Water and Environment Journal

Water and Environment Journal. Print ISSN 1747-6585

Water-sensitive planning: integrating water considerations into urban and regional planning

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Keywords
hydrology; integrated water management; land-use planning; planning; sustainability; water; water resources.

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doi:10.1111/j.1747-6593.2009.00172.x

Abstract

Water-sensitive planning (WSP) is an approach to sustainable development that integrates water considerations into urban and regional planning. Following a literature survey and a condensed report of our 15 years of studies, the paper presents WSP's goals, domains, principles and practices and the paradigms that underpin them, with special attention to stormwater management. It encompasses all planning scales, from the building lot to the catchment area. The paper ends with suggested generic planning principles that evolved with the growth of WSP but are intended to also serve other domains of planning for sustainable development.

Introduction

Water-sensitive planning (WSP) integrates water considerations into urban and regional planning. WSP aims to promote sustainable development and construction. Its goals are: Improving the planned environment for its users, augmenting water resources and improving their quality, reducing the negative impacts of stormwater, preserving ecosystems and achieving all this in a cost-effective way and with involvement of citizens. Thus, WSP serves simultaneously and synergistically social, environmental and economic goals and objectives.

This paper presents WSP as it evolved over 15 years of research work, case studies and contributions to the creation of national and municipal guidelines and statutory planning directives. It opens with a brief survey of related studies in several countries and an overview of our work with its special characteristics. In light of space limitation, we condensed the details of our studies and devoted most of the space to presenting and explaining its product: The principles we developed, the suggested practices and the paradigms that underpin them. These constitute the framework that we call WSP. The paper ends with a set of generic principles for sustainable development.

The evolving international knowledge and experience

New approaches to stormwater management have been developed contemporaneously in several countries in the last two decades, without much communication among the countries. All of them adopted sustainable development as an umbrella goal, yet different objectives motivated the initial research effort in the each country.

Researchers in Australia, like the Water Sensitive Urban Design Research Group (1989), were among the first to investigate the subject. Bekele & Argue (1994) connected urban planning with stormwater management mainly in order to protect groundwater in aquifers; Taylor & Wong (2002) published a series of technical reports regarding best management practices (BMPs) for treating stormwater quality; runoff quality is also the subject of a guide published by Engineers Australia, National Committee for Water Engineering (2006); Fletcher *et al.* (2004) dealt with flood protection and environmental objectives on the regional and national scale; a broad approach of Integrated Urban Water Management was suggested by Mitchell (2004). In spite of impediments, Australia has advanced on the way to implement WSUD, first in various states, including Western Australia, Victoria, New South Wales and Queensland, and later by the national government. Recently, because of the most severe drought since European settlement, the subject of stormwater management – quantity and quality – is considered a topic of national importance (Roy *et al.* 2008).

In the United States, protection of water quality in streams and lakes from overland flow pollution has been a driving objective for stromwater management since the

1970s [United States Environmental Protection Agency (USEPA) 1999]. More recently, drainage engineers (Konrad *et al*. 1995), landscape architects (Ferguson & Debo 1990; France 2002) and planners (JAPA 2007) have suggested new ways to promote the same and related objectives, working mostly in their separate disciplines and only lately with some degree of integration. Among approaches that have been suggested and tested are 'limiting imperviousness' (Arnold & Gibbson 1996; Moglen & Kim 2007), compact development and increased housing density (USEPA 2004, 2005, 2006), and low impact development (LID). LID was pioneered by Prince George's County (1999) in Maryland; it requires that the hydrological response (in terms of runoff volume from each storm leaving the developed unit) be kept as it was before development, while allowing the planner to select the means for achieving this. LID has been adopted by the USEPA (2007; see USEPA 2000 for a literature survey) as a leading planning approach for runoff management, stating that 'One of the most exciting new trends . . . today is the movement by many cities, counties, states and private-sector developers toward the increased use of Low Impact Development (LID) to help protect and restore water quality'. The USEPA estimated the cost of implementing sets of LID BMPs in comparison with conventional development in 17 locations; the results show savings of 15–80%, relative to conventional design, in all cases except one (USEPA 2000).

Japanese researchers, aiming at flood protection and urban stream restoration, developed models, and conducted longitudinal field studies in which they measured the regulating effect of retention, detention and infiltration on the volume and discharge of runoff (Herath *et al*. 1993; Musiake *et al*. 1999). The Government of British Columbia in Canada (2002, manual on the web) adopted an approach to stormwater management: 'ADAPT – Agree that stormwater is a resource; Design for the complete spectrum of rainfall events; Act on a priority basis in at-risk catchment basins; Plan at four scales – regional, watershed, neighbourhood and site; Test solutions and reduce costs by adaptive management'. A simulation model was developed (Canadian Water Balance Model online) and subsequently adopted by all Canadian Provinces for evaluation of planning alternatives. In Britain, the focus was primarily on sustainable design of urban drainage [Butler & Parkinson 1997; Butler & Davies 2000; Andoh & Iwugo 2002; Construction Industry Research and Information Association (CIRIA) 2004]. The British CIRIA subsequently widened the scope and turned from sustainable drainage to sustainable water (and wastewater) management in connection with land-use planning, taking into account social, economic and environmental aspects (CIRIA 2006). Last, but not least, extensive research in New Zealand (van Roon *et al*. 2005; van Roon 2007) strives to go beyond alternative stormwater management to an integrated urban and rural design and development process, studying the various relevant issues, including barriers to implementation.

The movement towards comprehensiveness, which has recently been taken by researchers in Australia, Britain, New Zealand and the United States, characterizes also our studies in Israel. We started small and gradually expanded. In 1993 we began with just one goal in mind and a limited geographical scale: Conservation of water resources, especially recharging runoff into groundwater in Israel's Coastal Aquifer, emphasizing 'on site' infiltration in individual (private and public) building lots. We used rainfall and land-use data in selected locations, with existing and self-developed models (SCS, SWMM and HMM), to simulate the differences in runoff volume and infiltration between conventional building practices and implementation of WSP means, mainly impervious areas (roofs, paved spaces) connected to pervious ones (lawn, garden) (Carmon *et al*. 1997; Shamir & Carmon 1999; Katz *et al*. 2001; Kronaveter *et al*. 2001). A main conclusion we reached is that by 1990 the Coastal Aquifer, Israel's main aquifer, had lost 70 million cubic metres of water per year through reduced infiltration due to urban development, and that if the same development practices continue, the loss would reach 150 mcm/year by 2020; this loss could be reduced significantly by simple means, such as connecting impervious to pervious areas in yards.

We moved from studies of the individual lot and urban block to the neighbourhood level, conducted field measurements of runoff quantity and quality that were compared with simulation results (Burmil *et al*. 2003). We increased our interest in additional goals of WSP, such as urban water conservation (Be'eri *et al*. 2005) and urban quality of life (Hadad 2007), and expanded to working on larger geographical scales – the region/river catchment basin and the country as a whole (Shamir & Carmon 2007).

Through 10 successive research projects in a period of 15 years, we gradually increased the scope of *comprehensiveness* and advanced towards *integration*. Currently, our work emphasizes the integrative principle of *Multiple goals and common means*, side by side with another four integrating principles:

(a) *Multiple goals and common means* – WSP's goals encompass preservation of water resources – groundwater, streams, etc. – quality and quantity; preventing – or at least decreasing – flooding, while reducing drainage costs; protection of ecological systems; using runoff water to reduce use from conventional sources; improved urban quality of life, in terms of green and healthy environment. Frequently, the goals include also promotion of social capital, through peoples' contacts to advance joint objectives, and interagency cooperation. Each of the WSP means/practices, such as detention, retention and infiltration facilities, can potentially serve several goals simultaneously, thus promoting integration and synergy in goals achievement.

(b) *Integrating research approaches and methods* – We combined critical reviews of the international literature with our own studies, covering a variety of methods: field measurements, simulation with hydrological models, workshops of brainstorming with practitioners in various professions, some economic analysis, social and administrative feasibility study; all these together are the basis of WSP policy and its principles.

(c) *Interdisciplinarily* – Not only multidisciplinary but also interdisciplinary work of planning and design, landscaping, hydrology and water resources management, ecology, economics and sociology. The various disciplinary professionals work together and are required to cooperate and integrate their work, starting from the initial stages of every planning project.

(d) *Integration along levels of planning* – Identifying common principles for planning at all levels, from the private yard to the neighbourhood, city and catchment area (see below 'The 3Ms of stormwater management').

(e) *Integration between research and implementation aspects* – Two-way flow of knowledge, insights and conclusions between researchers and practitioners.

This paper is the first publication of the integrated research project. [Our publications in English in the 1990s were mentioned above. Since then we issued research reports in Hebrew only, including a comprehensive policy report (Shamir & Carmon 2007), trying – with considerable success – to challenge and change the conventional wisdom and practices in Israel.] It focuses on our policy recommendations, on suggested principles and BMPs. Because of space limitations and our wish to present the integrated approach as a whole, not in all places could we elaborate the rationale and findings which support the suggested policies and guidelines, but we provide some essential support to most of them.

Urban WSP

WSP is intended to be implemented primarily in newly developed areas (greenfields). However, most of WSP's percepts and means are also relevant to infill and redevelopment projects (brownfields), and can be gradually introduced into existing urban fabrics as well.

Placement and design of open spaces and roads

A leading WSP principle is placement of open spaces and roads in accordance with the natural hydro-geographic layout. Compliance with this principle determines to a large extent the level of achievement of WSP's goals and the corresponding price. WSP requires planners to start the spatial planning of an area with such placement, before other land uses are located.

Open spaces play critical roles in city life, as places for leisure activities, as air refreshers and also as receptors of stormwater. This is true for all their sizes, from large urban parks to a private yard. Where open spaces are located in consideration with the natural stream system, they can also be used for preventing and mitigating floods by retention and detention of stormwater (Herath *et al*. 1993; Ishizaki *et al*. 1993; Musiake *et al*. 1999) and for purifying and infiltrating runoff, thus recharging groundwater with clean water (Burmil *et al*. 2003). Stormwater that reaches open spaces may be used for irrigation and also serve as landscaping elements (Glenn 2002; Hadad 2007).

Roads and streets constitute up to 70% of the impervious urban area (Wong *et al*. 2000) and serve primarily for transporting people and goods. But they also act as conveyors of stormwater; in fact, they constitute the major drainage system that serves as important flow path when the drainage pipes underneath are charged beyond their capacity [American Society of Civil Engineering & Water Environment Federation (ASCE & WEF) 1992, pp. 50–56, 250–260]. They should therefore be designed in close consultation between planners, road engineers and drainage experts, all taking into account WSP guidelines, including: Creating continuous flow paths along roads to the outlet of a regional drainage system, without going through local depressions that have no natural outlet; as far as possible, distance roads from natural tracks that serve to drain runoff from large built areas (2–3 km^2); and to the extent possible, lay out streets that avoid going down steep slopes, which increase the velocity of flow and act to accumulate runoff rapidly in the downstream areas.

Preservation and rehabilitation of urban streams

WSP advises cities that have a stream in or close to the built areas to maintain it, revive it if it has deteriorated, place along it open spaces and make it accessible to the public, in a manner that enhances its social and ecological functions, while preserving its role in the flood protection scheme. International experience shows that revitalizing streams can leverage urban quality of life and provide a central artery to the city, an asset that has the potential of changing the image of the city and carrying immense economic value. A striking example is the rehabilitation of the river Cheonggyecheon in Seoul, which required the displacement of a major highway in the middle of a city of 10 million residents (Seoul Museum of History 2005; more modest examples are found in Green Places 2007). Small creeks, even those that flow only in the rainy season, are also valuable as environmental and social assets. 'Day-lighting' of streams and creeks is becoming more common, as their value is recognized (Booth *et al*. 2004).

Urban stormwater management

In ancient time people stored rainwater close to their homes and used it. The Romans, great city planners, were among the first to plan sophisticated methods to get rid of urban runoff. Since their days, it became the tradition to consider runoff as a nuisance, which causes flooding that results in inconvenience and damages, and must therefore be removed quickly and effectively from the built areas. Our work (Carmon & Shamir 1997; Carmon *et al*. 1997; Burmil *et al*. 2003; Shamir & Carmon 2007) led us to state that *runoff is a resource*, not merely a nuisance. Much of the work, especially the studies conducted with our graduate students (six research theses), was devoted to understanding the practical implications of this conclusion. The guidelines we developed, based on these studies and on findings found in the international literature, are presented below.

The 3Ms of stormwater management

Stormwater management should always take into consideration the context of the whole relevant catchment area, including consideration of the flows upstream and downstream of the planned unit area. Within that, and with due consideration to local conditions, the following 3Ms should be followed for every spatial unit, from a single lot and building block up to a neighbourhood and the whole city:

(1) *Minimize* the difference in *runoff volume* leaving the area after development as compared with the volume before it.

(2) *Minimize* the difference in *discharge* leaving the area after development as compared with the discharge before it.

(3) *Minimize* the *pollutant load* in the runoff leaving the developed area.

It is evident that we believe in maintaining the natural hydrological balance as the preferred state of affairs. In many cases this is an ideal rather than a specific number, and still WSP requires planners, engineers and decision makers to try their best to arrive as close as possible to this ideal. Needless to say, we have a responsibility to protect people and property from harmful flooding, even where their houses were mistakenly planned and built on floodplains. Yet, the above rules require us to think 'outside the box', remembering that sometimes built mistakes can be corrected (see the Cheonggyecheon example mentioned above), and that instead of the conventional protective dikes and large drainage systems, one may consider buying out endangered properties or closing down basements in floodplains and compensate their owners, for example, with building permits on the roofs.

The main tools for implementing the 3Ms of stormwater management are BMPs that have been developed and studied in several countries. Japanese researchers (Ishizaki *et al*. 1993) compared measurements of runoff, over a 10-year period, from an urban area with BMPs to runoff from an adjacent area without BMPs, and reported the 40 largest storms over this period; they found that the volume (per unit area) from the former is always reduced by at least 70% compared with the latter, and by more than 90% in half of these large storms. At the same time, the peak discharge (per unit area) of these storms is also reduced by a factor of 2–3. Measurements in the United States of the effect of BMPs (primarily grass swales) showed reduction of pollutant concentrations ranging between 15% (nitrates) and 87% (phosphorus), and of heavy metals (copper, lead and zinc) in the range of 43–64% (USEPA 1999).

In our work, we distinguish three types of BMPs: One – land use planning; second – land cover design; third – constructed facilities, such as reservoirs, swales and pervious paved surfaces.

BMPs I: urban land use practices

Common urban land use practices can be used to control urban runoff quantity and quality. Prominent among them is *higher-density development,* which serves multiple goals: Social (enables more and better services), economic (reduced costs), environmental (lower pollution loads), and also – lower runoff per housing unit. The following figures for the effect of building density on generation of runoff were calculated (USEPA 2005): 1 housing unit per acre – 530 m^3/year, 4 units per acre – 175 m^3/year from each unit and 8 units per acre – 140 m^3/year from each unit. The low density thus generates three times more runoff per housing unit than the medium density and 3.8 times more than the high density. In addition, because it consumes less land to accommodate the same number of homes, higher density development can also better protect regional water quality. *Mixed land use* of housing, employment and services may also be regarded as a BMP, because it reduces the area of roads and sidewalks and the size of parking lots. Because roads and parking spaces and lots take up to one-third of the urban area, reducing them contributes to decreasing the impervious areas and their negative effect on water resources and flooding.

BMPs II: land cover design

Land cover design can provide most useful means for turning urban runoff from nuisance into a water resource. Where managed with the 3Ms in mind, it enables catching most of the runoff generated by small and medium rainstorm events (which constitute up to 90% of all rainfall events), for either direct use – irrigation and landscaping, including roof landscaping, and/or for indirect use through recharge into the groundwater. Field measurements by us (Burmil *et al*. 2003) and others in Israel (Asaf *et al*. 2004, 2005) showed that the level of contamination of urban runoff from residential areas is low enough to suit both irrigation and recharge to groundwater by infiltration.

In countries with limited water resources, the use of BMPs of land cover design for *infiltration of stormwater into the ground*, mainly for recharging groundwater, may be a significant method for augmenting and possibly improving the quality of a scarce resource. This is especially true for the semi-arid country of Israel, in which much of the population growth occurs in and around the metropolitan area of Tel Aviv that sits above the coastal aquifer, which is the largest water storage of the country. Hence, much of our research concentrated on infiltration and groundwater recharge as a means for augmenting the water resource, with relative ease of implementation and moderate cost. An indicative simulation result is: In a region with rainfall of 600 mm/year and a relatively flat and pervious soil (3% slope, 30 mm/h), connecting the drains from 100 square metres of roof to a 10 square metre pervious area in the garden/lot reduced annual runoff volume leaving the lot by as much as 70% (with no specially constructed facilities) (Carmon & Shamir 1997).

Based on our work and on findings in the international literature, the following relatively simple and inexpensive land cover BMPs for infiltrating clean urban runoff are hereby suggested:

- *Reduce impervious areas and increase pervious areas*, caring for their vegetation not to consume too much water.
- *Intersperse impervious with pervious areas*, to which flows from the impervious areas are directed.
- *Pass runoff through vegetated patches and/or through the ground*, to cleanse the water from pollutants, especially from suspended sediments.
- *On-site infiltration*, i.e., try to maximize infiltration as close as possible to where it is generated, while avoiding damage to buildings and infrastructure. If possible, runoff should be infiltrated in the yard itself; if not then in the building block or the neighbourhood, and only the excess is allowed to flow to the urban drainage system.

Rules for on-site infiltration, in private and public yards are:

- *Make each yard into a microcatchment*, by placing a low wall around it, with an outlet to allow excess water to flow out. [Under the conditions on the Israeli Coastal Plain, a 20 cm high wall around the lot, or at least surrounding its lowest part, suffices (Katz *et al*. 2001).]
- Direct runoff from roofs and impervious areas to the pervious areas.
- Maintain soil permeability by avoiding mixing it with building materials and imported heavy soils and compaction.

BMPs III: constructed facilities

The professional literature is replete with information on constructed BMPs, their function, design and sometimes also their cost (e.g. USEPA 1999). Roughly, they can be classified into three categories: (a) *Point structures* – for example: a recharge well which receives rainfall from a roof drain or a yard; a sand filter, used to improve runoff quality before it is discharged downstream or recharged into the ground; a small neighbourhood reservoir as part of the landscaping; parking areas covered with a pervious pavement; (b) *Linear structures* – for example: infiltration channel in a park or large yard; porous underground drainage pipe; swales along a road and (c) *Local reservoirs* – volumes for detention, retention, infiltration and wetlands, of a size and design that still fit into the built area without endangering residents, especially children. As the protected area increases, so does the storage volume required to control stormwater; a particularly striking example is the huge underground storage facility in the City of Saitama (Japan: Saitama Storm Sewer System online) for flood protection during the monsoon season.

WSP's approach to constructed BMPs gives preference to *small, simple and cheap structures*, introduced into the urban fabric without disrupting it. Moreover, WSP is probably unique in its guidance to use them to simultaneously and synergistically implement the 3Ms enunciated above, i.e., to minimize the volume and discharge coming out of every land unit (emphasis on 'on-site handling'), to improve the quality of the runoff before it reaches the outlet and to use the runoff locally to improve the landscape and environment (Shamir & Carmon 2007).

The effectiveness of constructed BMPs of the modest type was calculated for a planned 40 ha (283 000 m^2) neighbourhood of 1400 households in single- and multi-unit buildings on Israel's Coastal Plain, where the average rainfall is 600 mm/year and the soil is moderately pervious (13 mm/h). The WSP included reconfiguration of the housing location and orientation, addition of open narrow canals, and small detention and retention pools in public spaces. Comparison with a conventional plan for that neighbourhood indicated improvement of the landscape and water quality, while reducing runoff volume by 60%, which went largely to augment the groundwater (Hadad 2007).

Regional WSP

The framework for regional WSP is the drainage basin, the area from which runoff flows to a single outlet, such as a river, a lake or the sea. In recent years, with the trend towards sustainable development, the term used is: integrated catchment management (ICM). This concept is central in the European Union's Water Framework Directive (Thornes & Rowntree 2006) that calls for ICM plans for each European river basin within the next 15 years. Yet in most countries, even those that have partly adopted urban WSP practices, the implementation of regional WSP – or ICM – suffers from lack of appropriate data and cooperative work of scientists and developers (Bowden 1999), and in general is rare (Roy *et al*. 2008).

Some of the literature on ICM is strictly ecological: 'Integrated catchment management seeks to take into account complex relationships within ecosystems: Between flora and fauna, between geology and hydrology, between soils and the biosphere, and between the biosphere and the atmosphere' (Bowden 1999). Others are interested in modelling the relationships between surface water and groundwater (Wheater & Peach 2004). Our work belongs to the group that tries to connect the various aspects and stakeholders: Scientists, professionals, policy makers and the public (Johnson *et al*. 1996). Like Falkenmark (2004) we search for the balance between humans and nature. The catchment area links two mosaics, one of human water-related activities and the other of water-dependent ecosystems, terrestrial as well as aquatic. To make the two compatible, a management task is required.

Catchment area master plan (CAMP)

The tool that is suggested for ICM is a statutory framework of a CAMP, a plan with hydro-geographical rather than political boundaries. The CAMP determines the location of new settlements, extension of existing ones and 'large' land uses, such as parks, industrial zones, shopping malls, power and desalination plants, reservoirs and waste disposal sites. While the primary considerations in determining their location are political, economic and social, WSP requires CAMPs to add to their goals also: Preventing or at least reducing substantially flooding and flood damages; protecting the quality and quantity of water in its sources; preserving local fauna and flora; and nurturing water bodies, mainly lakes and streams that create the balance between built and open spaces. For promoting these goals, CAMPs should contain core requirements for runoff management, including delineation of flood plains at prescribed probabilities, location of retention and detention reservoirs, setting low and high flow limits at certain points along streams and flow paths, and stating runoff quality criteria. The plan may contain 'protection zones' for water sources, such as along lake shores and around principal springs and wells.

Flood prevention (Blaikie *et al*. 1994) is a central goal of regional WSP. Instead of merely protecting against flooding, WSP prefers tools for averting flooding downstream by reducing flows leaving constructed upstream areas of the watershed. A major means for reducing the discharge are urban BMPs throughout the catchment area. Nehrke & Roesner (2004) showed, by simulations with rainfall data from Denver and Atlanta a significant reduction of peak discharges for return periods from 1 to 50 years, by placing a detention reservoir at the outlet from a planned neighbourhood. Sinai *et al*. (2006) suggested constructing in upstream open spaces mini detention reservoirs in depressions of the topography and larger ones in the valleys. Such devices have the potential of serving multiple purposes, in addition to flood control, including: infiltration into the aquifer, direct use of the water for irrigation of agriculture or landscape elements, settling of suspended materials and its appended pollutants from the runoff to improve its quality before it reaches the lower sections of the stream.

Certain actions taken in the catchment area may incur costs to one segment of the population while benefiting another. For example, if recharge of runoff from individual lots into the aquifer is made mandatory then the cost is imposed on home owners, while the benefit may accrue to the regional water authority that manages the aquifer. Similarly, retention upstream will benefit downstream dwellers while imposing a cost upstream. A catchment area authority should hold responsibility for instituting regulations and financial instruments that make the catchment-wide development plan efficient and equitable in terms of sharing costs and benefits.

Partial catchment plan

Where political or practical conditions do not allow taking the catchment area as a single planning entity, then a partial catchment plan is a practical alternative (Thornes & Rowntree 2006). A partial plan should clearly indicate the 'boundary conditions' at its edges with other parts of the watershed: the expected parameters of runoff reaching it from upstream, and its own effect on areas downstream. Many cases of flooding result from inadequate consideration of such 'boundary conditions', for example: a new development upstream that increases flows downstream without consideration of the latter area's capacity.

Frequently, the motivation of a watershed plan is creation of a *regional/metropolitan park based on a rehabilitated river* (Brandeis 2004; Schanze *et al*. 2004). Regional parks may play a very significant role in a regional revitalization processes, may enhance economic, social and cultural regeneration in addition to environmental improvement, as is the case of the Emscher river in the Ruhr area in Germany (Londong & Becker 1994; European Academy for the Urban Environment 2007).

Delineation of floodplains

Special attention should be paid to delineation of floodplains – areas along the stream into which water enters when the flow is higher than can be carried by the stream channel. Water is stored in the floodplain, some of it evaporates and some infiltrates into the ground, until the rest can flow back into the stream as its flow recedes (California Department of Water Resources 2007). The extent and delineation of the floodplains and the frequency and depth of their flooding are matters of 'floodplain management', which must be compatible with the land uses in these areas (see a British approach in Purnell 2002). Human settlement in floodplains is dangerous, even if the flooding frequency is low. There have been too many cases of casualties and economic losses in floodplains, such as the documented Midwestern flood of 1993 that caused $12 to $16 billion in damages (Pinter 2005). Frequently, such losses are the result of spreading urbanization, as was the case in Curitiba, Brazil [World Meteorological Organization and the Global Water Partnership (WMO/GWP) 2004]. This led to a management policy that prevented construction and settlements in the floodplain. Buying out floodplain properties and designation of floodplains for recreation or for agriculture are good practices, as these activities can be suspended temporarily during flooding with acceptable losses. Where planners cannot stop construction in floodplains, measures such as raising the buildings should be obligatory.

Necessary and supporting conditions for implementing WSP

It has been pointed out by others that there are impediments to implementation of planning approaches similar to WSP (Goonrey *et al*. 2003; van Roon *et al*. 2005, and a comprehensive review by Roy *et al*. 2008). Experience in several countries, among them the United States, Japan, Australia and New Zealand, as well as our own experience in Israel, indicates that implementation of WSP requires two necessary prerequisites and promotion of several supporting means. The prerequisites are:

Legal and statutory frameworks

Laws and regulations should be revised in order to overcome institutional constraints, to create planning zones according to a hydro-geographic delineation, and to consider runoff as a resource, not merely a nuisance. Our experience in Israel indicates that this is possible. Recent legislation has created 11 Basin Authorities, and in 2006/2007 the Government approved a statutory national plan for integrating water considerations into urban and regional planning (TAMA 34 B), which was influenced substantially by our recommendations for policy and planning.

Training the relevant professional cadres in the spirit of WSP and interdisciplinary cooperation

Conventional paradigms must be abandoned and replaced by new water-sensitive ones, and practitioners should be equipped with the necessary knowledge of the appropriate professional guidelines and tools, including advanced calculation methods (see the Canadian Water Balance Model online).

A series of supporting means can promote the implementation of WSP, including:

Economic incentives

Recommended in order to encourage 'water-sensitive behaviour' by developers and home owners, in preference to rules and regulations designed to enforce such behaviour.

Public–civic partnerships (PCPs) and public–private partnerships (PPPs)

In an era of 'new governance' (Salamon 2002), partnerships with NGOs and/or private developers can promote effective and efficient implementation. The Spanish city Zaragoza, noted for its successful water saving programme, states that its success is due to partnership between all sectors of society (Zaragoza web site).

Publicity and education

Implementation of WSP, especially at the microlevel (infiltration of runoff on-site, water conservation), requires citizen commitment and participation. There is ample evidence from cities in Western countries that citizens show increasing interest in being 'green' ('blue/green' in our case), and yet, continuous investment in education and publicity for all stakeholder, from citizens – adults and children – to professionals and public officials, is necessary for sustainable success.

Continuous development of knowledge

The integration of water consideration into urban and regional planning, and the effect of BMPs require further studies and substantiation by pilot projects. Validating the 3Ms and other principles of stormwater management mentioned above requires additional field measurements and simulations, using both sophisticated (for research) and easy-to-use models (for wide implementation by practitioners). Feasibility studies of the cooperation and organization required for WSP implementation is called for. Last but not least, relevant experiences should be documented and lessons should be disseminated.

Conclusions

Work in progress and its paradigms

The paper reports on a work in progress. We started from sustainable management of urban runoff, moved to the larger space of the river catchment and to additional WSP subjects, including flood protection, streams rehabilitation, conservation of urban water and using alternative water resources (the last two are not detailed in this paper). Other fields are still waiting to be added to WSP, including soil conservation on the regional scale and wastewater management in the urban area. Beside the continuous scientific development of WSP fields, we pursue an educational effort, directed not only towards students in academia but also towards the relevant professional communities. A major difficulty is the need to change work habits and work paradigms. The suggested paradigms include:

(a) WSP states that water considerations are intrinsic to urban and regional planning and should be taken into account from the very beginning of every planning project. This requires all relevant professionals – hydrologists, water systems engineers, urban and regional planners, landscape architects, road engineers and ecologists – to work together in an integrated team rather than sequentially.

(b) The natural hydro-geographical structure (slopes, soils, water bodies and streams) should be the starting point for selecting the location and spatial layout of any built environment and its open spaces, in every location and at every scale, from a region to a building lot.

(c) WSP requires to treat stormwater runoff as a resource, not merely a nuisance. Instead of removing runoff from the built areas as quickly as possible, as is common in conventional practice, WSP guides the planner and engineer how to design land use and land cover for managing the quantity and quality of runoff, so that it can be used either directly, for improving the landscape, and/or indirectly for recharging the groundwater.

These paradigms are proposed for universal WSP implementation, while many of the WSP rules and guidelines suggested above that are place-related, i.e., their implementation depends on the specific land and water and other characteristics of each place.

Generic principles for sustainable development

WSP is a central partner in a family of planning approaches that aims to result in sustainable development. While working on WSP for the last 15 years, we have developed a set of principles that are – in our judgment – generic and should characterize any planning project for sustainable development. The eight principles are listed below with WSP-related illustrations.

- *Synergy in attaining environmental, social and economic goals* – WSP has the potential of conserving water resources while improving the urban environment, reducing the danger of flooding, increasing opportunities for recreation and leisure activities and reducing costs of flooding damages and drainage systems. The message is that planning for achieving multiple objectives within a single framework is more effective and efficient than dealing with each separately.
- *Professional cooperation and development of transdisciplinary new fields of research and action* – Disciplinary boundaries are removed, first by joint formulation of the issues, then in the cooperation for addressing them and finally in the development of new paradigms and models that would not have evolved within the separate disciplines.
- *Multiple goals achieved by common means* – Consider a park, designed according to WSP rules, that provides recreational services to the community and serves as an attraction to tourists, while at the same time filters runoff to improve its quality and also infiltrates some of it to replenish groundwater; or: a detention reservoir designed to reduce flood discharges and pollutant loadings that also serve as a visual and recreational amenity.
- *Anticipatory (rather than reactive) planning* – Investment in means that prevent damages, rather than merely coping with them after they occur. For example: effective land use regulations, proper road design and BMPs distributed throughout the watershed all help to retain runoff close to its origin and reduce runoff flows, thereby

reducing the need to protect downstream with large drainage systems and dykes.

- *Common planning principles at all spatial scales* – For example: A design that minimizes the volume, discharge and pollution loading of runoff is applied to regional plans as well as to city and neighbourhood, and down to the individual yard.
- *Work with nature (not against it)* – For example: Locate open and built areas, the road system and the drainage system in harmony with the area's geo-topo-hydrography, with special attention to the stream network, contrary to the tendency to sculpt the topography artificially.
- '*Small is beautiful*' (as coined by Schumacher 1973) – Experience demonstrates that large projects can lead to large and irreversible damages (see the debates regarding big dams), while small-scale development is more adaptable to local needs and wishes, and mistakes can be corrected more easily. WSP emphasizes micro- and mezzo-level (yard, neighbourhood) activities.
- *Finally, working with the community (not 'for the community')* – WSP is promoted in democratic societies, where civic awareness and civic participation are being advanced. WSP, like other ingredients of sustainable development, has to grow bottom-up, with support and participation of stakeholders, and cannot be promoted just top-down.

While the examples that demonstrate each principle were drawn from our experience with WSP, the set of eight planning principles is suggested for all projects aimed at sustainable development. Adopting them is expected to serve the planning of sustainable housing and sustainable transportation as well as WSP.

Acknowledgements

The Technion supported our studies, primarily through scholarships granted to the six graduate students who completed their MSc theses on WSP with us. We acknowledge our colleagues Dr. Avner Kessler, who collaborated with us throughout the way, Dr. Shmuel Burmil and Dr. Tal Alon-Moses, who also participated in some of our studies. Funding was provided by Israel's Ministry of Construction and Housing, the Israeli Water Commission, and the Ministry of Environmental Protection.

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