# REVIEW OF COMMON MANAGEMENT PRACTICES FOR CONTROLLING NUTRIENT LOADS IN URBAN RUNOFF WITHIN THE HAWKESBURY-NEPEAN BASIN FOR USE IN CMSS

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**ABSTRACT**

The application of the Catchment Management Support System (***CMSS***) software to predict the impact of urban growth on the nutrient quality of the waters of the Hawkesbury-Nepean Basin was commissioned by the Water Board in 1992 and completed late 1993. The ***CMSS*** program predicts the effects of changes in land use and management practices on average annual total phosphorus and total nitrogen loads generated within a catchment.

As an adjunct to this project, the Water Board commissioned a review of urban management practices commonly employed in the Basin to provide the data needed to describe these practices in ***CMSS***. From this review, the efficiency of the management practices at reducing total phosphorus and total nitrogen loads and the capital and ongoing costs of adopting the practices have been identified.

The review has highlighted the dearth of rigorous field trials which quantify the effectiveness of the identified management practices and the wide range of opinions of experts on the perceived effectiveness of the practices.

Toni Frecker, the major author of this document, reviewed the stormwater literature as part of her thesis for a Masters in Environmental Studies from University of New South Wales. She can be contacted at T.C.F. Ecos, 22 East Richardson St., Lane Cove NSW 2066.

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# Introduction

## 1 Background

In 1992 the Environment Management Unit of the Water Board, Sydney, contracted CSIRO Division of Water Resources to develop a predictive model to assist them assess the impact of urban development on water quality in the Hawkesbury-Nepean Basin. The Catchment Management Support System (CMSS) water quality prediction software was employed. This software predicts average annual total phosphorus and total nitrogen loads generated from land uses within a catchment. Loads can be changed by modifying the current land uses or by adopting management practices which reduce nutrient export. CMSS provides a vehicle for describing such changes and practices and predicting their effect on nutrient loads.

### 1.1 Issues

Much of the projected urban growth of metropolitan Sydney is within the Hawkesbury-Nepean Basin, particularly within the South Creek catchment. This growth will be accompanied by an increase in peri-urban development such as hobby farms and rural residential living and intensive industries such as livestock raising and turf farms. In addition the outfall from the Water Board's and local Councils' sewage treatment plants already contribute significant nutrient loads to these waterways.

One of the major urban development issues of concern to the Water Board is that of stormwater runoff quality associated with this urban development. Runoff quality is determined by the materials transported by it. These materials include dust and soil, litter, animal wastes, fertilisers, oil and grease, metal particles derived from corrosion and abrasion, and spills to land surfaces. In many cases urban runoff is now a major source of pollutants entering streams and the factor with the greatest impact on receiving water quality (SPCC, 1989). The nutrients, phosphorus and nitrogen, transported in stormwater have a significant negative impact on water quality and are among the factors being targeted by the Water Board for reduction. Nutrients may promote the rapid growth of aquatic plants reducing the suitability of the waterway for other life forms and uses such as boating, swimming and irrigation (SPCC, 1989).

### 1.2 Objectives of Review

The objectives of this review are to provide the data necessary to describe urban stormwater management practices in CMSS and to identify where information is lacking. The focus of description is the effectiveness of these practices in reducing phosphorus and nitrogen loads in runoff and the cost of the implementation of such practices.

## 2 Catchment Management Support System (*CMSS*)

### 2.1 The Program

CMSS is a decision support system which was originally developed by CSIRO to analyse environmental policies being proposed by the South Australian government in the Mt Lofty Ranges behind Adelaide. Under a Land and Water Resources Research and Development Corporation (LWRRDC) grant and the financial support of the Water Board, the program has been generalised so that it can predict the nutrient (currently total phosphorus and total nitrogen) loads entering the streams of any catchment.

A simple nutrient balance model predicts total loads produced in the catchment by calculating the nutrient loads generated from different land uses and summing these across all land uses within the catchment. Thus the ability to predict the impact of a change in land use (eg converting a grazing property to an urban development) can be modelled by modifying the areas of each land use in the catchment. Effects of land management practices (eg a reduction in fertiliser application on improved pasture) can be incorporated into the model by changing the nutrient generation rate for the particular land use (in this case improved pasture).

The program requires two, preferably three, data sets. These are:

- the distribution of land uses (both diffuse and point source) within the catchment;
- average generation rates (typically expressed as kg/ha/yr) from the specified land uses for the nutrients being predicted; and
- information on the effect of land management practices on nutrient generation.

## 2.2 Data Acquisition

For the Hawkesbury-Nepean Basin CMSS, the land uses and nutrient generation rates were acquired by CSIRO - the former documented in Laut et al. (1992) and the latter in Marston (1992, 1993). A complete report of the application is documented in Cuddy et al. (1994). Land management practices associated with agricultural land uses and sewage treatment plants were acquired by CSIRO and are documented in Cuddy et al. (1994). The Water Board agreed to acquire urban land management practices because they had better access to both the data and the regional experts. For this purpose, they engaged a University of New South Wales Masters student, Toni Frecker, primary author of this document. The literature search and interviews with experts were conducted during 1993 and the material presented as a Masters thesis in March 1994.

## 2.3 Land Uses

CSIRO developed a land use map which identified the following 20 categories of nutrient-producing land uses (Laut et al., 1992):

**Table 1 Land Use Categories - Codes and Brief Description**

| Code | Land Use | Description |
|---|---|---|
| 1 | Bushland | forested land, pine and poplar plantations |
| 2 | Established sewered urban | urban areas established for three years or more |
| 3 | Recent sewered urban | urban area established for less than three years *(considerable extent of bare surface evident)* |
| 4 | Unsewered periurban | discontinuous urban where buildings are within 100 m of each other and isolated buildings up to 200m apart where there is no integrated sewerage system |
| 5 | Industrial and commercial | including mining and warehousing |
| 6 | Intensive vegetable growing, turf farms | |
| 7 | Orchards | |
| 9 | Fertilised grazing | includes all fertilised grasslands and parklands without defined infrastructure items |
| 10 | Unfertilised grazing | includes all unfertilised grasslands and parklands without defined infrastructure items |
| 11 | Extensive agriculture | NB This category was not encountered in the Basin |
| 12 | Water | including all natural and man made water bodies |
| 13 | Disturbed land | including agricultural and urban disturbed lands |
| 14 | Poultry | poultry sheds (point source) |
| 15 | Dairy | dairy sheds and associated buildings (point source) |
| 16 | Stable | point source |
| 17 | Piggery | point source |
| 18 | Waste or water treatment | point source (identifies locations of STPs) |
| 19 | Established unsewered urban | established urban areas without integrated sewerage |
| 20 | Built-up miscellaneous | all other built-up areas |
| 31-67 | Sewage Treatment Plants (STPs) | point sources |

Table based on Laut *et al.* (1992)

## 2.4 Management Practices

CMSS has a particular syntax for describing management practices. The following items are recorded for each land management practice (LMP):

- Land Use
  land use to which management practice is applied
- Management Practice
  name of management practice
- Practice Code
  an internal storage number generated by ***CMSS***
- Adoption Level
  current adoption of the practice in the Basin as a percentage of total area of the land use. For Hawkesbury-Nepean ***CMSS*** this level was set to 0 for all practices as insufficient data were acquired to confidently assess the current level of adoption.
- Author
  principal person responsible for developing and researching the LMP
- Comment
  text describing LMP
- Cost Type
  code to describe type of LMP for calculating cost
  A - Area (for diffuse land uses)
  P - Point (for point source land uses)
  L - Linear (for linear spatial attributes such as streams)
- Initial Cost ($)
  up-front cost of implementing the LMP
- Initial Cost Error ($)
  uncertainty associated with initial cost
- Initial Cost Comment
- Ongoing Cost ($)
  annual cost of maintaining the LMP
- Ongoing Cost Error ($)
- Ongoing Cost Comment
- PHOSPHORUS Reduction (%)
  effectiveness of LMP at reducing total phosphorus (TP) generation rate expressed as a percentage
- PHOSPHORUS Uncertainty (%)
  uncertainty associated with reduction percentage
- PHOSPHORUS Comment
- NITROGEN Reduction (%)

effectiveness of LMP at reducing total nitrogen (TN) generation rate expressed as a percentage

• NITROGEN Uncertainty (%)

uncertainty associated with reduction percentage

• NITROGEN Comment

An example of an LMP entry in ***CMSS*** is given in Figure 1, Appendix 3.

# 3 Review Strategy

This review was confined to stormwater management practices practised in urban areas. Within the CMSS application, these were associated with three land uses: recent sewered urban, established sewered urban and disturbed land. However, they are also applicable to other land uses such as industrial and commercial and established unsewered urban.

## 3.1 Search Strategy

A number of different sources were used to obtain efficacy and costing information for this study. The major initial focus for data collection was placed on literature research. References were gained from computerised searches of bibliographic databases, and citations and references from journal and conference papers.

The bibliographic databases searched were:

• Compendex

This database (produced by Engineering Information Inc, New York) provides coverage of world engineering and technological literature

• Streamline

Australian Water Research database which contains bibliographic and research-in-progress information on all aspects of water and wastewater utilisation, including water quality, water resources investigation and development, salinity, erosion, water administration, urban water utilities, water use, machinery and equipment

• Aqualine

Water Research Centre (Great Britain) database of information on issues of interest to the water industry, including water management, treatment and quality.

- Waterlit

  South African Water Information Centre database covering international water literature available in South Africa

Initially emphasis was placed on Australian references. However when it was found that this research was limited, worldwide studies were considered and each assessed individually. Much of the work accessed in this study was based in the United States. Approximately 110 documents were reviewed. Many of these were discarded because they did not contain performance data or quoted other (primary) sources without contributing any new information. Fifty (50) primary source documents were retained and are referenced in this review.

Where gaps were found to exist in the published information, input was sought from those with knowledge and experience in the industry. Many organisations and individuals within the wastewater industry were also contacted to determine if any unpublished monitoring data existed. The organisations contacted are listed in Appendix 4. Any relevant information gathered from these contacts is summarised along with that gathered from the literature review in the tables in Appendix 2.

Information from published sources and contacts was then collated and assessed for relevance to the Hawkesbury-Nepean Basin. Only three published studies monitored the impact of stormwater management practices in this catchment. In many cases little or no monitoring was reported for a particular management practice. In these cases overseas studies or studies of other management strategies were used as the basis for an estimation of effectiveness. An explanation is given later in this report as to how the ranges for effectiveness and costs were derived from the source literature and expert opinions. These explanations are given for each management practice.

A summary of all recommended ranges for both effectiveness and capital and maintenance costs is given in Table 2.

**Table 2 Effectiveness and Cost of Identified Management Practices**

| Management Practice | % TP Reduction | % TN Reduction | Estimated Capital | Costs ($A/ha[1]) Maintenance[2] |
|---|---|---|---|---|
| Buffer Strips | 50 - 70 | 50 - 70 | | |
| Extended Duration Detention Basin | 10 - 20 | 10 - 30 | 300 - 1000[4] | 5 - 50 |
| Impervious Area Reduction | 0 - 40 | 0 - 40 | | |
| Retention Basin | 70 - 95 | 70 - 95 | 2000 - 20,000 | 60 - 600 |
| Street Sweeping - 30 day interval | 0 - 15 | 0 - 15 | 36 | 8 |
| Street Sweeping - 7 day interval | 0 - 50 | 0 - 50 | 152 | 35 |
| Wet Detention Basin<br>- recent sewered urban<br>- established sewered urban<br><br>- large catchments<br>- small catchments (1 ha) | <br>35 - 85<br>45 - 85 | <br>27 - 61<br>40 - 61 | <br><br><br><br>2000 - 6000<br>20,000 | <br><br><br><br>200 - 600<br>600 |
| Wetland/s | 17 - 94 | 18 - 74 | 100 - 400 | 5 - 10 |
| Sediment Controls[3] where soils < 10% dispersible materials | 20 - 90 | 20 - 90 | 5000 - 15,000 | |
| Sediment Controls[3] where soils >=10% dispersible materials (flocculation used ) | 20 - 90 | 20 - 90 | 5000 - 15,000 | 90 - 180 |
| Sediment Controls[3] where soils >=10% dispersible materials (no flocculation) | 20 - 50 | 20 - 50 | 5000 - 15,000 | |
| Gross Pollutant Trap and Wet Detention Basin (with sediment controls[3]) | 35 - 85 | 27 - 61 | 2500 - 7500 | 60 - 160 |
| Gross Pollutant Trap and Wet Detention Basin (without sediment controls[3]) | 0 - 75 | 0 - 61 | 2500 - 7500 | 60 - 160 |
| Gross Pollutant Trap, Wet Detention Basin and Wetland | 43 - 85 | 36 - 78 | 7500 | 160 |
| Gross Pollutant Trap, Off-line Detention and Wetland | 43 - 85 | 36 - 78 | 7500 | 160 |
| Sediment Trapping Pit and Mini-wetland | 40 - 60 | 40 - 60 | 200 - 600 | 25 - 50 |

1. All costings based on figures within the last five years unless stated otherwise.
2. Maintenance costs include operating costs.
3. Sediment controls based on Department of Housing Guidelines (NSW Dept. of Housing, 1993)
4. Indicates additional costs to those of a retardation basin.

## 3.2 Classification

The aim of stormwater management practices is to reduce the pollutant load in runoff. It is desirable to reduce this load to approximately that in runoff from an undeveloped site.

Stormwater management practices may be classified into three groups - source controls, in-transit traps and treatments, and in-storage controls (CEPA, 1993). Source controls include a widely varied number of strategies which all lead to less pollution being picked up by stormwater during its passage from rain to waterway. These include such strategies as sediment controls during construction, litter reduction campaigns, minimised bare soil areas in urban gardens and street sweeping.

In-transit traps and treatments include structures and grassed waterways which reduce the velocity of the stormwater so that some sediment, rubbish and associated pollutants are left behind. Sedimentation basins, gross pollutant traps and grass swales use this mechanism to improve the water quality of runoff.

The management practices which may be described as in-storage controls include wet retention basins, wetlands and urban lakes. These water bodies use a range of physical, chemical and biological processes to improve water quality and generally maintain a permanent pool of water.

A description of many different management practices is included in the glossary in Appendix 1. More detailed discussion is included in the sections specific to each management practice.

In many situations the most effective improvement of stormwater quality is achieved through the use of a number of management strategies in a treatment train. For instance, the reduction in the sediment load upstream of a wet retention basin by the use of a gross pollutant trap, increases the capacity of the wet retention basin to improve water quality. Further, the various management practices may, and do in some cases, impact on different components of the stormwater pollution load. Following on from the example given above, the gross pollutant trap causes only the larger sediment particles to settle out, while the wet retention basin acts using a complex array of processes to reduce both the suspended particle load and the dissolved nutrients. When management practices are implemented as part of a system, the practices involved generally treat the runoff in series or occasionally in parallel.

Many studies have investigated the impact of management practices as single treatments and not as part of a system. For the purposes of this project both situations have been looked at, with the data from the literature being collated for both single management practices and for system management practices.

The management practices included in this study have been selected as relevant to the Hawkesbury-Nepean Basin. Not all are currently used in this catchment, however some such as off-line detention or mini-wetlands may be applicable in the future. The system management practices included are a representative sample of the many different combinations of single management strategies that may be used in a treatment train.

### 3.3 Format for Describing Management Practices

Each management practice or system has a separate section which has five components:

- description
- nutrient reduction
- nutrient reduction references
- costs
- costs references.

The description is a general overview of each practice's design and use. Nutrient reduction (ie efficacy in reducing nutrient loads) and the costs of implementation are presented as ranges. These ranges represent the data obtained from the literature and in some cases from industry experts. The tables in Appendix 2 present a summary of the information gained from these sources.

Those references used to determine the ranges given for each management practice or system are listed under that practice or system in this section. However some information from the literature was not considered relevant to this study, and these are not referenced in this section but remain in the summary tables in Appendix 2.

# 4 Conclusion

Most management practices used to improve the quality of stormwater are engineering based. Little is known in a quantitative sense about the impact of source controls and the softer options such as grass swales and on-site retention. Also data relating to the impact of these practices specifically in the Sydney region is very limited.

The ranges recommended in this study are based on limited data, often from overseas, and must therefore be treated with some caution. To accommodate the limited information base, ranges have been set fairly widely to allow for the many different situations in which these practices may be implemented.

Further research into the effectiveness of all pollution control measures for stormwater is necessary to gain a true understanding of the processes involved and the impact on nutrient loads. In particular, source controls and the less structural practices need to be investigated to determine if they have a significant impact on pollution and nutrient loads and, if so, how they are best implemented.

# 5 Related documents

Several documents are available describing the application of CMSS to the Hawkesbury-Nepean Basin. Full references are given below.

Cuddy, S., Marston, F., Simmons, B., Davis, J.R. and Farley, T. (1994) Applying ***CMSS*** in the Hawkesbury-Nepean Basin. Vols I and II. Consultancy Report No 93/37, March 1994. CSIRO Division of Water Resources, Canberra.

Laut, P., Cuddy, S.M. and Marston, F. (1992) Land cover, infrastructure and land use in the Hawkesbury-Nepean Basin. Consultancy Report No 92/46, December 1992. CSIRO Division of Water Resources, Canberra.

Marston, F.M. (1992) Nutrient generation rates for land uses in the Hawkesbury-Nepean Basin. Consultancy Report No 92/23, August 1992. CSIRO Division of Water Resources, Canberra.

Marston, F.M. (1993) Diffuse source nutrient generation rates in the Hawkesbury-Nepean Basin. Technical Memorandum No 93/3, January 1993. CSIRO Division of Water Resources, Canberra.

# Single Management Practices

B

## 1 Buffer Strips

### Description

A buffer strip is a strip of vegetation left or developed downslope from earthworks or disturbed land, or a strip of vegetation maintained along the edge of a watercourse. The vegetation involved may consist of planted grasses, retired pasture land, retained forest or many other plant species/ecosystems.

Two other terms which are used at times to describe a strip of vegetation serving a similar purpose are vegetation filter strip (VFS) and riparian strip or zone (Barling and Moore, 1992).

Buffer strips may be used to reduce the nutrient load in runoff from most urban and some agricultural landuses. Because buffer strips reduce runoff velocity they are likely to have greatest impact on the nutrient load in runoff when a high sediment load exists, for example in the disturbed urban situation.

The most commonly recommended width for stream buffers is 20 - 30 metres (Yu et al., 1990; Barling and Moore, 1992). However this width may not be adequate under some site conditions, e.g. high slope or high soil erodibility (NSW Dept. of Water Resources, 1992). The flatter and wider the buffer strips are, the more effective they become (NSW Dept. of Housing, 1993). Sites with a slope greater than 10% are generally not suitable for buffer strips because runoff tends to move through the strip too quickly (ABARE, 1993). The effectiveness of a buffer strip will depend, in part on soil type, degree of soil aggregation, the contributing runoff area to the buffer strip and the rigidity of the vegetation (Hairsine and Grayson, 1992). The impact on runoff velocity is reduced if the buffer strip vegetation is flattened by the overland flow through it.

### Nutrient Reduction

| | % Reduction |
|---|---|
| Total Phosphorus | 50 - 70 |
| Total Nitrogen | 50 - 70 |

The review of the literature has not revealed any work which specifically relates the use of buffer strips to reduction in the nutrient load in urban stormwater. Many studies have concentrated on the runoff from agricultural lands and the reduction in sediment load as opposed to nutrient load. In the papers reviewed for this study the reduction in sediment load was found to be highly variable, ranging from 10% (Hairsine and Grayson, 1992) to 97% (Williams et al., 1990). Barling and Moore (1992) described several research projects which studied nutrient load reduction, however the degree to which the nutrients are sediment bound is significant in these results. The nutrient reduction levels shown by Barling and Moore (1992) ranged from 50% to 97% for phosphorus and from 50% to 94% for nitrogen. Table 3 gives more details of these studies.

Williams et al. (1990) found that when nutrients were associated with the water portion of the runoff, no reduction in concentration occurred during passage through a buffer strip. Assuming that at least some of the nutrient load associated with runoff is soluble, the upper limit of the recommended ranges given above is lower than that revealed for sediment reduction. The lower limit is based on the work described in Barling and Moore (1992).

## Nutrient Reduction References

Barling and Moore (1992); Hairsine and Grayson (1992); Williams et al. (1990)

## Costs

The cost of establishing a buffer strip has not been estimated as no specific information relating to the cost of urban buffer strips has been collected. However, the costs involved depend on a number of factors including:

- fencing costs if the buffer strip area needs to be protected
- planting costs if suitable vegetation does not already exist; and
- the loss of development profit for the area isolated from development (ABARE, 1993).

## Costs References

ABARE (1993).

# 2 Extended Duration Detention Basin

## Description

An extended duration detention basin is a retardation basin that is designed to extend the detention time of stormwaters beyond the time necessary for flood mitigation alone. This is normally achieved by modifying the outflow structure.

A retardation basin, or dry detention basin, can be constructed near or along an urban stream forming part of its floodplain. During large storm events when the flow of runoff waters exceeds the capacity of the drainage system, excess stormwater spills into the retardation basin where it is stored until the flow levels reduce. Since these structures remain dry most of the time they may be used for recreation, both active and passive.

## Nutrient Reduction

| | % Reduction |
|---|---|
| Total Phosphorus | 10 - 20 |
| Total Nitrogen | 10 - 30 |

No Australian data were available for this nutrient reduction strategy. Table 4 lists those studies from the U.S.A. that monitored extended duration detention basins. The results from these studies ranged from 10% to 56% for phosphorus reduction and from 10% to 33% for nitrogen reduction. A laboratory study by Randall et al. (1982) achieved the highest reduction rate for both nutrients. These results were not considered applicable to the field situation because the quiescent conditions achieved in a laboratory study cannot be guaranteed in the field and were thus discarded.

For phosphorus, the range determined by Stahre and Urbonas (1989) after their consideration of the North American data, is presented in this report as appropriate. The percentage reduction given is for an average detention time of 24 hours. These authors noted that the lower limit should be used when local data are not available. Grizzard et al. (1986) studied both a field and a laboratory situation. The extended duration detention basin they studied achieved a phosphorus reduction of approximately 14% with a detention time of 6 hours. This result fits into the range suggested by Stahre and Urbonas (1989).

The results gained for nitrogen reduction were more variable than those for phosphorus. Stahre and Urbanos (1989) suggested a similar range for the reduction in nitrogen by this management strategy. However Grizzard et al. (1986) found that the basin studied, with a detention time of only 6 hours, reduced total Kjeldahl nitrogen by approximately 28%. These researchers suggest that with a longer detention time, say 24 hours, a higher reduction rate may be achieved. This result is included in the wider range allocated to this strategy for nitrogen. Stahre and Urbanos (1989) noted that for nitrogen, also, the lower limit should be used when local data are not available.

## Nutrient Reduction References

Grizzard et al. (1986); Randall et al. (1982); Stahre and Urbonas (1989); Walesh (1991)

## Costs

| | $A/ha |
|---|---|
| Capital Costs | 300 - 1000 |
| Maintenance Costs[1] | 5 - 50 |

1. includes operating costs.

This study considers the cost of installing an extended duration detention basin to be only the additional cost necessary to modify a retardation basin, that is these costings do not include a component for the construction of the basin. Athayde et al. (1983) estimates that the outlet modifications necessary to extend the detention time of a retardation basin will increase construction costs by about 10% to 12%. SPCC (1989) provides an estimate of the cost to develop retardation basins as part of a truck drainage system for the Penrith area. These costs range from $3000 to $8000 per hectare of catchment and are based on 1986 figures. This manual also estimates operating and maintenance costs to be between 3% and 5% of construction costs.

The capital and maintenance costs given in the above table were derived by combining the costings reported in Athayde et al. (1983) and SPCC (1989).

## Costs References

Athayde et al. (1983); SPCC (1989)

# 3 Impervious Area Reduction (compared to traditional urban developments)

## Description

This management practice involves the use of any number of strategies which reduce the surface area that is impregnable to water, for example asphalt surfaces and concrete channels. Those strategies that contribute to such a reduction include :

- grass swales
- porous pavements
- lawn coring.

These nutrient reduction strategies may be applied in both recent urban and established urban areas, however the major implementation is likely to occur in new developments where the earliest stages of development planning can include these strategies.

## Nutrient Reduction

| | % Reduction |
|---|---|
| Total Phosphorus | 0 - 40 |
| Total Nitrogen | 0 - 40 |

The only data available for this management strategy was from USA in the early 1980s, i.e. Athayde et al. (1983). This series of studies investigated grass swales in three locations and found no significant reduction in nutrient levels. However these studies did not take into account the reduction in runoff volume and the subsequent impact on nutrient loads. Randall (1982) found that the effectiveness of grassed areas to promote infiltration and reduce runoff pollution was extremely high. However this paper reports no quantitative results for this strategy. Weeks and Crockett (1983) suggested that the impact of such strategies would be to reduce pollution by up to 40%. Clearly many environmental factors such as slope, soil type and rainfall intensity would impact on the effectiveness of these strategies. However the implementation of a whole range of strategies to reduce the typical area of impervious surfaces in an urban situation is likely to be more effective than one strategy alone.

The above recommended ranges for nutrient reduction by these management strategies have been selected to include both the study by Athayde et al. (1983) and the more qualitative information from the literature (Randall, 1982; Weeks and Crockett, 1983).

Table 5 details the results of the literature review regarding this management strategy.

### Nutrient Reduction References

Athayde et al. (1983); Randall (1982); Weeks and Crockett (1983).

### Costs

| | $A/ha |
|---|---|
| Capital Costs | |
| Maintenance Costs[1] | |

1. includes operating costs.

The cost of a number of the systems that may be used to reduce impervious areas are less than the traditional 'hard' options. The construction cost of impervious pavements is less than traditional impervious pavements and they eliminate the need for kerb and guttering thus further reducing the cost (SPCC, 1989). Grass swales are less expensive to install than traditional concrete lined drains, however maintenance costs associated with mowing and the removal of accumulated silt are higher (SPCC, 1989).

Although it is possible to compare the cost of these management strategies to less pervious options, more accurate costings have not been determined.

### Costs References

SPCC (1989)

## 4 Retention Basin

### Description

A retention basin holds storm runoff causing it to continue in the hydrological cycle by the processes of infiltration, percolation and evapotranspiration, and not by direct discharge to drainage lines and watercourses. (Somaratne and Argue, 1990). Some of these basins may discharge in very large storms or may be included in a system such that large flows bypass the retention basin. Because these basins rely on percolation and infiltration of stormwater, their implementation is limited by site characteristics such as soil type and water table depth.

They are applicable to both recent and established sewered urban areas.

## Nutrient Reduction

| | % Reduction |
|---|---|
| Total Phosphorus | 70 - 95 |
| Total Nitrogen | 70 - 95 |

The literature research revealed no Australian data for this nutrient reduction strategy, and only one American study considered a true retention situation, i.e. the study by Wanielista and Yousef (1986). This study indicated a reduction in both total phosphorus and total nitrogen of greater than 96% for a retention situation in which stormwater from the first flush is retained. This figure was determined using a simulation model based on 16 measured storm events and off-line retention of the first inch of rainfall. It is also based on a small catchment size. The study by Yousef et al. (1986) looked at a pond which discharges infrequently but still reduced nutrient loads by between 80% and 90%. This basin holds the runoff from an overpass road system and has a total drainage area of 19.8ha. The pond maintains a large standing crop of filamentous algae nearly all year round.

These results indicate that a relatively high reduction in nutrient loads can be achieved by retention basins, particularly an off-line basin which holds the first-flush of stormwaters. These results refer only to basins with small catchments. This is supported by the report by NSW Dept. of Housing (1993) which states that the first-flush phenomenon is most obvious in catchments less than 40ha in size.

As no data were available specifically for the Hawkesbury-Nepean Basin a lower limit has been suggested for the efficacy range for this management strategy than that found in the two studies described above.

Table 6 details the results of the literature review regarding this management strategy.

## Nutrient Reduction References

Wanielista and Yousef (1986); Yousef et al. (1986)

## Costs

| | $A/ha |
|---|---|
| Capital Costs | 2000 - 20,000 |
| Maintenance Costs[1] | 60 - 600 |

1. includes operating costs.

As no specific cost estimates have been located for this management strategy, the estimates determined for a wet detention basin are suggested as appropriate until more specific information is available. A discussion of these costings is given in the wet detention basin section.

### Costs References

See section on wet detention basin.

# 5 Street Sweeping

### Description

Urban streets are usually cleaned by sweeping, vacuuming or washing down. Since many of the pollutants are associated with particulate matter, their removal by street cleaning may be an effective means of reducing pollution concentration in runoff. Studies of street sweeping have shown the most effective sweepers are the vacuum types (SPCC, 1989). Non-vacuum sweepers simply redistribute the finer particles, which carry a significant pollutant load, over the road surface. Street washing cleans the streets but only transfers accumulated pollutants to gully pits and stormwater drains (SPCC, 1989).

As a management strategy to reduce stormwater nutrient loads, street cleaning may be applied in all urban catchments. In a disturbed urban situation street sweeping, if carried out effectively, may remove from road surfaces the extra soil dropped there by trucks and earthmoving equipment.

The frequency of street sweeping determines, in part, its impact on the nutrient load in urban runoff. Consequently, two ranges are allocated to this management strategy, 1 for street sweeping every 30 days, and 1 for street sweeping every 7 days.

### Nutrient Reduction

**Street Sweeping every 30 days**

| | % Reduction |
|---|---|
| Total Phosphorus | 0 - 15 |
| Total Nitrogen | 0 - 15 |

**Street Sweeping every 7 days**

| | % Reduction |
|---|---|
| Total Phosphorus | 0 - 50 |
| Total Nitrogen | 0 - 50 |

Only limited Australian data for this management strategy were available in the literature reviewed, so North American research has been considered. Most studies indicated that the impact of street sweeping is highly variable. Marsalek (1978) reported results ranging from 3.2% to 43.2%, with a range of 3.2% to 13.6% for sweeping every 30 days and a range of 10.3% to 43.2% for sweeping every 7 days. However, Weeks and Crockett (1983), the only Australian paper to address this management strategy, suggested that the impact of street sweeping on the nutrient load would be a reduction of less than 10% in that load. It should also be noted that Marsalek (1992) stated that the impact of street sweeping on the nutrient load in stormwater is 'questionable'.

The recommended ranges given above reflect the highly variable impact of street sweeping and the effect of the frequency of street sweeping on that reduction rate. Table 7 contains details of the percentage reduction in nutrient loads brought about by street sweeping as reported in the literature.

## Nutrient Reduction References

Athayde et al. (1983); Marsalek (1978); Marsalek (1992); Weeks and Crockett (1983)

## Costs

**Street Sweeping every 30 days**

| | $A/ha |
|---|---|
| Capital Costs | 36 |
| Maintenance Costs[1] | 8 |

1. includes operating costs.

**Street Sweeping every 7 days**

| | $A/ha |
|---|---|
| Capital Costs | 152 |
| Maintenance Costs[1] | 35 |

1. includes operating costs.

The cost of street sweeping depends largely on two main components; the capital cost of machinery, i.e. street sweeper and the labour cost. The estimates above have been established using 1986 costings given in SPCC (1989) and an estimated 300 metres of kerbing per hectare of development. The figures reported in SPCC (1989) are a capital cost of $110,000 and a yearly labour cost of $25,000 to clean 31km/day.

### Costs References

SPCC (1989)

# 6 Wet Detention Basin

### Description

A wet detention basin may be defined as a natural or artificial basin which maintains a permanent pool of water, and, when designed specifically for water quality control, should have a minimum depth of no less than 1.5m and an average depth of 2.5m. The size of the pond may vary, but to have a significant water quality impact, a minimum surface area of approximately 1% of the catchment area is necessary. Macrophyte growth normally occurs around the edge of these basins facilitating nutrient uptake (SPCC, 1989).

Wet detention basins, water quality control ponds and urban lakes have been combined in this management strategy as all three terms are used to describe structures maintaining a permanent water body with similar physical and biological performance.

### Nutrient Reduction

**Recent Sewered Urban**

| | % Reduction |
|---|---|
| Total Phosphorus | 35 - 85 |
| Total Nitrogen | 27 - 61 |

**Established Sewered Urban**

| | % Reduction |
|---|---|
| Total Phosphorus | 45 - 85 |
| Total Nitrogen | 40 - 61 |

Table 8 lists the nutrient reduction performance of a number of wet detention basins and urban lakes as reported in the literature. The work described by Lawrence and Goyen (1987) in Canberra was considered relevant to this study. However, as the earlier literature relating to this work has not been located, these results have not been included.

The percentage reduction in total phosphorus ranged from 10% to 100%. Hammerschmid (1991) found that the efficacy of this management strategy was reduced under the higher sediment load from a developing catchment. This finding has been incorporated into this report by identifying a higher lower limit for the efficacy range for an established urban situation than for a recently urbanised area. The latter has a higher percentage of surfaces unprotected against surface runoff.

The results from three studies were discarded in arriving at the phosphorus reduction figure of 45% to 85%. These are: the low figures given by Ellis (1990) as they are based on an English site; those given by Rosich and Cullen (1979) for Lake Burley Griffin as this lake has a primarily rural catchment; and the 100% upper limit given by Hammerschmid (1991) as this was achieved under laboratory conditions and is unlikely to be repeated in the field. The reduction range for phosphorus reflects those of the remaining studies.

The percentage nitrogen reduction ranged from 18% to 100%. The study by Martin (1988) was not considered relevant because of the low average detention time, i.e. < 1 day. The upper limit given by Hammerschmid (1991) was also discarded as this performance is based on laboratory tests under quiescent conditions. However the increased performance under a lower sediment load as found by this researcher was considered significant. The ranges chosen reflect the results given by the remaining studies.

## Nutrient Reduction References

Athayde et al. (1983); Ellis (1990); Hammerschmid (1991); Hey (1982); Hvitved-Jacobsen et al. (1987); Martin (1988); Oliver and Grigoropoulas (1981); Randall (1982); Rosich and Cullen (1979); Yu and Benelmouffok (1990).

## Costs

### Large Catchments

| | $A/ha |
|---|---|
| Capital Costs | 2000 - 6000 |
| Maintenance Costs[1] | 200 - 600 |

1. includes operating costs.

### Small Catchments (1 hectare)

| | $A/ha |
|---|---|
| Capital Costs | 20,000 |
| Maintenance Costs[1] | 600 |

1. includes operating costs.

The cost of the construction of a wet detention basin depends largely on the amount of excavation necessary to create the water holding basin and may vary greatly from site to site. The size of the catchment has an impact on the per hectare cost as economies of scale come into play for those basins with a large catchment. For the purpose of this study a small catchment is considered to be around 1 hectare.

The estimated range given above for a larger catchment is based on two basins constructed in Western Sydney, one at Liverpool (pers. comm. K. Robinson and R. James) and one at Penrith (pers. comm. Penrith City Council and Morse et al., 1992). Woodward (1986) updated the costs provided by North American experience in the early 80's. These costs are used for both the small catchment situation and for maintenance costs. The costing information used as a basis for the tables above is described in more detail in Table 12.

## Costs References/Sources

Morse et al. (1992); Woodward (1986)

K. Robinson, Wattle Grove Joint Venture, Liverpool, NSW.
R. James, Wattle Grove Joint Venture, Liverpool, NSW.
Penrith City Council, NSW.

# 7 Wetlands

## Description

Wetlands which are used to reduce nutrient loads in urban runoff may be natural or artificial. It is recommended that the surface area of a wetland comprises at least 0.5% of its catchment area (SPCC, 1989). They must be shallow, and emergent aquatic plants should be encouraged. More than 25% of any permanent water should be less than one metre deep and the remainder of any open water should not be deeper than two metres.(SPCC, 1989).

Wetlands are most efficient when combined with upstream flow retardation, sediment traps and trash racks (Joint Council's River Committee, 1988; SPCC, 1989). For this reason a wetland should only be considered as part of a treatment train which includes some form of sediment and litter removal upstream of the wetland. It is not unusual for more than one wetland to be included in the treatment train.

For the continued efficient performance of a wetland, it is sometimes necessary to harvest the aquatic plants on a regular basis (Macarthur Regional Organisation of Councils, 1992). De-silting may also be necessary at times (SPCC, 1989).

Wetlands may be used for stormwater quality enhancement in urban catchments where the sediment load is not too high or where the sediment load has been significantly reduced by other management practices, e.g. established urban areas.

## Nutrient Reduction

| | % Reduction |
|---|---|
| Total Phosphorus | 17 - 94 |
| Total Nitrogen | 18 - 74 |

The efficacy of wetlands in reducing the phosphorus and nitrogen loads in urban runoff, as established in various studies is given in Table 9. Although a number of the studies were based overseas, these have been included because of the limited data available here. The figures given by Lenehan (1992) for a wetland in South Australia seem very high. However, as these results have been confirmed by later data (pers. comm. B. Ormesby, 1993), they have been included in the range allocated to this management strategy.

The figures of 17% to 94% for phosphorus reduction and 18% to 74% for nitrogen reduction reflect the range of performance shown in the literature for wetlands with varying retention times, from half an hour to more than 18 days, and growth conditions. It should be noted that the lower limit of this range is for a wetland with persistent anaerobic conditions at the water/sediment interface which resulted in phosphorus being recycled back into the water column (Martin, 1988).

## Nutrient Reduction References/Sources

Graham (1991); Gumbricht (1993); Lenehan (1992); Martin (1988); Meiorin (1989); Swanson (1992); Swanson (1992a)

B. Ormesby, Salisbury City Council, South Australia

## Costs

| | $A/ha |
|---|---|
| Capital Costs | 100 - 400 |
| Maintenance Costs[1] | 5 - 10 |

1. includes operating costs.

The only report found in the literature giving costing for wetlands was ABARE (1993) which describes a wetland at Carcoar, NSW. The catchment of this wetland although containing an urban area, is mainly rural. Its establishment involved the use of some voluntary labour (White et al., 1993). The figures provided by ABARE (1993) were considered too low to be applied to the urban situation so were discarded.

The estimate provided by J. Stricker (pers. comm.) of $20,000/ha of wetland has been used as the basis for the recommended range. SPCC (1989) recommends that the surface area of a wetland be at least 0.5 % of the catchment which it serves. This figure has been used as the lower limit for the size of a wetland designed as a stormwater improvement strategy.

White et al. (1993) report preliminary ongoing costs of $6 per kilogramme of phosphorus removed from the water for the Carcoar wetland. As these are the only ongoing costs reported for a wetland these have been combined with a nutrient generation rate range of 0.9 to 1.7kg of phosphorus/ha/yr. (Marston, 1993) to provide an estimated cost for maintenance of an urban wetland of $5 to $10 /ha/yr.

## Costs References/Sources

ABARE (1993); Marston (1993); White et al. (1993).
J. Stricker, Water Board, Sydney, NSW.

# System Management Practices

C

## 1 Sediment Controls (based on NSW Department of Housing (1993) guidelines

### Description

The management strategies discussed under this heading are specifically applicable to disturbed land and development sites. They are designed to reduce the increased sediment load which is carried in stormwater from soil which has been exposed, i.e. has no or little vegetation or other surface covering. They include such measures as:

- temporary soil conservation measures
- sediment retention traps
- sediment retention barriers
- protection of stockpiles
- diversion of runoff around the disturbed site
- flocculation of ponds where necessary
- timely revegetation.

These guidelines include specific mention of soil texture and the percentage of dispersible materials in the soil on which development occurs. Dispersible soils are structurally unstable in water and readily disperse into their constituent particles (sand, silt and clay) with the very fine particles (< 0.005mm) staying in suspension for a much longer time than predicted by the application of Stokes' Law, which describes only physical settling. These soil types are common in Western Sydney in the Hawkesbury-Nepean Basin where extensive urban development is expected in the next few decades. It is for this reason that these guidelines were selected for inclusion in this study.

It is stated in the Department of Housing guidelines (NSW Department of Housing, 1993) that where a soil has greater than or equivalent to 10% dispersible materials, i.e. where more than 10% of the soil material is dispersible clay, sediment retention basins will require dosing with chemical flocculation agents such as gypsum. This practice is not always carried out in the field so the management strategies included in this report have been selected to cover both the practised and recommended situations.

## Nutrient Reduction

**For soils < 10% dispersible materials**

| | % Reduction |
|---|---|
| Total Phosphorus | 20 - 90 |
| Total Nitrogen | 20 - 90 |

No data relating reduction in nutrient loads are available in the literature for this group of management strategies. Consequently the opinion of workers in this field was sought. The estimates of pollution reduction were given as reduction in sediment load, and are detailed in Table 10.

Both I. Mathews (pers. comm.) and R. Morse (pers. comm.) believe that, if the guidelines are followed, sediment load in runoff can be maintained at pre-development levels. As the pre-development landuse may vary, the impact of the sediment controls is also highly variable when described as a percentage reduction in sediment load. When calculated using the nutrient generation rates suggested by Marston (1993) for a disturbed site, these reduction levels range from 20% to 99%.

For the purpose of this study it has been assumed that reduction in nutrient load is equal to the reduction in sediment load. It should be noted however that this assumption does not consider the dissolved nutrient load. The above recommended reduction rates have been based on the opinion of several experts regarding sediment load reduction lowered to allow for the non-removal of any dissolved nutrients.

**For soils >= 10% dispersible materials (flocculation used where appropriate)**

| | % Reduction |
|---|---|
| Total Phosphorus | 20 - 90 |
| Total Nitrogen | 20 - 90 |

Stormwater from these soils contains a percentage of the sediment load which will not settle out of the water column without the use of flocculents, or extremely long detention times. The high turbidity of this runoff makes it unsuitable for direct flow into wet detention basins and wetlands.

Hammerschmid (1991) found that a high percentage of nutrients (total phosphorus and total Kjeldahl nitrogen) were bound to soil particles finer than 2mm for two subcatchments monitored in the Hawkesbury-Nepean Basin. This included up to 60% of all phosphorus and up to 40% of all nitrogen exported from a developing urban catchment in the Camden area.

When flocculation is used in the settling ponds associated with development on soils with a high dispersibility, it is assumed in this study that the effectiveness of the sediment controls will equal that of controls on a non-dispersible soil, i.e. as described above for soils < 10% dispersible materials.

**For soils >= 10% dispersible materials (no flocculation used)**

| | % Reduction |
|---|---|
| Total Phosphorus | 20 - 50 |
| Total Nitrogen | 20 - 50 |

Where no flocculation is used in the settling ponds which receive runoff from disturbed land or a development site on this soil type, the effectiveness of the sediment control strategy is greatly reduced.

The literature research revealed no reported studies for this sediment control strategy, so again the opinion of industry experts was sought. D. Blewitt (pers. comm.) suggested that the greatest effect sediment controls could achieve in the Camden area was a 50% reduction in sediment load. The figures for reduction in sediment load are used again as an estimate for the reduction in nutrient loads.

## Nutrient Reduction Sources

D. Blewitt, Camden Municipal Council, Camden, NSW.
I. Mathews, NSW Department of Housing, Liverpool, NSW.
R. Morse, Morse, Mcvey & Assoc., Picton, NSW.

## Costs

| | $A/ha |
|---|---|
| Capital Costs | 5000 - 15,000 |
| Maintenance Costs[1] | 90 - 180 |

1. flocculation costs/yr

For this management strategy capital, maintenance and operating costs have been combined into the capital costs category because sediment controls are normally implemented for a short time during the construction period. The only maintenance costing which has been estimated separately is the cost of flocculation of sediment basins.

Costing estimates from industry did not include separate maintenance costings and ranged from $5,000 to $17,000 with two specific developments costing between $10,000 and $11,500 per hectare of development. These developments followed the Dept. of Housing (1993) guidelines (P. Farnhill, pers. comm.; I. Mathews, pers. comm.). A third development in western Sydney had lower costs but did not use extensive sediment controls. Runoff turbidity was controlled by storage in a large detention basin and flocculation when necessary. This development had costs around $3,000 per hectare (K. Robinson and R. James, pers. comm.).

### Costs Sources

P. Farnhill, Rose Consulting Group, Blacktown, NSW.
I. Mathews, NSW Department of Housing, Liverpool, NSW.
K. Robinson, Wattle Grove Joint Venture, Liverpool, NSW.
R. James Wattle Grove Joint Venture, Liverpool, NSW.

# 2 Gross Pollutant Trap and Wet Detention Basin

### Description

These combined management strategies are sometimes implemented during the development stage in an urban catchment. Both the gross pollutant trap (GPT) and wet detention basin may be constructed in the early phase of a development to help reduce the nutrient load in runoff from the development. However, the efficacy of this treatment train is reliant on the effective use of sediment controls. This is particularly true on highly erodible soils.

The GPT and wet detention basin generally remain after development is completed to form part of the pollution reduction system for urban runoff. The figures given below apply specifically to a developing or disturbed catchment.

### Nutrient Reduction

**With sediment controls**[1]

| | % Reduction |
|---|---|
| Total Phosphorus | 35 - 85 |
| Total Nitrogen | 27 - 61 |

[1] Based on Department of Housing guidelines (NSW Dept. of Housing, 1993) including flocculation where appropriate.

As no specific data were found in the literature relating the use of a GPT/wet detention basin and sediment controls to a disturbed situation, the figures given for a wet detention basin have been recommended. An assumption has been made that the sediment controls have been effective in reducing the sediment load significantly. The GPT is designed to trap coarse particles greater than 0.04 mm. These particles tend not to carry a significant nutrient load (NSW Dept. of Housing, 1993).

To achieve the reduction levels recommended here, sediment controls must be in place above these systems in the treatment train. However the percentage reduction in nutrient loads brought about by sediment controls is not included in the above figures.

**Without sediment controls**[1]

| | % Reduction |
|---|---|
| Total Phosphorus | 0 - 75 |
| Total Nitrogen | 0 - 61 |

The findings reported by Morse et al. (1992) indicate that without sediment controls the efficacy of a GPT/wet detention basin treatment train may be greatly reduced. Morse et al. (1992) found that a wet detention basin in the Penrith area had no significant impact on nutrient loadings. This basin received runoff from a development site with limited sediment controls. These results are shown in Table 11. This study was the only monitored field application of such a system. However as indicated in the sediment control guidelines (NSW Dept. of Housing, 1993) the efficacy of reduction techniques is controlled, in part, by soil type.

The recommended value has been selected to include both the results of Morse et al. (1992) and the recommended values for a wet detention basin in a more stable urban environment, e.g. recent sewered urban catchment.

## Nutrient Reduction References

Hammerschmid (1991); Morse et al. (1992); NSW Dept. of Housing (1993).

## Costs

| | $A/ha |
|---|---|
| Capital Costs | 2500 - 7500 |
| Maintenance Costs[1] | 60 - 160 |

1. includes operating costs

Estimates for the costing of a GPT/wet detention basin system were collected from both the literature and experienced workers in the industry. These estimates ranged from $3,000/ha for a system at Penrith (Morse et al., 1992; Penrith City Council, pers comm) to $7,500 for a similar system near Liverpool (K. Robinson and R. James, pers. comm.). Both these treatment trains contain two GPTs. The number of GPTs will depend on the shape of the catchment and drainage design.

Known maintenance costs for these systems include only the cost of cleaning accumulated silt and rubbish from the GPTs. These costs were estimated by both Morse et al. (1992) and Liverpool City Council (1992) and ranged from $58/ha/yr to $160/ha/yr.

### Costs References/Sources

Liverpool City Council ((1992); Morse et al. (1992).

K. Robinson, Wattle Grove Joint Venture, Liverpool, NSW.
R. James, Wattle Grove Joint Venture, Liverpool, NSW.
Penrith City Council, Penrith, NSW.

# 3 Gross Pollutant Trap, Wet Detention Basin and Wetland

### Description

This management strategy has become one of the most commonly designed treatment trains for the reduction of pollution, including nutrient loads, in urban stormwater.

It is generally more easily applied in new urban areas where development plans can allocate the necessary space for inclusion of these facilities. Although included in new developments, this management strategy is frequently designed to have the greatest impact on stormwater quality when the development phase is complete and the area is established.

### Nutrient Reduction

| | % Reduction |
|---|---|
| Total Phosphorus | 43 - 85 |
| Total Nitrogen | 36 - 78 |

A summary of the literature reviewed which included data relevant to this series of management strategies is given in Table 11. The average residence time of waters within a system containing a wet detention basin and a wetland determines in part its efficacy in reducing the nutrient loads (Graham, 1989; Hammerschmid, 1991). While this factor was acknowledged in most studies the residence time was not always reported, so the recommended range has been extended in the lower end of the range to include some systems with a lower than optimum residence time.

The values provided by the literature were within the range 0% to 90% for phosphorus reduction and 0% to 78% for nitrogen reduction. The results described by Tuovila et al. (1988) were discarded as the system reported on included filtration which is not included in this management strategy. The very low levels reported by Morse et al. (1992), i.e. no significant reduction, described a situation where the system is being inundated with high sediment loads from a developing catchment. It was not designed to treat this type of runoff (pers. comm. Penrith City Council). For this reason these results were discarded, however they highlight the fact that this treatment train cannot be used in isolation to significantly improve the runoff quality from a developing urban catchment in some parts of western Sydney.

The recommended reduction rates reflect the results of the remaining studies including that of Martin (1988) which describes a system in which the residence time was significantly reduced by short circuiting during some storms.

## Nutrient Reduction References

Graham (1991); Martin (1988); Meiorin (1989); Morse et al. (1992); Oberts and Osgood (1991)

## Costs

| | $A/ha |
|---|---|
| Capital Costs | 7500 |
| Maintenance Costs[1] | 160 |

1. includes operating costs

The cost of installing this particular management strategy has been estimated for an area in the Liverpool area (Liverpool City Council, 1992). The system described in this document has several GPTs and detention ponds with associated wetlands. No other costings for this management strategy have been obtained.

### Costs References

Liverpool City Council (1992).

# 4 Gross Pollutant Trap, Off-line Detention and Wetland

### Description

Nichols and Short (1992) describe the application of this strategy to small catchments in the Illawarra region south of Sydney. This is the only coverage for this strategy given in the literature. In this system, the first flush of runoff is directed into a treatment facility, i.e. the wet detention pond and wetland. During periods of high flow other runoff bypasses these structures.

The topography of many of the new development areas in Sydney's west make it difficult to keep catchment size to less than 40ha (Department of Housing, 1993). However these are the catchments in which the first flush phenomenon is most pronounced. It would seem that the application of this management strategy is limited in the Hawkesbury-Nepean Basin to areas where development is less extensive such as the Blue Mountains.

### Nutrient Reduction

| | % Reduction |
|---|---|
| Total Phosphorus | 43 - 85 |
| Total Nitrogen | 36 - 78 |

No monitoring of this treatment train has occurred to date, however study of its efficacy in reducing pollutant loads should begin soon. It can be assumed that this management strategy would be more effective than a similar system with on-line detention. However, as no data are currently available, the recommended values for such an on-line system, i.e. a GPT, wet detention basin and wetland, are considered appropriate here.

### Nutrient Reduction References

Nichols and Short (1992); Section on GPT, wet detention basin and wetland.

### Costs

| | $A/ha |
|---|---|
| Capital Costs | 7500 |
| Maintenance Costs[1] | 160 |

1. includes operating costs

No costing information has been acquired specifically for this management strategy, so again information for a system containing a GPT, wet detention basin and wetland are suggested as appropriate. It should be noted that, as this management strategy is designed for small catchments, costs are likely to be higher than those given here and further work is necessary to determine more accurate costing information.

### Costs References/Sources

See section on GPT, wet detention basin and wetland.

# 5 Sediment Trapping Pit and Mini-Wetland (Stormwater Treatment Zone)

### Description

Stormwater Treatment Zones have been used by Wyong Shire Council in new developments and to retrofit small (<600mm) stormwater pipe outlets which feed directly into Tuggerah Lakes. Each consists of a sediment trapping pit constructed of earth and gabions and an artificial mini-wetland planted with freshwater plants, e.g. Phragmites. (Wyong Shire Council, 1990; S. Merry, pers. comm.).

The catchment areas served by these zones are small, typically 5 to 10 hectares, although larger catchments have been included in the program more recently (S. Merry, pers. comm.).

One of the benefits of this stormwater management strategy is the fact that the stormwater treatment zones can be retrofitted in sites where larger scale solutions are impractical. Such an site would be an established urban area with many stormwater outlets into local waterways. Although the Hawkesbury-Nepean Basin does not contain any implementations of this strategy at present, these zones may offer a practical solution in the future to some problem sites.

## Nutrient Reduction

| | % Reduction |
|---|---|
| Total Phosphorus | 40 - 60 |
| Total Nitrogen | 40 - 60 |

Analysis of the performance of the Wyong Stormwater Treatment Zones was carried out, although not published in the scientific literature. Wyong Shire Council (1990) reports that these systems reduce the nitrate levels in runoff by 50% to 60%. J. Bell (pers. comm.), the developer of these systems, estimated that the phosphorus reduction is about 60%.

As no further data were obtainable, these figures have been used to derive the percentage reduction figures for this management system for both total phosphorus and total nitrogen.

## Nutrient Reduction References/Sources

Wyong Shire Council (1990)
J. Bell, Brisbane City Council, Brisbane, Qld.
S. Merry, Wyong Shire Council, Charmhaven Depot, Charmhaven, NSW

## Costs

| | $A/ha |
|---|---|
| Capital Costs | 200 - 600 |
| Maintenance Costs[1] | 25 - 50 |

1. includes operating costs

The installation cost and maintenance cost of these Stormwater Treatment Zones were estimated by S. Merry (pers. comm.) and depends on the catchment size, slope and current landuse. Maintenance involves removal of silt, repair of fences, etc.

## Costs Sources

S. Merry, Wyong Shire Council, Charmhaven Depot, Charmhaven, NSW.

D

# References

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# Appendix 1 - Glossary

**Buffer Strip**
A buffer strip is a strip of vegetation left or constructed downslope from earthworks, or maintained along the edge of a watercourse. The flatter and wider the buffer strips are, the more effective they become (NSW Dept. of Housing, 1993).

Minimum buffer length should be about 25m for good pollutant removal efficiency (Yu and Benelmouffok, 1990).

**Extended Duration Detention Basin**
An extended duration detention basin is basically a retardation basin which has been designed such that the detention time of stormwaters in the basin has been extended. This is normally achieved by modifying the outflow structure.

**Flocculation**
Flocculation describes the coagulation of finely divided particles into particles of greater mass. The use of a flocculant in stormwater with a high percentage of suspended solids reduces the detention time required to settle those solids out of the water column. Gypsum is a commonly recommended flocculant.

**Gross Pollutant Trap**
This system consists of a sediment trap, normally concrete, and a trash rack. They are designed to removed the gross pollutants, mainly particles >0.04mm in diameter, and litter. Although these devices have limited impact on nutrient loads they are essential as a precursor to other structures within the treatment train.

**Off-line Detention**
This management strategy as referred to in this report involves the use of a wet detention basin to treat the 'first flush' runoff from a small catchment. The basin is designed such that only the first flush is detained irrespective of the duration of the storm event (Nichols and Short, 1992).

**Reduction in Impervious Areas**
This management practice involves the use of any number of strategies. Those strategies which contribute to such a system include:

- grass swales
- porous pavements
- lawn coring.

**Retardation Basin**
The purpose of a retardation basin is to control flooding and erosion potential in an area downstream from a development. The objective of the basin is to limit peak flow to a predetermined level, generally that which occurred before development within the catchment. These basins employ a bottom outlet with a restricted hydraulic capacity. Runoff from smaller storms flows along the bottom of the basin and discharges without restriction. Large flows are backed up in the basin temporarily. Ponding occurs only during larger storms and for relatively short periods of time (Athayde et al., 1983).

**Retention Basin**
A retention basin holds storm runoff causing it to continue in the hydrological cycle by the processes of infiltration, percolation and evapotranspiration, and not by direct discharge to drainage lines and watercourses (Somaratne et al., 1990). Some of these basins may discharge in very large storms or may be included in a system such that large flows bypass the retention basin.

**Sediment Controls (Department of Housing, 1993)**
These are the controls described in relation to soil management, drainage works and building sites in NSW Dept. of Housing (1993). They include such measures as:

- temporary soil conservation measures
- sediment retention traps
- sediment retention barriers
- protection of stockpiles
- diversion of runoff around the disturbed site
- flocculation of ponds where necessary
- timely revegetation.

**Sediment Trapping Pit and Mini-wetland**
These systems consist of sediment trapping pit constructed of earth and gabions and an artificial mini-wetland planted with freshwater plants, e.g. Phragmites (Wyong Shire Council, 1990 and pers. comm. S. Merry, 1993). The term used to describe these systems as used in the Wyong Shire at small (< 600mm) stormwater pipe outlets into Tuggerah Lakes is Stormwater Treatment Zones.

**Trash Rack**
A trash rack is a grid which is constructed across the flow of water to remove floating debris and litter. These form a component of a gross pollutant trap.

**Treatment Train**
This term is used to refer to any group of management strategies used together to reduce the pollutant load in stormwater. Generally, treatment facilities are implemented in series although in some circumstances they make work in parallel. A typical treatment train in an urban

situation would contain one or more gross pollutant traps, wet detention basins and wetlands.

**Wet Detention Basin**
These basins maintain a permanent pool of water, and when designed specifically for water quality control should have a minimum depth of no less than 1.5m and an average depth of 2.5m. The size of the pond may vary, but usually would have a minimum surface area of about 1% of the catchment area. Macrophyte growth normally occurs around the edge of these basins facilitating nutrient uptake (SPCC, 1989).

**Wetland**
Wetlands which are used to reduce nutrient loads in urban runoff may be natural or artificial. They must be shallow, and emergent aquatic plants should be encouraged. More than 25% of any permanent water should be less than 1m deep and the remainder of any open water should not be deeper than 2m (SPCC, 1989).

In many instances, an artificial wetland will be more efficient in improving water quality because the substrate can be designed to enhance pollutant removal.

A wetland should only be considered as part of a 'treatment train' which includes some form of sediment removal system, e.g. a sediment retention basin, and litter removal upstream of the wetland. It is not unusual for more than one wetland to be included in the 'treatment train'.

For the continued efficient performance of a wetland, it is sometimes necessary to harvest the aquatic plants on a regular basis. De-silting may also be necessary at times.

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# Appendix 2 - Summary of Published and Field Information

Abbreviations used in the following tables:

- P phosphorus
- TP total phosphorus
- N nitrogen
- TN total nitrogen
- TKN total Kjeldahl nitrogen
- av. average

**Table 3 References on Sediment Load Reduction by Buffer Strips**

| Reference | Buffer Length | Sediment Load Reduction | Comments |
|---|---|---|---|
| Hairsine and Grayson (1992) | | ( 20 - 97)% | • literature review based on field and rainfall simulator experiments<br>• Australian report of USA papers |
| Williams *et al.* (1990) | average 30m | (10 - 90)% | • model simulations of filter strips below cropped land<br>• assumed that vegetation is generally grasses and fully grown<br>• USA |
| Reference | % P Reduction | % N Reduction | Comments |
| Barling and Moore (1992) | (50 - 99)% | (50 - 94)% | • literature review reporting both field and rainfall simulator experiments<br>• Australian report of USA papers |

**Table 4 References on Nutrient Reduction by Extended Duration Detention Basin**

| Reference | Detention Time (av.) | % P Reduction | % N Reduction | Comments |
|---|---|---|---|---|
| Athayde *et al.* (1983) | 4-8 hours | TP < 15% | Organic N - 30%<br>Nitrate/Nitrite - 10% | • USA |
| Grizzard *et al.* (1986) | 6 hours | TP - ~14%<br>(read from graph) | TKN - ~28%<br>(read from graph) | • 47 inflow & 33 outflow events<br>• USA |
| Randall *et al.* (1982) | 36 hours | TP - 56%<br>(42 - 71)% | TN - 33%<br>(9 - 77)% | • column studies using runoff from parking lots<br>• results suggested use of flocculants may be necessary<br>• USA |
| Stahre and Urbonas (1989) | 24 hours | TP - (10 - 20)% | TN - (10 - 20)% | • based on field studies from USA and design guidelines<br>• NOTED that lower limit should be used when local data not available<br>• USA |
| Walesh (1991) | | TP - 12% | | • modified retardation basin<br>• USA |

**Table 5 References on Nutrient Reduction by Non-Structural Measures**

| Reference | Strategy | % P Reduction | % N Reduction | Comments |
|---|---|---|---|---|
| Athayde *et al.* (1983) | Grass Swales | TP - 0 | TN - 0 | • only compared inflow & outflow; not impact of reduced runoff<br>• 3 sites monitored<br>• USA |
| Weeks and Crockett (1983) | Grass Swales, porous pavements, and soil stabilisation | TP < 40% | TN < 40% | • no study of this strategy reported |

**Table 6 References on Nutrient Reduction by Retention Basins**

| Reference | % P Reduction | % N Reduction | Comments |
|---|---|---|---|
| Wanielista and Yousef (1986) | TP - > 96% | TN - >96% | • off-line retention<br>• based on storage of 1st inch of rainfall<br>• USA |
| Yousef *et al.* (1986) | dissolved P - 90.1% | Nitrite/Nitrate - 86.5%<br>ammonia N - 81.6% | • pond rarely discharges<br>• Florida, USA |

### Table 7 References on Nutrient Reduction by Street Sweeping

| Reference | % P Reduction | % N Reduction | Comments |
|---|---|---|---|
| Athayde *et al.* (1983) | TP - (0 - 50)% | TN - (0 - 50)% | • 10 studies with controls, highly variable data. USA |
| Marsalek (1978) | TP - 3.2% | TN - 5% | • **Broom** sweeping every **30** days more details in paper. USA |
| | TP - 13.9% | TN - 13.6% | • **Vacuum** sweeping every **30** days more details in paper. USA |
| | TP - 10.3% | TN - 15.9% | • **Broom** sweeping every **7** days more details in paper. USA |
| | TP - 44% | TN - 43.2% | • **Vacuum** sweeping every **7** days more details in paper. USA |
| Marsalek (1992) | questionable | questionable | • literature review<br>• questioned efficacy of this practice in reducing nutrient load |
| Weeks and Crockett (1983) | TP - < 10% | TN - < 10% | • no specific study<br>• Canberra, Australia |

### Table 8 References on Nutrient Reduction by Wet Detention Basins

| Reference | Detention Time (av.) | % P Reduction | % N Reduction | Comments |
|---|---|---|---|---|
| Athayde *et al.* (1983) | > 10 days | TP - ( 45 - 79)% | TKN - (27 - 60)% | • 3 basins from NURP[1] program<br>• USA |
| Brown and Molinari (1987) Geary (1990) | | TP - 65% | TKN - 50% soluble nitrate - 50% | • general comment<br>• no study |
| Ellis (1992) | | TP - 21% (10 -58)% | | • London, UK |
| Hammerschmid (1991) | 48 hours | particulate bound P - 38.1% | TKN - 34.8% | • laboratory study<br>• based on quiescent conditions, using soils from **developing** urban area<br>• Camden, Australia |
| | 16 days | particulate bound P - (38.1 - 100)% | TKN - (34.8 - 100)% | • laboratory study<br>• based on quiescent conditions, using soils from **developing** urban area<br>• Camden, Australia |
| | 48 hours | particulate bound P - 53.2% | TKN - 60.9% | • laboratory study<br>• based on quiescent conditions, using soils from **developed** urban area<br>• Camden, Australia |
| | 16 days | particulate bound P - (53.2 - 100)% | TKN - (60.9 - 100)% | • laboratory study<br>• based on quiescent conditions, using soils from **developed** urban area<br>• Camden , Australia |

| Reference | Detention Time (av.) | % P Reduction | % N Reduction | Comments |
|---|---|---|---|---|
| Hey (1982) | 28 days | TP - 60% | | • urban lake with recreation use<br>• summer and spring account for 71% of flow<br>• freezes in winter<br>• some wave action<br>• thorough study<br>• Lake Ellyn, USA |
| Hvitved-Jacobsen *et al.* (1987) | | TP - (55 - 68)% | | • monitored 10 storm events<br>• urban catchment<br>• Viborg, Denmark |
| Martin (1988) | < 1 day | TP - 38% | TN - 18% | • short circuiting during some storms<br>• 0.5% of catchment<br>• Florida, USA |
| NSW Dept. of Planning (1993) | typically 13 days. | 70% | | • water quality control pond<br>• recommendation only<br>• Australia |
| Oliver and Grigoropoulas (1981) | 28 days | TP - 65% | | • urban lake - lake is 5% of catchment<br>• residential and commercial catchment<br>• sampling between April and October<br>• Lake Frisco, USA |
| Randall (1982) | | TP - 59.2%<br><br>TP - 69.8% | TKN - 37.1%<br>Nitrate/nitrite - 83.6%<br>TKN - 45.8%<br>Nitrate/nitrite - 71.1% | • macrophytes present<br>• 259 storms monitored<br>• USA<br>• macrophytes present<br>• 259 storms monitored<br>• USA |
| Rosich and Cullen (1979) | | TP - 40%<br>(12 - 91)%<br><br>TP - 83%<br>(80 - 83)% | | • urban lake - 3% of catchment is urban contributing 3.5% of P load<br>• Lake Burley Griffin, Australia<br>• urban lake - 16% of catchment is urban<br>• Lake Ginninderra, Australia |
| Weeks and Crockett (1983) | | TP = 85.5 + 30.5 log t ( t = hydraulic res. time (days)) | | • Canberra, Australia |
| Yu and Benelmouffok (1990) | | TP - 70% | | • studied 5 storm events<br>• Virginia, USA |

1. National Urban Runoff Program, USA

## Table 9 References on Nutrient Reduction by Wetlands

| Reference | Detention Time (av.) | % P Reduction | % N Reduction | Comments |
|---|---|---|---|---|
| Graham (1989) | | TP - 84% | TKN - 66%<br>$NH_3$-N - 96% | • *Phragmites* and *Typha* reed bed in drainage line<br>• data for low summer flow only<br>• Melbourne, Australia |
| Graham (1991) | 1/2 hour to 2 days | TP - (40 -50)% | TN - (28 -52)% | • data collected outside summer growth period<br>• Melbourne, Australia |
| Gumbricht (1993) | | TP - 86% | TN - 62% | • temperatures >10$^o$C<br>• water from polluted stream<br>• parallel canals<br>• Sweden |
| | | TP - 62% | TN - 32% | • temperatures -1 - 17$^o$C<br>• water from polluted stream<br>• parallel canals<br>• Sweden |
| Lenehan (1992) | > 7 days | TP - 94% | TN - 74% | • preliminary results (1st year's data found to be consistent with later data - pers. comm. B. Ormesby)<br>• runoff from developing industrial area, also receives extra stormwater from large residential catchment when necessary<br>• Adelaide, Australia |
| Martin (1988) | | TP - 17% | TN - 21% | • covers 1.8% of catchment<br>• persistent anaerobic conditions. USA |
| Meiorin (1989) | | TP - 51% | | • catchment is 66% urban, 28% agriculture<br>• USA |
| Swanson (1992a) | | TP - 25%<br>(< 50)% | TN - 18%<br>(< 50)% | • 2 wetlands in series<br>• wet weather flow, so a shorter retention time than dry flow<br>• Katoomba, Australia |
| Swanson (1992) | > 18 days | TP - 49% | TN - 40.4 | • 2 wetlands in series<br>• dry weather flow only<br>• Katoomba, Australia |
| Tomlinson *et al.* (1993) | > 15 days | TP - 73% | TN - 64% | • wetlands fed by channel and swale<br>• urban catchment<br>• Adelaide, Australia |

## Table 10 References on Sediment Reduction by Sediment Controls (based on NSW Department of Housing (1993) guidelines)

| **Reference** | **% Sediment Load Reduction** | **Comments** |
|---|---|---|
| pers. comm. D.Blewitt, Camden Municipal Council (1993) | 50% | • guesstimate |
| pers. comm. I. Mathews, Dept. of Housing (1993) | 20 - 99% | • sediment load reduced to pre-development levels |
| pers. comm. R. Morse, Morse, McVey & Assoc. (1993) | 20 - 99% | • sediment load reduced to pre-development levels |

**Table 11 References on Nutrient Reduction by System Management Practices**

| Reference | Strategy | Detention time (av.) | % P Removal | % N Removal | Comments |
|---|---|---|---|---|---|
| Graham (1991) | Litter traps, wetlands and detention pond | 33 days | TP - 85% | TN - 78% | • limited data on outflow quality so conclusions are tentative<br>• artificial wetlands<br>• Melbourne, Australia |
| J. Bell pers. comm | Sediment Trapping pit and mini-wetland | | TP - 60% | | • estimate |
| Martin (1988) | Wet Detention Basin/ Wetland | | TP - 43% | TN - 36% | • short circuiting during some storms<br>• 2.3% of catchment<br>• % calculated using regression of loads<br>• USA |
| Meiorin (1989) | Debris Basin, lagoon, Overland flow & Ponds, and Wetland | 1 to 14 days | TP - 48% | | • most rainfall fell during winter<br>• observed turbulence & scouring in overland flow<br>• 66% urban, 28% agriculture<br>• Fremont, USA |
| Morse *et al.* (1992) | GPTs and Water Quality Control Pond | | TP - 0% | TN - 0% | • designed for established urban<br>• limited construction controls used<br>• Penrith, Australia |
| Nichols and Short (1992) | GPT, Off-line detention and Wetland | | | | • for a small catchment<br>• design only<br>• noted application in catchment with steep slopes<br>• Illawarra, Australia |
| Oberts and Osgood (1991) | Detention pond and wetlands | | TP - 77% | TN - 76% | • involved sampling when detention pond iced over<br>• Minnesota, USA |
| Tuovila *et al.* (1988) | Detention pond, filtration and wetland | | TP - 90% | TN - 75.9% | • included a bypass operation when flow too great; led to increase in nutrient load at those times<br>• Florida, USA |
| Wyong Shire council (1990) | Sediment Trapping pit and mini-wetland | | | Nitrate - (50 - 60)% | • only installed at stormwater outlet pipes < 600mm |

## Table 12 References on Capital and Maintenance Costs

| Strategy | Capital Costs $A/ha[1] | Ongoing Costs $A/ha/yr | Reference | Comments |
|---|---|---|---|---|
| Perimeter banks, Catch drains, Level spreaders, sediment traps and sediment retention ponds | 2 - 4% of contract value of land development projects | | Brouwer, M.D. (1987) | • Tuggeranong Town Centre development |
| Hay bales on site and sandbags in street pits (on site)<br>Sediment retention barriers (hay bales near street culverts), Street sweeping (vacuum) | 3,200<br><br>NOTE: these include maintenance | | pers. comm.K. Robinson and R. James,Wattle Grove Joint Venture | • costs are probably on the low side<br>• water quality control pond is a licensed discharger so within EPA regulations |
| Flocculation of Water Quality Control Pond | | 90 - 180 | | |
| Sediment Controls[2] | 10,200 | | pers. comm. Ian Mathews, Dept. of Housing | • figures for NW Sector |
| Sediment Controls[2] | (5,000 - 17,000) | | | • general figures |
| Sediment Controls[2] | 11,500 | | pers. comm. P. Farnill, Rose Consulting Group | • based on $1150/lot and an estimated 10 lots /ha<br>• Parklea, NSW |
| Wet detention Basin | 2,000 - 20,000 | 60 - 600 | Woodward (1986) | |
| Retardation Basin -<br>residential<br>industrial | <br>3300 - 8000<br>5200 - 7300 | <br>100 - 400<br>150 - 370 | SPCC (1989) | • Penrith City Council 1986 costings<br>• based on 10 residential lots/ha |
| Extended Duration Detention Basin | increase retardation basin costs by 10 - 12% | | Athayde *et al.* (1983) | |
| GPTs (2)<br><br>Wet Detention Basin (WQCP) | 1500<br><br>6000 + 6000 for lake embellishments | | pers. comm.K. Robinson and R. James, Wattle Grove Joint Venture | • form a system<br>• lake is approx. 3% of catchment<br>• feeds into drain which is lined with macrophytes |
| 2 GPTs and Water Quality Control Pond | 3000<br>GPTs - 1100<br>Pond - 1800 | cleaning of GPTs - 58 | Morse *et al.* (1992) confirmed in part by pers. comm. D. Johnson, Penrith City Council | • GPTs over engineered (pers. comm. Council)<br>• pond = 1% of catchment<br>• minimal maintenance |
| GPTs and detention ponds with wetlands | 7,400 | cleaning of GPTs - 160 | Liverpool City Council (1992) | • estimated costs only<br>• for 1% AEP event |
| wetland/lakes system and sediment basin | 1700 - 3200 | | Camden Municipal Council (1992) and report by Sinclair Knight | • based on section 94 contributions to Harrington Lakes System |
| Sediment Trapping Pit and Mini-wetland | 200 - 600 | 25 - 50 | pers. comm. S. Merry, Wyong Shire Council | • 231 installed<br>• includes costing for fences, safety gate and access roads<br>• maintained approx. 4 times/year ... cont'd |

| Strategy | Capital Costs $A/ha[1] | Ongoing Costs $A/ha/yr | Reference | Comments |
|---|---|---|---|---|
| GPT - major | 1350 | cleaning of GPT - 80 | pers. comm. David Dunkley Southern Region, Water Board | • Botany Wetland GPT<br>• involved some rehabilitation to wetland and extra costs<br>• catchment - 890ha |
| GPT - major | 8000 | cleaning of GPT - 360 - 500 | pers. comm. David Dunkley Southern Region, Water Board | • Orissa Street GPT<br>• retrofitted in an urban area<br>• involved relocation of some services<br>• catchment - 55ha |
| GPT - major | 620 - 710 | cleaning of GPT - 70 - 75 | pers. comm. David Dunkley Southern Region, Water Board | • Woolli Creek GPT<br>• tendered<br>• catchment - 1128ha |
| Major GPT | 120 - 2400 | 3- 5% of capital cost | Phillips (1992) | |
| Wetlands - artificial | 20,000 wetland (200 - 400) | | pers. comm. Jay Stricker, Water Board | • estimate based on experience |
| Wetlands - artificial | 12 - 170 | | ABARE (1993) | • rural and urban catchment<br>• costs may be higher for more sophisticated system<br>• voluntary labour used in part |
| Wetlands - artificial | | $6/kg of P | White *et al.* (1993) | • preliminary results<br>• based on 30% removal efficiency<br>• high due to weir construction and special design considerations |
| Dual use Drainage Systems | 6000 | significant | NSW Dept. of Planning (1993) | • compared with traditional 'hard' option - • $20000/ha |
| Grass Swales | cheaper than concrete channels | cost of mowing etc. ?? | Macarthur Regional Organisation of Councils (1992) | |
| Street cleaning:<br>Mechanical<br>Hand<br><br>Mechanical - daily<br>Mechanical - weekly<br>Mechanical - fortnightly<br><br>Hand - daily<br>Hand - weekly<br>Hand - fortnightly | <br>110,000<br>200<br><br>1065<br>152<br>72<br><br>7.50<br>1.10<br>0.50 | labour -<br>25,000<br>23,000<br><br>242<br>35<br>17<br><br>900<br>128<br>64 | SPCC (1989) | • (1986 figures)<br>• 31 km/day<br>• 8 km/day<br><br>• based on above figures and 300m kerb/ha development<br>• capital costs determined for 1 years' use only |

1. Australian dollars per hectare of catchment
2. NSW Department of Housing (1993) guidelines

# Appendix 3 - Nutrient Reductions used in *CMSS*

| *CMSS* Land Use | Control Strategy | % TP Reduction | % TN Reduction |
|---|---|---|---|
| Disturbed Urban | Sediment Controls[1] where soils < 10% dispersible materials | 55 ± 35 | 55 ± 35 |
| | Sediment Controls[1] where soils >= 10% dispersible materials (flocculation used ) | 56 ± 36 | 56 ± 36 |
| | Sediment Controls[1] where soils >= 10% dispersible materials (no flocculation used) | 35 ± 15 | 35 ± 15 |
| | Buffer Strips | 60 ± 10 | 60 ± 10 |
| | Gross Pollutant Trap and Wet Detention Basin (with sediment controls[1]) | 60 ± 25 | 64 ± 17 |
| | Gross Pollutant Trap and Wet Detention Basin (without sediment controls[1]) | 38 ± 37 | 31 ± 30 |
| Recent Sewered Urban | Wetland/s | 56 ± 38 | 46 ± 28 |
| | Wet Detention Basin | 60 ± 25 | 44 ± 17 |
| | Extended Duration Detention Basin | 15 ± 5 | 20 ± 10 |
| | Retention Basin | 82 ± 13 | 82 ± 13 |
| | Street Sweeping - 30 day interval | 7 ± 7 | 7 ± 7 |
| | Street Sweeping - 7 day interval | 25 ± 25 | 25 ± 25 |
| | Reduction in Impervious Areas | 20 ± 20 | 20 ± 20 |
| | Buffer Strips | 60 ± 10 | 60 ± 10 |
| | Gross Pollutant Trap, Wet Detention Basin and Wetland | 64 ± 21 | 57 ± 21 |
| | Gross Pollutant Trap, Off-line Detention and Wetland | 64 ± 21 | 57 ± 21 |
| | Sediment Trapping Pit and Mini-wetland | 50 ± 10 | 50 ± 10 |
| Established Sewered Urban | Wetland/s | 56 ± 38 | 46 ± 28 |
| | Wet Detention Basin | 65 ± 20 | 50 ± 11 |
| | Extended Duration Detention Basin | 15 ± 5 | 20 ± 10 |
| | Retention Basin | 82 ± 13 | 82 ± 13 |
| | Street Sweeping - 30 day interval | 7 ± 7 | 7 ± 7 |
| | Street Sweeping - 7 day interval | 25 ± 25 | 25 ± 25 |
| | Reduction in Impervious Areas | 20 ± 20 | 20 ± 20 |
| | Gross Pollutant Trap, Wet Detention Basin and Wetland | 64 ± 21 | 57 ± 21 |
| | Gross Pollutant Trap, Off-line Detention and Wetland | 64 ± 21 | 57 ± 21 |
| | Sediment Trapping Pit and Mini-wetland | 50 ± 10 | 50 ± 10 |

1. Sediment controls based on Department of Housing Guidelines (NSW Dept. of Housing, 1993

# Example of Management Practice stored in CMSS

**Land Use** : 2 (Established sewered urban)
**Management Practice** : **Extended duration detention basin**
Practice Code : 52
**Adoption Level (%)** : 0
**Author** : Toni Frecker, Water Board

**Management Practice Comment:**

An extended duration detention basin is a retardation basin that is designed to extend the detention time of stormwaters beyond the time necessary for flood mitigation alone. This is normally achieved by modifying the outflow structure.

A retardation basin, or dry detention basin, can be constructed near or along an urban stream forming part of its floodplain. During large storm events when the flow of runoff waters exceeds the capacity of the drainage system, excess stormwater spills into the retardation basin where it is stored until the flow levels reduce. Since these structures remain dry most of the time they may be used for recreation, both active and passive.

References:

Athayde, D.N., Shellet, P.E., Driscoll, E.D. and Gaboury, D. (1983). Results of the Nationwide Urban Runoff Program, Vol. 1, Final Report, PB84-185552, Water Planning Division, USEPA, Washington DC.

Randall, CW, K Ellis, TJ Grizzard and WR Knocke (1982) Urban Runoff Pollutant Removal by Sedimentation. In Proc of the Conf. on Stormwater Detention Facilities. DeGroot, W (ed) Henniker, 2-6 Aug.

Stahre, P. and Urbonas, B. (1989). Stormwater Detention for Drainage, Water Quality, and CSO Management. Prentice Hall. New Jersey.

USEPA (1983) Final report, results of the nationwide urban runoff program, Water Planning Division, US EPA, Washington DC

Walesh, SG (1991) Retrofitting storm water detention facilities for quantity and quality control. in New Technologies in Urban Drainage. C Maksimovic (ed) UDT '91

**Cost Type** : A
**Initial Cost ($)** : 650
**Initial Cost Error ($)** : 350
**Initial Cost Comment** :

This study considers the cost of installing an extended duration detention basin to be only the additional cost necessary to modify a retardation basin, that is these costings do not include a component for the construction of the basin. Athayde et al. (1983) estimates that the outlet modifications necessary to extend the detention time of a retardation basin will increase construction costs by about 10% to 12%. SPCC (1989) provides an estimate of the cost to develop retardation basins as part of a truck drainage system for the Penrith area. These costs range from $3000 to $8000 per hectare of catchment and are based on 1986 figures.

The capital cost was derived by combining the costings reported in Athayde et al. (1983) and SPCC (1989).

References

Athayde, D.N., Shellet, P.E., Driscoll, E.D. and Gaboury, D. (1983). Results of the Nationwide Urban Runoff Program, Vol. 1, Final Report, PB84-185552, Water Planning Division, USEPA, Washington DC.

SPCC (1989). Pollution Control Manual for Urban Stormwater. State Pollution Control Commission, Sydney.

**Ongoing Cost ($)** : 28
**Ongoing Cost Error ($)** : 22
**Ongoing Cost Comment**:

SPCC (1989) provides an estimate of the cost to develop retardation basins as part of a truck drainage system for the Penrith area. This manual estimates operating and maintenance costs to be between 3% and 5% of construction costs.

The maintenance cost was derived by combining the costings reported in Athayde et al. (1983) and SPCC (1989).

**PHOSPHORUS Reduction (%)** : 15
**PHOSPHORUS Uncertainty (%)** : 5
**PHOSPHORUS Comment** :

No Australian data were available for this nutrient reduction strategy. Table 4 (Frecker and Cuddy, 1994) lists those studies from the U.S.A. that monitored extended duration detention basins. The results from these studies ranged from 10% to 56% for phosphorus reduction and from 10% to 33% for nitrogen reduction. The laboratory study by Randall et al. (1982) achieved the highest reduction rate for both nutrients. These results were not considered applicable to the field situation and were thus discarded.

For phosphorus, the range determined by Stahre and Urbonas (1989) after their consideration of the North American data, is presented in this report as appropriate. The percentage reduction given is for an average detention time of 24 hours. These authors noted that the lower limit should be used when local data ares not available.

**NITROGEN Reduction (%)** : 20
**NITROGEN Uncertainty (%)** : 10
**NITROGEN Comment** :

No Australian data were available for this nutrient reduction strategy. Table 4 (Frecker and Cuddy, 1994) lists those studies from the U.S.A. that monitored extended duration detention basins. The results from these studies ranged from 10% to 56% for phosphorus reduction and from 10% to 33% for nitrogen reduction. The laboratory study by Randall et al. (1982) achieved the highest reduction rate for both nutrients. These results were not considered applicable to the field situation and were thus discarded.

The results gained for nitrogen reduction were more variable than those for phosphorus. This is reflected in the wider range allocated to this strategy for nitrogen. The literature suggested higher reduction with longerdetention time. Randall et al (1982) indicated reduction of 33% if 36hrs detention. Stahre and Urbonas's figure of 10-20% reduction was based on field studies from USA and design guidelines with 24hr retention. Stahr and Urbanos noted also that for nitrogen the lower limit should be used when local data is not available.

**Fig 1 Example of Management Practice stored in *CMSS***

# Appendix 4 - Organisations Contacted

4

Australian Water Technologies, Urban Runoff Group
Blue Mountains City Council
Camden Municipal Council
Conservation and Land Management
Engineering and Water Supply Department of South Australia
Environment Protection Authority
Fairfield City Council
Liverpool City Council
Morse McVey and Associates
NSW Department of Housing, Liverpool
Penrith City Council
Rose Consulting Group
Salisbury City Council (Adelaide)
University of Newcastle
University of Technology, Sydney
University of Western Sydney, Hawkesbury
Water Board, Sydney
- Clean Waterways Program
- Environmental Management Unit
- North-west Region
- Southern Region

Wattle Grove Joint Venture
Wyong Shire Council