STORMWATER MANAGEMENT CONCEPTS AND THEIR APPLICATION TO TOWN PLANNING

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Die konvensionele stormwaterbeheer praktyk het dikwels meer probleme geskep as wat dit opgelos het. Dit het gelei tot die ontwikkeling en toepassing van die nuwe tegnologie wat bekend staan as 'stormwaterbestuur'. Dié nuwe praktyk geniet 'n toenemende mate van aanvaarding en die beginsels is ingelyf in die voorgestelde "Riglyne vir die voorsiening van Ingenieursdienste in Residensiële Dorpsgebiede".

In hierdie artikel word sommige breë beginsels uitgewys en voorbeelde van hul toepassing word gegee. Die feit dat stormwaterbeheer as 'n geintegreerde deel van die beplanningsproses beskou moet word en nie as 'n geïsoleerde aktiwiteit nie, is beklemtoon.

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1. INTRODUCTION

The realization that conventional stormwater practice creates more problems than it solves has led to the development of the technology termed "Stormwater Management". Stormwater management concepts are aimed at managing a resource, which stormwater undoubtedly is, in a cost effective, environmentally sound, creative way so that the community which it serves, derives continued benefits from the resource.

These concepts are gaining widespread acceptance through the activity of the National Building Research Institute of the CSIR and have been incorporated into the proposed "Guidelines for the provision of Engineering Services in Residential Townships".

2. THE WATER CYCLE AND STORMWATER RUNOFF

The implications of stormwater runoff as an integral part of the water cycle have not adequately been taken into account in the past by planners and engineers.

Under natural conditions, rainfall runs off the land into streams, or infiltrates into the ground to appear as springs or seeps. Some groundwater reaches deep aquifers taking perhaps centuries to move slowly toward the sea, eventually to close the cycle by evaporating into the atmosphere.

Stormwater runoff is part of this water cycle, and usually occurs in amounts that form the natural drainage system. The drainage pattern of an area has evolved over a long period of time until it has reached a stage of dynamic equilibrium.

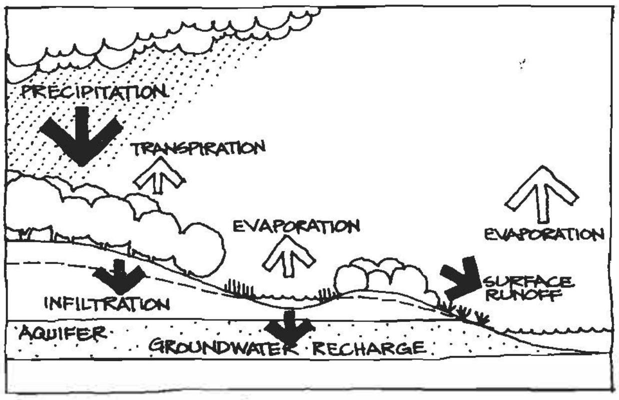
However, the removal of vegetation and the concentration of stormwater from large paved areas into concrete-lined channels and stormwater pipes increases the amount and rate of water discharged from the drainage area, which adversely affects the hydrological regime. By affecting one component of the water cycle, such as the amount or rate of runoff water, the dynamics of the whole drainage system can be affected.

3. HYDROLOGICAL EFFECTS OF URBANISATION

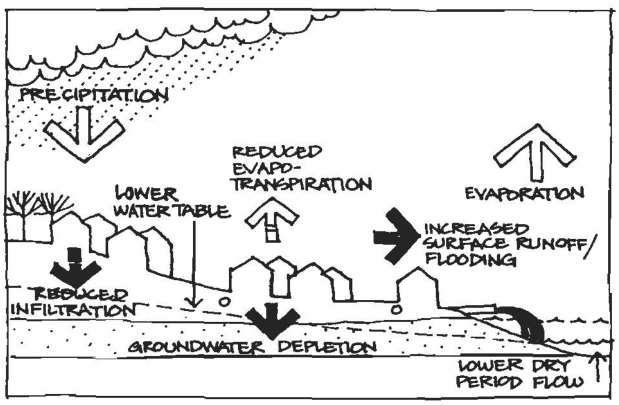
Urbanisation of raw land invariably leads to an increase in the hardened area within a catchment. Stormwater drainage practices in the past have been aimed at the removal of the water, as quickly as possible and in the most efficient manner possible. Invariably this has meant larger and larger stormwater pipes in which the runoff is transported quicker than it was over the raw land. Stormwater systems have been designed in the past to meet this narrow goal without regard for the possible environmental effects – particularly the impact on rivers.

The consensus of opinion of experts in the USA and Canada, current leaders in this field, regarding the major problems encountered with the previous policy, are:

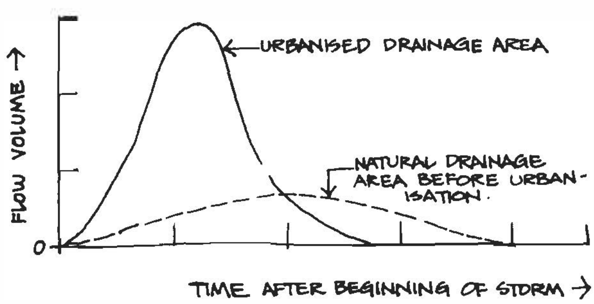
* High peak flow rates and volume discharges from an area requiring progressively bigger and more expensive installations as the flow passes down a catchment.
* Increased damage from flooding due to the volume and rate of runoff occuring at a more frequent time interval, and a reduced time lag between a rain storm and the discharge of stormwater from the system. This in turn triggers the building of flood control structures and larger storm sewers.
* A reduction in groundwater recharge and a lowering of the water table, thus detrimentally affecting the existing vegetation.
* A reduction in the normal flow down rivers, lower flows and possibly drought conditions during dry periods, which upset the balance of aquatic life.
* Increased and excessive erosion of river banks due to the higher peak flows at more frequent intervals, resulting in increased siltation downstream.
* Increased pollution of rivers and water sources from industrial and residential fallout onto hardened surfaces. The surfaces are washed clean



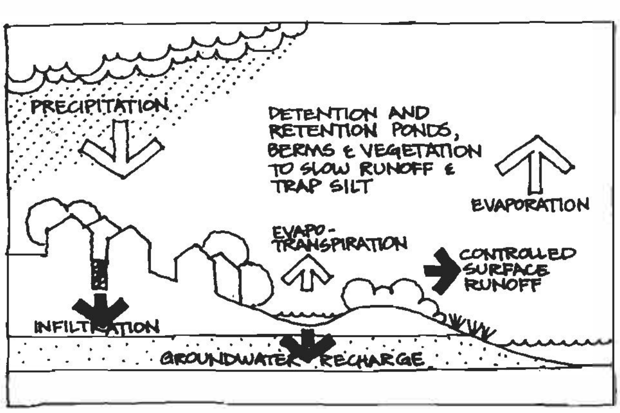
WATER CYCLE: NATURAL WATER BUDGET



EFFECTS OF URBANISATION ON THE WATER CYCLE



SCHEMATIC HYDROGRAPH SHOWING RUNOFF CHARACTERISTICS BEFORE, AND AFTER URBANISATION WITHOUT STORMWATER ATTENUATION.



STORMWATER MANAGEMENT TO MAINTAIN HYDROLOGICAL EQUILIBRIUM

by rainfall runoff and the pollutants carried to the river body.

4. STORMWATER MANAGEMENT CONCEPTS

The principles embodied by stormwater management attempt to prevent these problems. Techniques are used to neutralise the effect of concentrated stormwater runoff, and to maintain as far as possible the equilibrium which occurs under natural conditions. The main concepts can be stated as follows:

* *The natural drainage pattern should be retained intact* as far as possible in any new development. Generally, the more the natural land patterns are altered, the greater the engineering and development costs for a site will be.
* *In any urban development there exists two separate drainage systems; the minor system consisting of pipes and canals and the major system consisting of overland flood routes with preordained servitudes.* The major system will be activated whenever the capacity of the minor system is exceeded or malfunctions. Therefore the minor system should be designed to cater for the nuisance and inconvenience value attached to frequent small storm events whereas the major system should be designed to protect and alleviate flood damage from the infrequent large storm events.
* *Rain falling on a site must be retained and infiltrated after development* such that the runoff from the site will be nearly equal to both the rate and volume of runoff occurring from the site prior to development.
* *Peak flow rates and discharge volumes can be reduced* by the design and construction of stormwater detention and infiltration facilities in order to match the runoff rates and discharge volumes occuring before development. The concentration of runoff water can be minimised by avoiding large impervious surfaces and extensive concrete-lined channels.
* *Stormwater is a part of the water resource* which must be protected rather than disposed of without careful consideration. Runoff water should be allowed as far as possible to seep back into the ground to

replenish streams and groundwater resources. Natural flood plains and vleis are areas which require special consideration.

* *Pollution of the water resource, erosion of natural channels, siltation of estuaries can be controlled* and the effects ameliorated. Detention facilities, retention facilities, undulations, berms, silt traps and vegetation cover are all measures that can be combined to ameliorate these problems.
* *"Blue-green" facilities which combine the land use applications of stormwater and recreational areas provide multi-purpose facilities for the community.* Within the management of the stormwater runoff from an urban area, the opportunity exists to provide recreational areas associated with stormwater facilities. This type of facility is popular with the community and local authorities.

5. APPLICATION OF CONCEPTS

5.1 Planning Implications

One of the modern trends in town planning, especially in the new towns under development, is towards a higher density of housing, on smaller plots with a greater concentration of hardened areas. These developments have incorporated a greater amount of open space in the form of green belts, play parks and pedestrian walkways.

The design and implementation of the major drainage system should ideally be incorporated within these green belts. In other words the green belt system should be located along the overland flood routes, which will be the topographically low areas within the development. Once the objective is achieved of allowing the stormwater to flood into a linear green belt system flood attenuation techniques can be incorporated in the green belts.

The drainage routes, required for movement and storage of urban stormwater, can provide an extension of a linear park and open space network which can link residential areas to employment areas, shopping centres, schools, and parks. Drainage servitudes provide ideal paths for pedestrian routes, jogging pursuits and bicycle paths.

Stormwater detention/retention facilities themselves provide opportunities for park and recreational areas. If they are incorporated into stormwater flood routes and the linear park system, they can provide the nodes for larger activities such as soccer fields, cricket fields, rugby fields, golf courses, etc.

5.2 Design Techniques

Some of the techniques which could be applied in the green belts are:

* detention ponding areas with positive drainage to empty within the shortest design period (e.g. 4 hours).
* gently graded grassed areas with a longitudinal gradient equal to or slightly less than that of the original groundline;
* landscaping the green belt in order to lengthen the flow path of the runoff;
* small berms, shaped so that mowing is easy, can be used to detain portions of the flood waters.

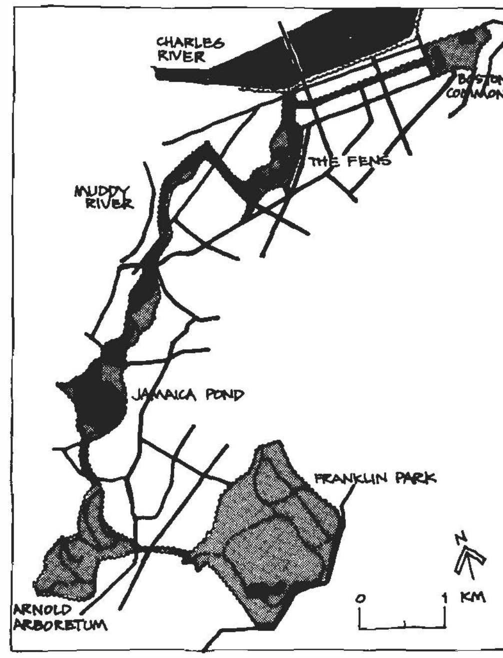
The operational aspects of the major system require careful consideration and design. Once the major system is designed the level of flood frequency required for the minor system can be optimised. Street layout and grade design can eliminate some small pipes and reduce the minor system to a minimum if the togographical features of the site are used to advantage.

5.3 Some Examples

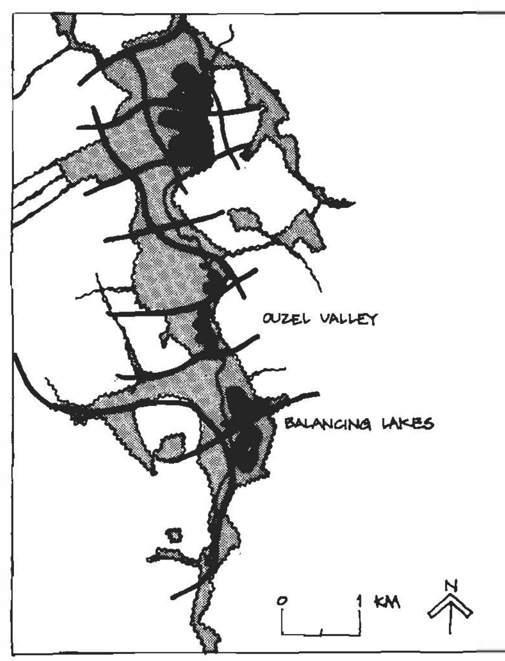
The linear park system in Boston, developed by Olmstead in the 1880's served not only for recreational uses, but also for flood control along the Muddy River, and became a model for open space planning in many other cities.

A more recent example of stormwater management on a large scale, is that of Milton Keynes New Town in the U.K. The network of linear parks, based on river valleys and other natural features, forms one of the main structuring elements of the new town. The park areas include flood land and balancing lakes to control runoff from the new urban development.

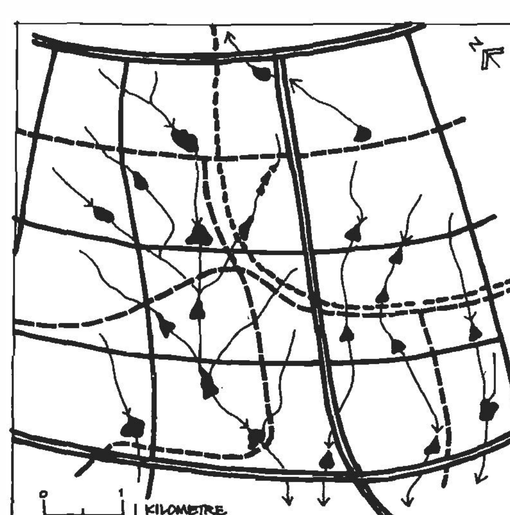
The Atlantis 2 New Town, which is currently being planned, will incorporate a comprehensive network of stormwater detention facilities as part of the open space system. Since Atlantis is located on a sandy, wind-formed landscape, with poorly developed surface drainage, the stormwater system will have to be more contrived.



BOSTON'S LINEAR PARK SYSTEM WITH FLOOD CONTROL PONDS



MILTON KEYNES PARK SYSTEM WITH BALANCING LAKES FOR FLOOD CONTROL



STORMWATER DETENTION SYSTEM FOR 100-YEAR FLOOD AT ATLANTIS TOWN 2.

5.4 Atlantis New Town Detention Facilities

The existing urban development at Atlantis is divided into sub-catchment drainage areas. Each sub-catchment is drained by the conventional pipe system which discharges into a detention pond at the low point in the catchment. At the pond the flood peak is reduced so that the peak flow rate and the discharge volume during the hour of maximum discharge are nearly equal to that which would have occurred if the sub-catchment had not been developed.

Six such ponds have been constructed, four of which have been operating since October 1978. The inlet pipe size to these ponds have been in the order of 1 500 mm diameter and outlet pipe size in the order of 525 mm diameter. The cost savings in the stormwater conveyance system downstream of the ponds has been conservatively estimated at 50% of the cost.

The ponds have been designed to operate so that they will be dry between runoff events. This lends the ponds to development for recreational facilities. One of the ponds is shortly to be grassed and used as two soccer playing fields, and as the community grows, their needs will formulate programmes to develop the remaining ponds into multi-purpose recreational facilities.

5.5 Atlantis New Town: Major-minor Drainage with on Site Detention

In a recent residential development at Atlantis this technique was applied with a result that:

* an estimated 12% saving in the stormwater drainage cost was achieved;
* increased flood protection was provided. The major system provided for flood protection against a 100 year event whereas the compared conventional design provided for protection against a 10 year event;
* landscaping of the green belt area formed part of the stormwater drainage costs. Previously the development of the green belts was allocated a separate cost therefore an additional saving was achieved on the green belt development costs.

Other environmental benefits of stormwater management are greater seasonal equilibrium in river flow, reduced erosion and siltation, and replenished groundwater supplies for irrigation and tree growth – an important factor in the water-stressed environment of the West Coast.

6. REGULATORY CONTROLS

There is a movement in South African drainage practice by local authorities towards imposing restrictions on the increase in stormwater runoff from any new development. The wider implications of this movement can only be to the benefit of the community.

The U.S.A. and Canada have been enforcing restrictions in runoff for a number of years. Generally, they have found that if a stormwater management plan for an area is to be successful, the local authority controlling the whole catchment should coordinate and supervise the activities. However, it is also accepted that stormwater problems are site specific and each particular site needs careful consideration. The use of performance standards applied on a site-by-site basis, rather than uniform zoning, is more likely to be responsive to the natural landscape, since different combinations of soil types, slopes and vegetation cover determine the amount of runoff from a site. A model has been put forward, which sets limits on the amount of impervious cover – houses, driveways and streets – permitted on a site based on the natural capacities of that site.

The maintenance of the facilities required for stormwater control must, inevitably, rest with the local authority. Non-performance of the facilities, due to poor maintenance, will adversely effect the operation and acceptability of the facility. Careful design can prevent most of the problems, however, the local authority must exercise its control to ensure design solutions that will not unnecessarily add to the maintenance budget.

The impending publication of "Guidelines for the provisions of Engineering Services in Residential Townships" by the C.S.I.R. will probably signify a major movement by local authorities to restrict and improve the quality of stormwater runoff. Few places have progressed to undertaking overall municipal stormwater management within a watershed context.

7. CONCLUSION

The escalating cost of providing for the removal of stormwater from urban areas has led engineers to look for alternative methods by which stormwater can be effectively managed. An important solution to this problem is the recognition that the combination of parks and outdoor recreation facilities with urban drainage servitudes, scenic recreation ponds and stormwater detention facilities is feasible and moreover attractive to the community.

The engineer realises he cannot provide the cost saving or the community benefits accruing from a stormwater management policy without the active participation of the town planners, landscape architects and architects. The topographical features constrain the positioning of stormwater facilities and premature planning without full consultation between the drainage engineer and the planners might prejudice the opportunities for applying stormwater management principles at a particular site. Properly coordinated within a design team of professionals, stormwater facilities can be provided in a creative way, to be both attractive, functional and cost effective.

The narrow approach, where stormwater design is treated as an isolated activity, has proved to be inadequate, and is being replaced by a more realistic approach in which stormwater management is seen as an integral part of the urban planning process.

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