A trench should be excavated from about the mean streamflow level to below the streambed. Live stakes (dia. 4-5cm and 0.7m.long) should be driven into the surface of the slope in a triangular pattern about 0.5 -1.0m apart and to half their length. One or two layers of branches are placed on the slope at right

Group No	Group of measures
9.7	**Point protection and stabilization of streambanks**

Measure name	Synonym
Brush Mattresses	Weiden Spreitlage

Group No	Group of measures
9.8	**Point protection and stabilization of streambanks**

Measure name	Synonym
Live Cribwalls	Krainer-Wand, Holzgrünschwelle

This measure normally requires little maintenance. If the branches root and grow vigorously, it will become a self -healing structure as the structural timbers deteriorate and if damage does occur. But because this mesure tends to be used only in critical highly erodible areas, it should be inspected frequently for damage. Willow is not shade tolerant and there may be a loss of effectiveness of the measure after adjacent plants begin to shade each other out. Periodic coppicing would keep the stand vigorous and effective. Where breaks in the stand occur, young willows growing adjacent can be bent over and lashed down to help heal the scar. Th

9.9

Group No

9.9	**Point protection and stabilization of streambanks**

Live Fascines	Lebendfaschinen

Group No	Group of measures
9.10	**Point protection and stabilization of streambanks**

Measure name	Synonym
Live Wattle Fences	Lebender Flechtzahn

To protect and stabilize moderately to steeply sloping streambanks by constructing low, live wattle retaining fences at intervals on the slope which, after backfilling will take root and provide long term protection. To reduce erosion and slippage of upper soil layers on sloping banks, and to reduce slumping. Live wattle fences are often used to create a stable framework on banks that are to be seeded and planted with permanent vegetation.

Effective to create linear protection along streams. The measure will tend to confine the stream to its channel and will also prevent floating debris from littering the floodplain during flood events. For streams with high velocity flows, live fences can be managed as a traditional hedge by periodically bending down the vertical growths and weaving them between stakes spaced about 1m. apart to

Group No

9.10

Group of measures

Point protection and stabilization of streambanks

Measure name

Live Wattle Fences

Synonym

Lebender Flechtzahn

Maintenance

If the live material roots and grows vigorously these stuctures should be self-healing if damaged. Sediment will be deposited behind the fences. This process can be encouraged until sediment levels build up to the top of the fence, but to do this, about every 4 years, the vertical growths of willow (dia. 3-7cm.) should be bent down and woven between selected willow trunks (dia 10-15cm.) that have been cut at the desired height. Sediment can be stabilized with live material as it accumulates.

The fences give immediate mechanical protection after installation. Very little if any machinery is needed on site.

Installation is labour intensive and requires skill. Not suitable on stony or rocky terrain. Rooting and growth of live material may not occur if conditions

Example Photos

Group No

9.11

Group of measures

Point protection and stabilization of streambanks

Measure name

Vegetated Rock Gabions

Synonym

Begrünte Drahtschotterkörbe

Purpose

Gabions are rectangular wire baskets that are filled with small to medium sized rock to create a massive structure which (unlike a monolithic concrete structure) has some flexibility, and can adapt to some undercutting or other instability. Gabions can be laced together in various configurations to form terraces or walls. Gabions are also available to fabricate rock mattresses which are sometimes used to protect steambeds subject to excessive scour.

Applications

Gabions are particularly useful when rock of sufficient size is not availabe locally, and for applications where a vertical or very steeply sloping structure is required. The wide range of gabions that are available including rectangular box gabions, mattress gabions and cylindrical gabions make them adaptable for many uses. Because of their inherent flexibility and ability to adjust to minor instabilty in their foundations, gabions are useful in many stream stabilization applications.

Gabions are wire baskets of various sizes and configurations, constructed of heavily galvanized or coated wire mesh. The most commonly used size is 1X1X2m. When being used to protect streambanks, a trench is excavated to about 0.7m. below the streambed with the base angled so that the gabion will take up the desired bank angle. If the proposed structure is more than one gabion in height, the trench should be sufficiently wide to accommodate t0 g10.1(w)21,.inor i22.39 0 TB186 0 TD-0.0016 Tc0.0038 Tw((fsie tb)11.67 fsie . Adjacnt s1(

9.11	**Point protection and stabilization of streambanks**

Vegetated Rock Gabions	Begrünte Drahtschotterkörbe

Group No	Group of measures
10.1	**Stabilization of upper streambank and floodplain areas**

Measure name	Synonym
Hedge Layers, Brush Layers, Hedgebrush Lavers	Heckenlage, Heckenbuschlage, Buschlage

Purpose	Applications
This measure uses live materials to form a linear hedgelike barrier on slopes parallel to the contour. The measure was developed by Schiechtl and others mainly for upland slope protection and erosion control on steep dam and highway embankments (Schiechtl p. 54). The measure is similar to „live wattle fences“ (measure 9.10) used to stabilize stream banks. In floodplain areas hedge layers can be used to stabilize steep banks that sometimes occur between floodplain terraces. They can also be used as longitudinal barriers to trap flood debris before it spreads over the whole floodplain.	Hedge layers are useful for stabilizing the steep embankments that are often seen between terraces on floodplains. They are also used to trap floating debris during flood events and are therefore useful on rivers and streams that carry large debris loads. The filtering effect of these hedges will also trap sediment which will gradually build up forming levee like structures that will tend to reduce the extent of flooding. Hedge layers are not appropriate where the floodplain is being managed as riparian woodland

Schiechtl (p 54) recommends that live brances of willow (0.7m-1.5m long) are placed in trenches (min depth 0.5 m) excavated parallel to the contour and buried with one quarter of their length protruding above the ground. This should be carried out during dormancy. If soil moisture is sufficient, the branches should root. Ideally the trench sould be deep enough so that the base of the branches is close to ground water table. On drier sites, rooted nursery stock of alder, willow, osier dogwood or other flood plain shrub species can be planted 0.5m apart during the dormant season. Most flood plain species are tolerant of periodic inundation and accumulation of sediment above the root collar. Rooted plants will be effective more quickly than unrooted branches. If appropriate, hedge layers can be managed as traditionl hedges once they are established. In cases where it is desired to restrict access to the river channel or to all or some of the flood plain these hedges can be highly effective. In late winter

Group No

10.1

Group of measures

Stabilization of upper streambank and floodplain areas

Measure name

Hedge Layers, Brush Layers, Hedgebrush Lavers

Synonym

Heckenlage, Heckenbuschlage, Buschlage

Maintenance

If the live hedge material roots and grows vigorously these stuctures should be self-healing if damaged by floods. Sediment will build up along the hedge but the plants will root into these deposits as they accumulate. Gradual build up of sediment along the length of the hedges could form a levee and significantly reduce the frequency of flooding of flood fringe areas upslope. In some cases this could be beneficial. If not, it might be necessary to remove the hedge.
Clean up of flood debris will be necessary after a storm event but a hedge layer will make this maintenance task easier by trapping the debris along a single line.

Advantages

This measure can be installed with very little if any machinery.
The measure can be used to restrict access to certain areas of the stream corridor without using fences

Disadvantages

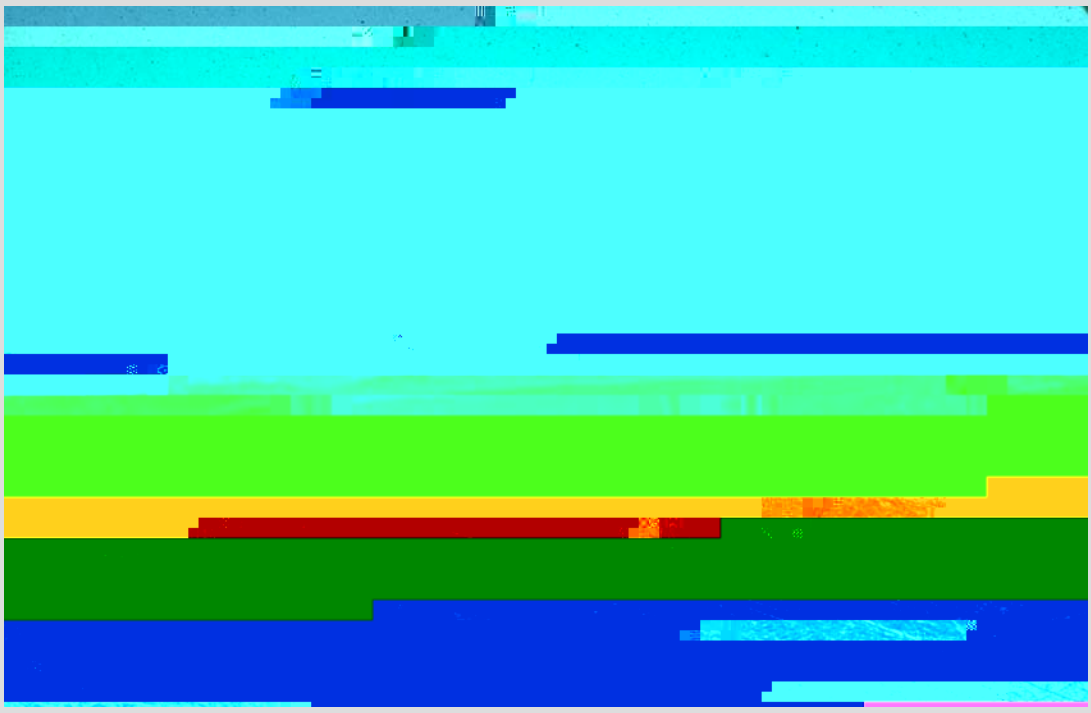
The measure will be ineffective if rooting and growth of live material does not occur.
If it is desired to manage the hedge to restrict access from some areas of the stream corridor, the maintence requirements to make the hedge impassable are costly

Examples

Photo courtesy of Robin B. Sotir & Associates, Inc. Marietta, Georgia, USA

Schiechtl, p 54
Schiechtl, Hugo M.; Stern, Roland: Handbuch für naturnahen Wasserbau. Eine Anleitung für ingenieurbiologische Bauweisen. Österreichischer Agrarverlag, Wien 1994; Begemann, Wolf; Schiechtl, Hugo M.: Ingenieurbiologie. Handbuch zum ökologischen Wasser- und Erdbau. Bauverlag, Wiesbaden 1994;

Example Photos



Group No

10.2

Group of measures

Stabilization of upper streambank and floodplain areas

Measure name

Reforestation of Riparian Forest

Synonym

Gehölzbestandene Uferrandstreifen

Purpose

To restore the beneficial filtering effect of riparian forests in removing pollutants from surface runoff and shallow groundwater flow. Also to restore the infiltration capacity of riparian soils to reduce runoff flowing directly into the water body.

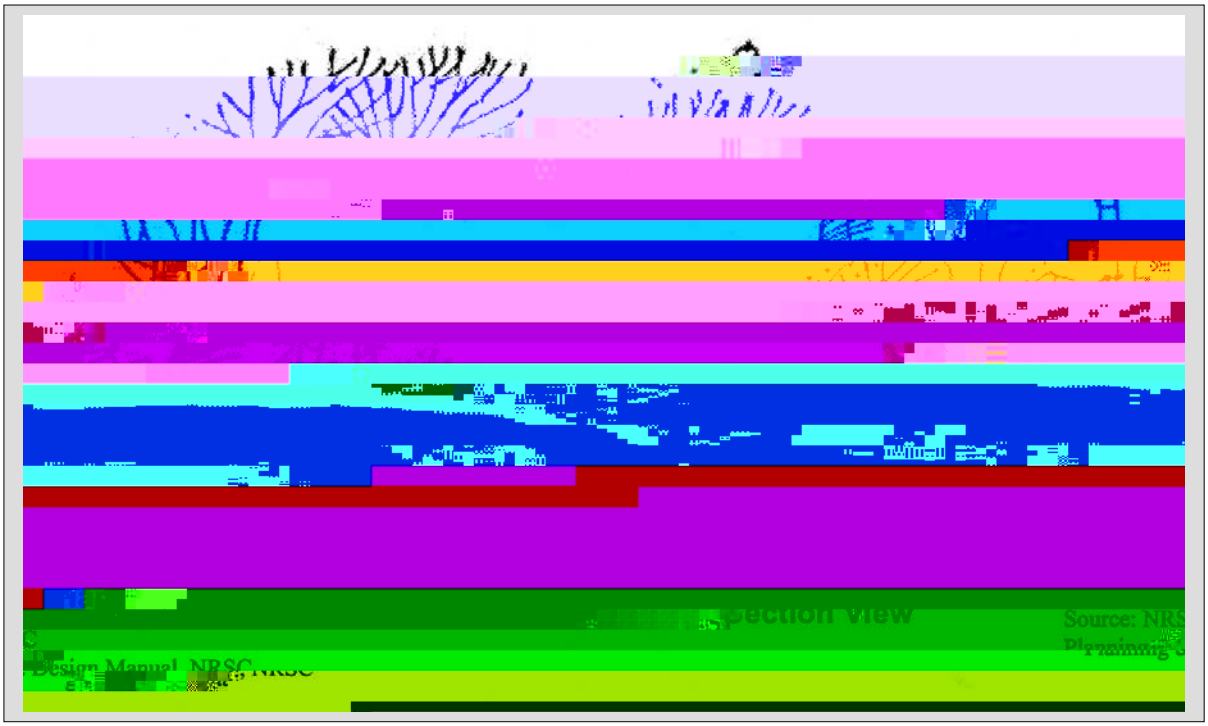
Applications

Reforestation should be considered wherever the forest has been removed from the riparian zone and where urban development has not pre-empted the space. It is valuable for stream reaches needing of bank stabilization where bioengineering methods are employed. Reforestation is also useful in farming areas where runoff contains high nutrient and/or sediment loads and where the land has been cleared unto the edge of the water

Description

Whenever possible riparian forest buffers should be re-established adjacent to water bodies through a combination of natural regeneration, and replanting. Stands of exotic plants should be cut, dug, or pulled out. A study of nearby healthy riparian forests will provide a useful guide for the choice of plant species and the appropriate diversity of the plant community. Unstable areas along streambanks should be identified and appropriate stabilization measures should be implemented before reforestation begins.
In areas designated for natural regeneration, a no-mow zone should be established and carefully monitored to encourage growth of native species. This strategy is most successful if the area was cleared of forest recently and seed of indigenous species is still viable. Exotic species that emerge should be removed.
Planting of forest is most effectively carried out using small, bare-rooted plants, closely spaced and thinned as they become established and start to compete. Larger, container-grown stock is only appropriate on sites where an immediate effect is necessary.
As the forest becomes established the available light will diminish. Pioneer species are usually intolerant of shade and will die as a canopy of longer-lived trees becomes established. Successful reforestation requires a balance between species with differing light requirements. Care should also be taken to establish a community of understory and herbaceous plants. This is essential for a healthy riparian forest.

Illustration /Sketch



10.2	**Stabilization of upper streambanJ6i0.02 164.88 747.5003 Tmasloodplain a747s368.8 23.960**

Reforestation of Riparian Forest

10.3	**Stabilization of upper streambank and floodplain areas**

Maintenance of Existing Riparian Forest

Group No	Group of measures habitar fgr w
10.3	**Stabilization of upper streambank and floodplain areas**

Maintenance of Existing Riparian Forest	Gehölzbestandene Uferrandstreifen

Group No	Group of measures
10.4	**Stabilization of upper streambank and floodplain areas**

Measure name	Synonym
Live Stakes and Dormant Posts	Steckhölzer, Palisaden

To stabilize banks using short live stakes driven into the ground at varying spacing. These live stakes, usually species of willow, will root and not only stabilize the bank, but also extract soil moisture. Live stakes are also used to peg down mattresses (measure 9.7), rolls(8.1) and other bio-technical devices. Larger live stakes (called “Dormant Posts” by USDA,1996.p. 16-38 and SCRH 32), also harvested during dormancy can be used can be used on lower sections of the streambank. Successful rooting rate for large stakes is lower than for smaller stakes.

A simple, low cost technique, applicable on all sloping sites that do not require substantial mechanical protection during establishment (when Measure 9.7 Brush Mattresses would be appropriate). Valuable for stabilizing persistently wet areas. Live stakes can also be used in combination with several other measures.
The measure is usually used to stabilize banks above bankful stage but may be used on lower slopes if combined with an erosion control fabric or other bio-technical measure. Larger dormant posts are more appropriate on the lower bank.

Group No	Group of measures
10.5	**Stabilization of upper streambank and floodplain areas**

Measure name	Synonym
Seeding Grass and Legumes	Deckbauweisen Grass Leguminose

Purpose	Applications
Seeding of grass or a mix of grass and legumes is used to stabilize sites not susceptible to serious erosion. Sod may be used when soil protection is required immediately	Seeding with grass can be used on sites not susceptible to serious erosion and where a quick, low-cost solution is required. Legumes may be included in the seed mix if pH conditions are correct.

Temporary Cover Crops. Disturbed areas subject to erosion can be protected through a temporary cover crop until a permanent cover is established. Cover crops are usually agricultural crops, selected for rapid growth and good coverage. Small grains, which can be planted in the spring or an over-winter crop in the fall, are often used. Species chosen may be Barley, Oats, Rye, Italian ryegrass, Millet, Boer or Lehmann's Lovegrass or Sudangrass. **Permanent Cover**. Erosion characteristics, as well as the intended use of a site and growing conditions should be considered when selecting a seed mix. It is also important to select a seed mixture suitable for a maintenance program, which is realistic on the long term. Legumes are capable of fixing atmospheric nitrogen and should be included in seed mixes for areas where growth is poor

10.5	

Seeding Grass and Legumes

Group No	Group of measures
11.1	**In-stream habitat improvement**

Measure name	Synonym
Fish Ladders	Fisch-Aufstiegshilfen

Maintenanc0.75294 g0.5983 -0.0427 TD(p)m7 8(70.0427V)Tj0 g-0.0427 0.0427 TD(n)Tj1l5.752.o(70.0 434 w6 -2D-527 .04.88 lS0.08 reW n317T948558 92.4 631.82

All fish passages tend to clog with floating debris during storm events and require frequent maintenance. This particularly applies to Basin Passage Fish ladders and Vertical-Slot-Passes.
Denilpasses and Ground Ramps are less susceptible to clogging.

11.2	**In-stream habitat improvement**

Log, Brush or Rock Shelters

11.2	

Log, Brush or Rock Shelters

Group No

11.3

Group of measures

In-stream habitat improvement

Measure name

Lunker Structures

Synonym

Lunker Fischunterstand

Purpose

The principal purpose of a Lunker structure is to improve stream habitat by providing an undercut shelter for fish. The structure will also give some protection of eroding streambanks but other bank protection techniques are more cost effective unless habitat improvement is important.

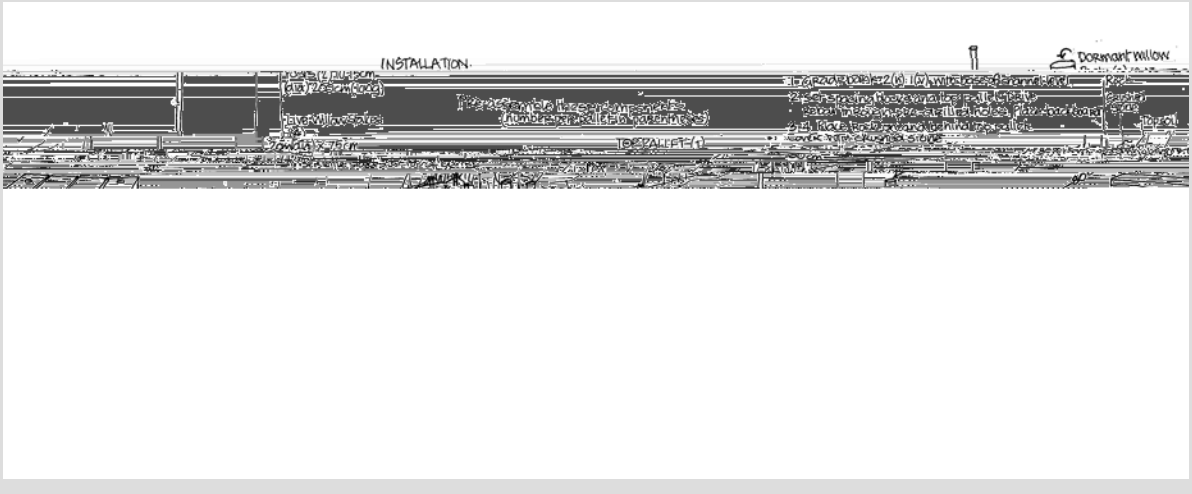
Applications

Applicable for sites where the improvement of fish habitat is a high priority and where streambank erosion protection is also needed. The outside of bends where a deep shaded pool is desired are usually most suitable sites. Lunker structures should be used on streambanks where the depth of water during baseflow conditions is at least 25 cm. This is to insure that the structure is always below water and permanently waterlogged. Otherwise wetting and drying cycles will cause the structure to decompose rapidly

Description

Lunker structures are cell-like structures made of two pallets of stout oak boards separated by wooden spacing blocks. One pallet is placed horizontally on the bed of the stream against an eroding bank. Oak spacing blocks are placed at each corner and a second pallet laid on top. This top pallet should be below baseflow water level. Large rock and crushed stone are then placed over the structure and finally topsoil graded smooth with the existing bank. Pallets should be pre-constructed off-site. Both pallets are 80 cm square. The bottom pallet is constructed of two stringers 5 X 20 cm and three cross boads with the same dimensions nailed at 90 degrees. For the top pallet the stringers are 160cm long allowing 80 cm to be buried in the stream bank. Four crossboards are used, butted tightly together. Spacing blocks should be 20 cm square and predrilled with 1.5 cm holes for rebar spikes. These holes should be aligned with four holes drilled in both pallets, aligned with the holes in the spacing blocks on each corner. The structure may consist of one or a series of cells along the streambank. The length of streambank to be treated is first prepared by cutting back with a backhoe and levelling the stream bed. The streambed must be perfectly level or piched very slightly into the bank. The bottom pallets are placed im position and weighed down temporarily. Spacing blocks are placed at each corner and the second pallet on top with the excess stingers sxtending into the bank. The structure is then secured by driving 1.5 m lengths of 1.5 cm rebar through the predrilled holes in the pallets and spacing blocks into the bed of the stream channel. A 5 X 25 cm oak backboard is then placed vertically against the rear side of the structure. The space between the bank and the stucture is then backfilled with rock (dia 30 cm) which shoud extend over the „roof“ of the structure. Crushed stone is placed over the rock followed by a 30 cm layer of topsoil. Dormant willow posts (measure 54) can be used to provide long-term bank protection and habitat improvement.

Illustration /Sketch



11.3

11.4	**In-stream habitat improvement**

Boulder Clusters

11.4	

Boulder Clusters

12.1	**Flood damage control**

Levees and Floodwalls	Deiche, Hochwasserschutz

12.2

Flood damag6f3cntrol

Flood Proofing and Water Pollution Control

Gro

12.2	**Flood damage control**

Flood Proofing and Water Pollution Control	Struktur Hochwasserschutz

Group No

12.3

Group of measures

Flood damage control

Measure name

Emergency Access and Flood Warning Svstems

Synonym

Zugang für Rettungsfahrzeuge, Flut Warnsystem

Purpose

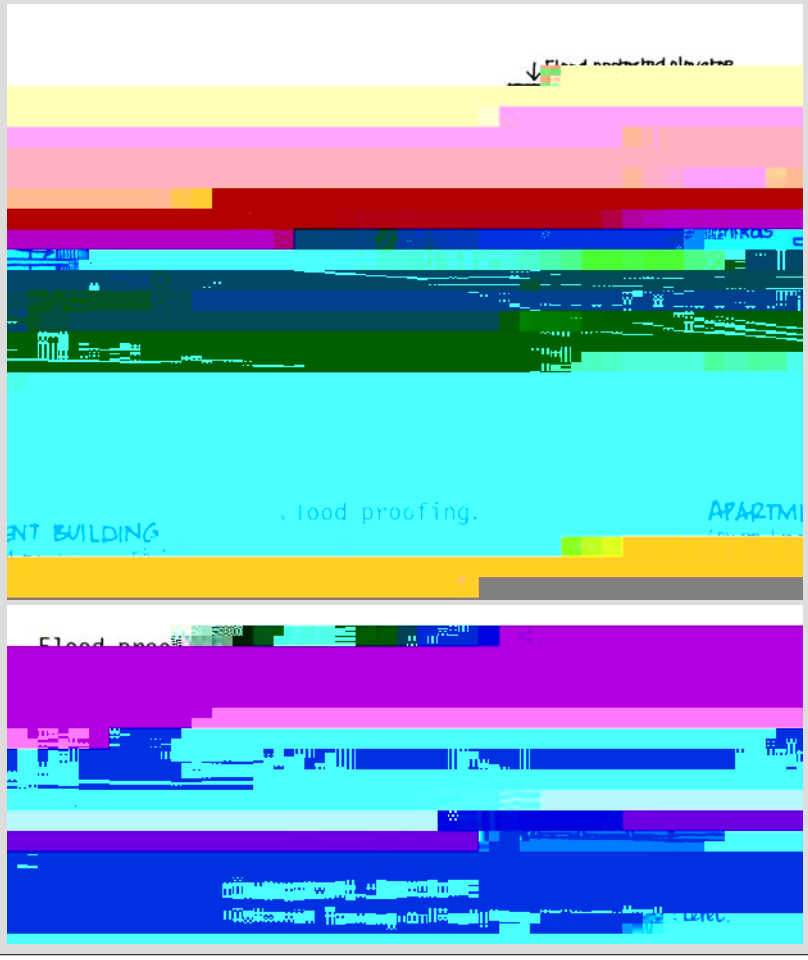
Structures should be accessible by elevated access ramps and catwalks. For structures with high intensity uses access ramps need to be suitable to be used by emergency vehicles. Flood warning systems for communities should be developed to be timely, accurate and neighbourhood specific. To provide early warning of potentially damaging flood events that are as accurate and area specific as possible.
To provide access to critical facilities located in flood prone areas during flood events.

Applications

Flood warning systems are applicable to all flood prone areas. Access to facilities in the flood plain during a flood event may be critical for some uses such as wastewater treatment plants.
Early warning is also critical for flood managers on controlled river systems who are responsible for allowing flooding of some rural areas to relieve pressure on urban areas.

Descriptionn

Early flood warning systems are essential for all food-prone areas to avoid danger and property damage. Flooding due to the cresting of flood flows in major river systems are easier to predict than local flash flooding due to convectional storms. On controlled river systems, it is usual to allow some rural areas to flood to relieve pressure on urban areas downstream. In these cases, it is essential that the sequence of flooding be based on a sound interpretation of flood warning systems. Clearly assigned responsibilities and procedures on receiving food warnings are critical. Structures can be made accessible during floods by elevated access ramps and catwalks, but care should be taken to avoid exacerbating the turbulence of flood flows. For some structures with high intensity uses, access ramps must be accessible by emergency vehicles. The columns on which elevated structures are built must be designed not only to withstand storm flows but also the accumulation of floating debris that may increase loading greatly.



Group No

12.3

Group of measures

Flood damage control

Measure name

Emergency Access and Flood Warning Systems

Synonym

Zugang für Rettungsfahrzeuge, Flut Warnsystem

Maintenance

Periodic practice of flood drills are advisable and help to eduacate all who live or work in food-prone areas about the nature of floods and effective actions that can be taken. These drills will also draw attention to emergency routes that must be kept clear at all times in case of emergency.

Advantages

Flood warning systems can allow sufficient time to evacuate threatened areas. They can also give time for emergency prevention measures to be taken.

Disadvantages

Electronic warning devices, such as TV and radio may be damaged by the storm causing the flood

Examples

The Master Plan for the "Hafencity" waterfront development calls for elevated emergency routes and pedestrian catwalks at an elevation of 7.20 m to permit evacution during flood events.
Source: City of Hamburg, Germany

References and suggested reading

Tourbier, J. Toby; Westmacott, Richard: Water Resources Protection Technology. A Handbook of Measures to Protect Water Resources in Land Development. ULI- The Urban Land Institute; Washington, D.C. 1981.

Example Photos