CHALLENGES AND SOLUTIONS IN URBAN STORMWATER INFRASTRUCTURE

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Abstract
Stormwater infrastructure has evolved over the years from having a primary orientation towards addressing flooding issues, to considering water quality, and now to consideration of aquatic resource protection. More recent consideration relates to stormwater reuse for other site purposes. A clear direction internationally is the move to more sustainable design.

While all of this evolution is good from a knowledge base, significant problems are created for the urban stormwater infrastructure. Programme infrastructure is not able to keep up with technical changes that are occurring. Changes such as programme direction and increasing responsibility have major impacts on programme organisation and structure.

Master planning, detailed design, construction, post-construction maintenance, and education are all essential programme elements and must now be considered from a new more comprehensive context. Sustainable design has made delivery of stormwater outcomes very complicated. The issue of funding and institutional structure becomes extremely important and very few programme are adequately funded or resourced. In addition, the role of education becomes increasingly important as programme evolution is now impacting on a significant segment of society. This is usually done in a political environment that has its ebbs and flows which can accelerate or destabilise a programme. All of these factors and issues are discussed in a context of future needs and direction.

Additional Keywords: erosion, mitigation, source control, funding

Background

Stormwater management has undergone a radical shift in direction over the past thirty years. Historical efforts were related to drainage and getting the water off the land as quickly as possible. Recognizing that we were not really generally solving flooding problems and were only transferring those problems further downstream, programme evolution then progressed into the design and construction of large, normally dry, ponds whose purpose was to temporarily store stormwater runoff and control the peak rate of release for design storms. This approach still allowed for efficient conveyance of stormwater from upstream areas to ponds while preventing, to some degree, the increase in downstream flood levels. So far things were still pretty simple from a stormwater management perspective.

In the early 1980-90's, there was increasing concern about stormwater quality, as a result of studies of urban stormwater (most notable being EPA, Results of the Nationwide Urban Runoff Program, 1983) in conjunction with various areas around the world experiencing localised receiving system degradation, such as the Chesapeake Bay. Since there was an existing stormwater related programme, it was a natural extension of that programme to move into water quality considerations. The basic mentality of the programme was still focused on regional ponds, which were asked to provide greater benefits for water quantity plus water quality. As these approaches have been implemented, there are several issues which had previously not been considered but were becoming increasingly recognized as being important including stream channel erosion and aquatic resource protection.

Stream channel erosion
The implementation of regional stormwater management facilities abandons the upstream channel to increased stormwater discharges. Downstream of the regional facility, the duration of flows due to increased volumes of stormwater increases the work done on the channel boundaries and thus may increase erosion potential. There is evidence that, in urban catchments, the greatest source of sediment is from stream channel erosion. With sediment being recognized as a contaminant, there is greater attention being given to protection of stream channel boundaries. The recognition that this has become a programme element requires a rethinking of existing approaches.

Aquatic resource protection
As programmes have moved into consideration of water quality treatment, a question has to be asked regarding the purpose of water quality treatment. The highest priority has to relate to human health, but a very close second

consideration must also consider impacts that stormwater has on aquatic receiving systems. The linkage with human health is obvious if eating seafood is considered. Health advisories for consumption of certain fish and shellfish have been around for years, but aquatic resources are now being considered as a barometer of success for stormwater programmes. There is also greater interest in looking at non-tidal streams as valuable resources rather than only as drainage systems.

Where We Are Going?

Low impact design

Low impact design (LID – NZ and US), water sensitive urban design (WSUD- Australia), conservation design (US), and sustainable urban design systems (SUDS – England and Wales) are all fairly recent and evolving approaches to stormwater management that represent a significant shift from historical approaches. They really represent a blend of treatment in conjunction with source control. We have traditionally considered stormwater management as an "end of pipe" technology that relies on ponds, wetlands, or filter systems having efficient conveyance systems to get flow from around a site into the management practices. These more recent approaches make stormwater management less efficient in terms of conveyance. The central tenet is to slow the water down, make it travel through a torturous path, and reduce the overall volume of water that is discharged.

What this entails is consideration of stormwater from where the rainfall hits the tree canopy, roof, or ground. The suite of practices now includes consideration of roof runoff, revegetation of land, swale flow, bio-retention, enhancement of natural features, and practices that reduce the overall volume of stormwater runoff.

Catchment considerations

Historical efforts have been directed towards solving large problems in large receiving systems, such as Puget Sound, the Chesapeake Bay, etc. As these efforts have evolved, there is a greater awareness that we must look at individual elements of the entire system. There is no easy fix and there are almost countless pieces to the puzzle. Individual activities are important but they must be considered in context to the overall catchment. By looking at a problem from a catchment perspective, individual actions can be prioritised. We can look at a variety of approaches in different tributaries of the overall system and consider available options. These options can be very different depending on the existing level of development in the tributaries and the sensitivity of the receiving environment.

Land use planning

Stormwater management approaches have historically been mitigative in approach. We recognize that adverse impacts (hydrological, water quality, disruption of habitat) are going to occur and we attempt to minimise, to the extent "practicable" those adverse impacts. We need to recognize that land use planning is an essential stormwater management tool and must be considered in conjunction with any building programme. Basic questions have to be asked when land is considered for development, and consideration of stormwater related issues must be integral to overall site development:

- Can the building program be modified in terms of total number of units?
- Can the style of development be modified in terms of lot sizes and type of structures (single family versus multi-family)?
- Can a sensitive receiving environment be protected from degradation through upstream land use controls as opposed to the traditional end of pipe mentality that has characterised existing approaches?

Moving to the top of the catchment

A common approach to stormwater runoff is to construct efficient conveyance systems on individual sites and then worry about how to deal with adverse impacts at the bottom end of the site or further downstream. There is increasing recognition that the volumes of stormwater flows and flow patterns need, to the extent possible, to mimic predevelopment volumes and flow paths. Water has an amount of energy to dissipate based on its elevation above sea level and increasing the volume of stormwater runoff and shortening flow paths at the top of the catchment will increase erosion potential downstream. We need to look at the very top of the catchment if downstream areas are to be protected.

Using natural mechanisms

Structural approaches to stormwater management (ponds, wetlands, filters, etc.) are fairly well recognised and accepted/endorsed by stormwater programme people. Natural mechanisms, on the other hand, are not generally used (although that is changing) as stormwater management tools. Leaving native vegetation, minimising earthworking, preserving topsoil on site, protecting wetlands or depressional areas, and other natural systems can

provide significant stormwater management benefits. Depending on the level of site development, structural practices may still be necessary, but the amount of work that those structural practices have to do will be reduced. In that regard, a pre-development site resources plan should be a mandatory stormwater submission requirement. That plan would detail what features exist and their location. Site development would then, using that information, be designed to be protect sensitive areas.

Source control

Reducing contamination is becoming more recognised as being a priority over treatment. Preventing contamination in the first place is easier to deal with than treating the contamination once it is in the water column. Good examples of this exist in many forms. The removal of lead from petrol has shown a significant drop in its concentration in streams to the point where lead is not considered as much of a problem as either zinc or copper. Recent work in determining sources of zinc has indicated that some roof materials and paints may contribute significant levels of zinc to stormwater. Using different roofing materials or paints may have a significant impact on reducing zinc in waterways. If there is an area that warrants additional investigation it is the area of source control.

Programme Structure

We have to reconsider the historical structure of stormwater management programmes. They have evolved almost unchanged from the original programmes whose goals were related to water quantity control. If we are now focusing on the health of receiving systems, a multi-disciplined approach is necessary, and we have to provide for ongoing monitoring to assess the effectiveness of our efforts. Resourcing issues are so important and must be addressed up front. Having inadequate resources when a programme is initiated without a framework for how necessary resources will be obtained in the future is a recipe for programme failure. We cannot do programme implementation, do monitoring, or conduct catchment planning if we don't have the financial support.

This has become a much more important area with the advent of LID, WSUD, etc. These approaches require a much more “hands-on” approach to stormwater management than has historically been necessary. Individual building consents must be considered for roof tanks, swales, and rain gardens and construction inspection and subsequent maintenance responsibilities are increased enormously. There has to be a suitable programme infrastructure to achieve the evolving goals that are necessary to meet changing public expectations. The days of a small group of people in a back room planning regional stormwater ponds is a vestige of the past.

Institutional frameworks

These institutional elements can simply be stated in the following list. Some of the items will require action by the Territorial Authority (TA) to make structural change within their councils to provide the framework for implementation.

- Basic goals of the programme must be defined
- Programme authority and implementation structure is necessary (relationship and linkage to other TA programmes)
- Performance standards must be developed
- There must be permitted activities
- Design guidelines and assistance must be available
- Master planning (includes catchment management planning) must occur
- Inspection procedures must be prescribed
- Programme funding must be secure and ongoing
- Programme staffing
- Educational activities
- Compliance and enforcement procedures
- Operation and maintenance plans and schedules
- Programme evaluation and evolution reviews

Without these institutional elements, the TA will have difficulty meeting programme goals and that fact must be recognised. Each element can be considered as a link in a chain with the chain being only as strong as the weakest link.

Funding
Presently, stormwater activities are funded mainly from general rates, with incremental funding from development contributions. Borrowings are also used to fund major infrastructure investments as required. Recent work in the Auckland Region (Infrastructure Auckland, 2004) has indicated that funding necessary to meet stormwater objectives (flooding relief, erosion protection, swimming, eating seafood, receiving system health, recreation) will cost in the vicinity of $7-12 billion for capital projects. That is a significant sum of money and reflects the need to improve existing quantity and quality situations while addressing new development.

As expected, developing a funding mechanism to provide adequate resources for effective programme implementation cannot be addressed using a single funding approach. The following table provides a brief description of possible funding approaches. Each of these approaches has strengths and weaknesses that need to be considered in developing a programme funding package. Unless funding is provided, programmes cannot meet stated objectives and that message needs to be clearly stated.

Table 1. Stormwater funding options

Option	**Description**
Rates on Property Value	Allocating a portion of the general rates to stormwater activities, or charging a separate identifiable rate applied directly to stormwater programmes.
Rate on Land Use	Charging a differential fee based on size and primary land use: ie Large, Medium and Small, Residential, Commercial and Industrial parcels.
Rate on Property Area	Charging a fee based on the size of the parcel of land.
User Charges (based on Land characteristics)	Charging a fee which reflects characteristics of the land that contribute to stormwater runoff. This charge is typically levied on impervious surfaces, but could also reflect other characteristics such as soil type and slope.
Road User Charges	Charging road users for the contribution to stormwater runoff generated by roads and road use.
Development Charges	Charging developers a fee for infrastructure projects required to serve the development.

An initial review of funding options indicates that most funding currently in place for stormwater does not necessarily reflect equity or efficiency principles. There is little incentive for the generators of stormwater runoff and contaminants to change their behaviour. The introduction of a funding mechanism that addresses polluter pays issues would be a significant step in gaining acceptance from the public that stormwater management is an issue. If a community wishes to benefit from the improved outcomes that enhanced stormwater management provides, then an equitable and efficient funding mechanism is required.

Education
Regardless of how well recognized, it is always necessary to discuss the importance of education. Many people, even today, don't understand cause and effect with respect to what they do on their land and the potential downstream impacts. Education is essential, it is never ending, and must be done on a routine basis as an ongoing program activity.

Education is even more important if new streams of programme funding are being pursued. Integrated community outreach programmes must be done prior to advancing any funding request that will require higher individual or corporate rates. People need to understand why stormwater programmes are important and what they will get for their rate increase. Without public buy in, it is an easy decision for politicians to say no to increased funding. Education is also important as we move further into the source control arena. Source control, by its nature, requires individual commitment to make it effective. People have to understand and accept why we are asking them to make

lifestyle changes. These changes may be minor (such as proper disposal of cigarette butts) but without acceptance the benefit will not result.

At the same time that we discuss education, it is important to share information. All of us are involved in activities that rely on information. Too often we work in a vacuum and don't share information that would benefit our own or other areas. This occurs between agencies but also is common in a single one. We have to get over our ownership syndrome and remember that aquatic resource protection is the ultimate goal and not who dies with the most private research results.

Conclusion

A book could easily be written on the number of important items that should be incorporated into stormwater management approaches, but there is one key point that should be made. The way that we are addressing stormwater management, with few exceptions, is based on failure. We exempt or waive activities from requirements either for political or resource based (staffing, monetary support) issues. It is not that those activities do not cause significant impacts downstream but rather we don't have the political will or resource base to address them. We have to look at what we are trying to address with program implementation and determine what a program structure should be and then determine our resource needs.

We, as technical people, have an obligation to place issues and associated costs to the politicians and force them to make the hard decisions. For too long, we have made those decisions at the program level and made life easier for them. If a political decision is made not to address a problem, it is our job to ensure that a decision is made on an informed basis. We cannot afford to continue ignoring the hard questions if we want to protect and maintain our existing natural resources and our own quality of life.

In order to provide issues to decision makers we have to have access to the best information available. To date there is not enough research on the beneficial effects that our actions might have. There is pretty good information on cause and effect of urban stormwater but little information exists on the ability of our current approaches (whatever they are) to protect aquatic resources. With billions of dollars being invested globally each year on stormwater programmes, we have to have a better understanding of outcomes from those investments. We can no longer just rely on logic to define programme success (e.g. less pollution is better). We have to lay out an investigation programme that defines what the existing situation is, clearly defines the problem, considers expectations related to programme implementation, and provides a relative expectation of success. Without having that, we will lose political and public support.

Related to the discussion of roles is also the requirement for commitment. Commitment related to stormwater must be at a personal and an agency level if efforts are to be effective. We have set an example for those around us and there are obligations associated with that. At a personal level we should respect our world and at an agency level we should accept our responsibility to minimise pollution. Source control and mitigation should be essential components of our day-to-day activities. Only by moving away from our historic approach to life which is based on resource consumption are we going to provide a desirable world for our children.

References

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