How sustainable are stormwater management targets?

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Abstract

This paper attempts to highlight the comparative levels of sustainability that are likely to arise from the application of various water quality targets to subdivision development. We compare the NSW EPA's Council Handbook approach, the Neutral or Beneficial Effect approach (as defined in SEPP 58) and a modified approach to that included in Australian Runoff Quality. We use a case study to demonstrate how compliance with each of the objectives can be achieved. We show that ARQ (when applied in the way chosen) is the most stringent of the three approaches in the case study chosen and is the only approach likely to lead to a sustainable outcome for a range of development scenarios. We question how the use of quantitative water quality targets can achieve a sustainable outcome and be sympathetic to the tenets of Ecologically Sustainable Development.

1. INTRODUCTION

Since being defined at the United Nations Conference on Environment and Development in 1992, Ecologically Sustainable Development (ESD) has been espoused globally. However, its implementation has been complex and demonstrating achievement of ESD has been difficult to prove.

1.1. Sustainability and stormwater

Applying ESD principles at the local government level is particularly relevant to stormwater as almost all stormwater management is undertaken at this level of government. This presents an opportunity to manage an issue such as stormwater using ESD principles to produce more sustainable outcomes.

In NSW, the principles of ESD were incorporated into the Local Government Act in 1997. Soon after, the Environment Protection Authority (EPA) directed every Local Government Authority in New South Wales to prepare a Stormwater Management Plan (SMP). The directive required that each Council prepare a plan to manage its stormwater quality as well as quantity. A publication which became known as the “Council Handbook” (EPA 1997) included a Model SMP. The Model SMP included typical targets for the management of stormwater from new developments and a range of stormwater management principles including ESD and Water Sensitive Urban Design (WSUD).

Until SMPs were reviewed in New South Wales in 2002-04, many practitioners ignored the stormwater management targets for new development and the principles such as treatment trains. Others simply did not understand them. All too often, interpretation of SMPs resulted in end-of-pipe treatment approaches. However, their true intent was to manage stormwater in a hierarchy of controls forming a treatment train. Such approaches were seen to have the most beneficial impact on both water quality and quantity, and therefore result in development that is more sustainable.

The establishment of the quantitative water quality targets in many SMPs was based on the Council Handbook and therefore did not consider the receiving water, the assimilation “benefit” of the receiving water or even a whole of catchment approach.

1.2. Description of stormwater management targets

There are commonly three different approaches to the setting of quantitative water quality targets for new developments in New South Wales. Hereafter they will be referred to as the approaches, viz:

1. Managing Urban Stormwater, Council Handbook (EPA, 1997) requirements – hereafter refer to as the Council Handbook target type;
2. The concept of achieving a Neutral or Beneficial Effect (NORBE) – hereafter referred to as NORBE; and
3. The “sustainable load” approach adopted in Australian Runoff Quality (ARQ) – hereafter referred to as the ARQ target type. (ARQ, 2003).

Council Handbook approach (Environment Protection Authority, 1997) - The Department of Environment and Conservation's Managing Urban Stormwater, Council Handbook (EPA, 1997) stipulates the 45% post-development retention targets for both Total Phosphorus and Total Nitrogen (TP and TN). The targets are achieved, for instance, when it is demonstrated that a proposed development retains at least 45% of the average annual load of TP and TN that would otherwise be exported to the receiving water. The Council Handbook includes other pollutant targets such as suspended solids retention, however, nutrient retention is likely to be the governing objective from a design perspective. This paper focuses only nutrient retention.

NORBE approach- The concept of achieving Neutral or Beneficial Effect (NORBE) is described in State Environment Planning Policy (SEPP) 58. SEPP 58 relates to development within Sydney Water’s drinking water catchments and is administered by the Sydney Catchment Authority. There are a number of different tests within SEPP 58 to assist in the determination of a development, NORBE being one of these. SEPP 58 defines NORBE as follows:

> “…whether the development or activity will have a neutral or beneficial effect on the water quality of rivers, streams or groundwater in the hydrological catchment, including during periods of wet weather,”

In this case it is assumed that the test is applied on a loads based approach, i.e. matching pre- and post-development pollutant loads.

ARQ approach - The approach adopted in Australian Runoff Quality (ARQ) (IEAust, 2003) aims to keep the export of pollutants from a new development to a load that is less than or equal to a load that the receiving water can sustain. The state of health and reproductive capacity (conceived in this approach as the ability to rehabilitate) of the receiving water is firstly classified as is the type of aquatic receiving environment. Typical trigger values for these environments can be derived from tables in ARQ (based on the relevant environmental and health classification). A sustainable load for the receiving water could be determined based on a modelled approach that first defines the daily export rates and then transposes these into daily in-situ receiving water quality values for appropriate stressors. The in-situ values are then compared with guideline trigger values and the median daily in-situ value needs to be less than the guideline trigger value. This target type therefore adopts elements of a risk-based approach where the consequence of a decline in health (biodiversity or water quality) is also implicitly assessed.

Uniquely this approach when applied using the translation of daily export rates into in-situ receiving water quality values inherently considers the assimilative capacity of the receiving water. In this paper we have not undertaken the additional step of translating daily exports into in-situ water quality values. Thus we have not allowed for the assimilative capacity of the receiving water. Thus the application of the ARQ approach adopted in this paper is considered to be conservative. We consider that this approach is limited and demonstrates the importance of undertaking the translation process which will otherwise result in conservative and costly responses.

ASSESSMENT OF THE THREE TARGET TYPES

The Council Handbook approach is widely used across NSW. The NORBE approach is used throughout Sydney’s water supply catchment and in some other parts of NSW. The ARQ approach is still in its infancy but its use is likely to become more widespread. There may be some confusion and a lack of understanding in the community caused by the use of three different target types. If ESD is a universal goal then it is useful to know what level of sustainability each is likely to deliver. We have undertaken a case study to attempt to show the differences in results and therefore sustainability of the three different approaches.

1.3. Case study description

The case study is an assessment of the three different target approaches on a fictitious subdivision on the coast of NSW. The subdivision proposes to develop 108 lots on land that has previously been used for agricultural purposes (Figure 1). This development is likely to be representative of a typical coastal subdivision in NSW.

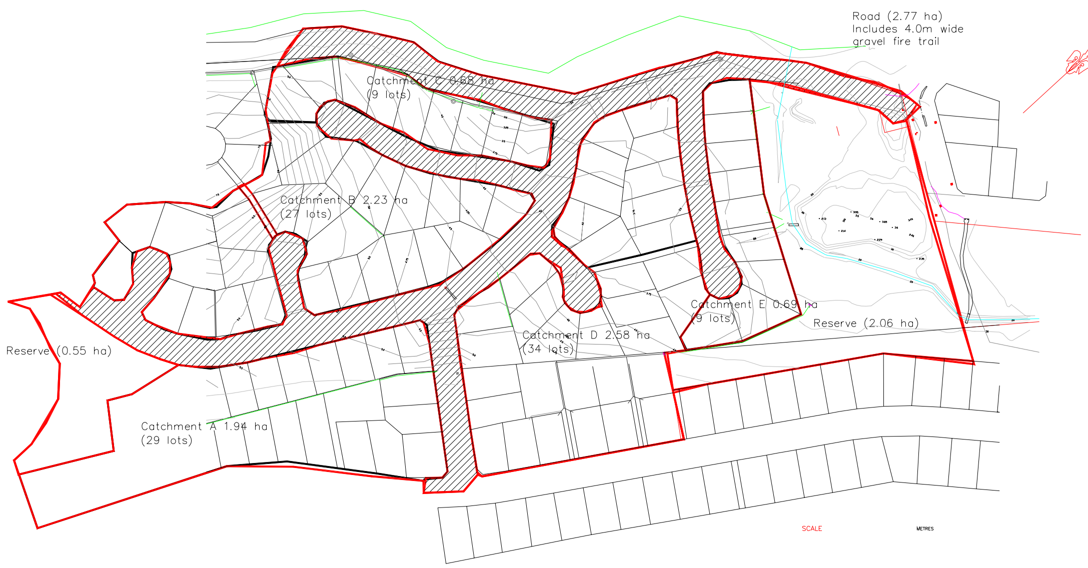

Figure 1: Fictitious subdivision that forms the basis of the case study for modelling purposes

It is important to note that this case study represents an assessment of a change in land use from agricultural to urban. Results will differ for areas with different pre-development land uses other than cleared farmland, such as forested or brownfield sites. However, this particular scenario is likely to be common on the east coast of Australia, outside of major urban areas.

In order to test if the proposed subdivision would comply with any or all of the water quality target types we modelled the water quality leaving the subdivision in a number of states, viz:

- Pre-development state to enable comparison with post development (NORBE).
- Post-development state without any stormwater treatment, leading to estimates of what the development would export without any controls in place. This forms the base case for the Council Handbook target type.
- A post-development model that includes a treatment train aiming to achieve compliance with all three target types.

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) was chosen to model water quality.

1.4. Case study model inputs

Table 1 presents the modelling inputs and assumptions for the case study.

Table 1 MUSIC model input detail

MUSIC model inputs	Data/Description
Catchment data	The total site area is 13.5 Ha broken up into sub-catchments based on contours, drainage and roads. Note that the pre-development condition was modelled as one singular catchment.
Land use data	Parks/reserves = 2.61 Ha Lot area = 8.12 Ha Roads = 2.77 Ha
Lot data	A typical lot was determined to be 750 m2, with a roof of 275 m2. It was assumed that the overall impervious portion of each lot was 63%. A typical lot would be: Lot size 750 m2 Roof size 275 m2 Garden area 270 m2
Rainfall data	As we were to model the effectiveness of grassed swales we chose to model the treatment train using 6-minute pluviograph data from a local weather station used
Pollutant loads	Pollutant load parameters, based on a review of stormwater quality in urban catchments undertaken by Duncan (1999) were adopted.
Receiving water	Lowland Creek

1.5. Treatment trains

Three treatment rains were modelled to assess what was necessary to meet the different water quality target types, *viz*:

- 10kL roof water tank and grass swales
- 10kL roof water tank, grass swales and end of line sand filter
- 10kL roof water tank, grass swales, end-of-line sand filter and irrigation reuse

Table 2 describes the treatment train components.

Table 2 Treatment train detail

Treatment Train Component	Description
10kL Tank	10 kL rainwater tank for each lot, plumbed into the house to supply 87% of indoor water use (i.e. hot water, laundry and toilet flushing) and outdoor water use (assuming a family of three)
Grass Swales	Grass swales along roads collecting road runoff and runoff from lot areas (excluding the roof area). These grass swales were on one side of the road only (i.e. roads had one-way cross fall). The swale had a base width of 1.0m and top width of 5.0m. The swale had depth of 0.33m, vegetation height 0.25m and a seepage loss of 1 mm/hr (medium to heavy clay).
End-of-line Sand filter	Surface area: 500m2 Filter area: 225m2 Surface storage depth: 0.6m
Stormwater Reuse	Irrigate a 1000m2 park with on average 50mm of water each week (scaled by PET) and assuming sufficient flow to supply

1.6. Pollutant targets to be achieved.

To enable an objective comparison of the different target types, Table 3 outlines the different targets for this particular case study.

Table 3 Pollution Target levels

Target Type	Pollutant measure	Total Phosphorous	Total Nitrogen
1. NSW EPA Handbook approach	Load (kg/y)	45% reduction of post development load 11.15	45% reduction of post development load 111.15
2. NORBE approach	Load (kg/y)	28.3	214
3. ARQ concentration approach	Median flow percentile concentration (for lowland creek, μg/l)	50	500

The various treatment trains were modelled for the development and the results compared against the pollutant targets listed above. This provides an indication of the extent of treatment required to meet the different targets.

2. COMPARATIVE RESULTS OF THE THREE APPROACHES

Table 4 shows how using a treatment train comprising rain tanks and swales would allow compliance with EPA's Council Handbook and NORBE targets. The NORBE target is more easily achievable than the Council Handbook target. In this case, even less stormwater treatment could still be sufficient in meeting the NORBE target. The extent of treatment required when using NORBE targets is strongly dependent on the pre-development pollutant loads.

It is also worthwhile to note that the treatment train approach also reduces the runoff volumes significantly which further contributes to ESD by reducing ecosystem impacts in receiving waters.

Table 4: Results from Treatment Train approach

Annual Load	Pre-Development	Post-Development – no treatment	Post-Development with rain tanks and swales only	% Reduction in load due to tanks and swales
Flow (ML/yr)	82.9	110	68.7	37.5%
TP (kg/yr)	28.3	24.7	11.7	53 %
TN (kg/yr)	214	247	132	47 %

Table 5 below, outlines the median pollutant concentration goals as set by ARQ for lowland creeks and includes the three treatment trains modelled in MUSIC and their corresponding median pollutant concentrations.

Table 5: Pollutant concentrations for pre--development and post-development treatment trains

Pollutant (median flow percentile concentration)	ANZECC Trigger value for lowland creek	Pre-development Median export concentration	Post-Development Median Export with rain tanks and swales only (Treatment Train 1)	Post-development median export with tanks, swales and sand filter (Treatment train 2)	Post-development median export with tanks, swales, sand filter, and reuse of stormwater (Treatment train 3)
Total Phosphorus (μg/l)	50	135	143	40	0
Total Nitrogen (μg/l)	500	1220	1680	480	0

Table 5 shows that, although Treatment Train 1 is acceptable for Council Handbook and NORBE targets, the treatment train would not meet ARQ targets with further treatment required to reduce pollutant concentrations. The addition of a sand filter only to the treatment train will produce median stormwater pollutant concentrations sufficient for the protection of aquatic ecosystems in the receiving waters of this development. It was found that the reuse of stormwater reduced the median export of nutrients down to a level of zero. This may be explained because very frequent low flows that would otherwise leave the site are being captured and reused almost exclusively.

The reader is reminded of the adoption of a modified ARQ approach used in this paper.

3. DISCUSSION

As one would expect, the use of three common quantitative water quality targets could cause some confusion in the community. Indeed one recent local government DCP in New South Wales has adopted the precautionary principle and included all three objectives.

NORBE as defined for this case study (i.e. meeting pre-development pollutant loads), is the least stringent of the three targets. ARQ is the most stringent target in this instance. Adoption of the EPA's Council Handbook targets is more stringent than NORBE's in this case and is likely to lead to a more robust stormwater quality treatment train.

Of the three approaches, only the ARQ targets explicitly consider the relative health and assimilative capacity of the receiving water and future catchment management activities. Thus ARQ targets allow for a catchment to be rehabilitated over time if it is currently degraded. ARQ attempts to define "sustainable" loads for the receiving waters where sustainable loads are in turn based on ANZECC guideline trigger values. There is no implicit or explicit accounting of a sustainable loading concept in the other two approaches.

The benefit of ARQ when compared to NORBE is that it explicitly defines concentrations and loads that need to be met if the sustainability of the receiving ecosystem is to be ensured. NORBE is less explicit and requires a greater deal of interpretation in both the modelling stage and interpretation and development determination stages. Without explicit definitions there is a greater deal of subjectivity in the assessment of a development using NORBE.

It is widely accepted that there is a law of diminishing returns associated with stormwater quality treatment. This law applies both across a treatment train as well as up the treatment train, i.e. it is relatively easy to remove the first 20% of a pollutant with much more work required to remove the next 20% and so on. This is applying the law of diminishing returns across the treatment train.

From analyses of three water quality target approaches, and given that there is a law of diminishing returns, one may conclude that it is relatively easy to develop a catchment in a poor condition that exports larger quantities of pollution. Conversely, development on land that is in pristine condition is very difficult to comply with. This applies only to the NORBE and ARQ approaches as the pre--development condition of a catchment is not considered in the Council Handbook approach. The NORBE and ARQ approaches may then encourage development of more degraded land with the inability to develop in some pristine areas.

The Council Handbook approach could reward poor development practices. This could happen by making the post-development base scenario result in a greater potential export of pollution through poor practices (such as unsealing roads or increasing the runoff potential by increasing the imperviousness of the site, etc). In such instances, it would be relatively easy to comply with the 45% nutrient retention criteria.

Additionally, in considering the likely error range and the implications of the law of diminishing returns, the application of the Council Handbook approach would appear to be even less likely to achieve a sustainable outcome. The same could not be said for ARQ given that a specific target is to be achieved and any errors in either over-estimating or underestimating pollutant concentrations are significantly less relevant to the outcome.

ANZECC targets for lakes and estuaries are much more stringent than for creeks. It is likely that one viable way to comply with the guideline trigger values where development is to proceed adjacent to lakes, estuaries or the ocean will be through the use of stormwater reuse projects that aim to reduce the flow leaving the site so that the median export value is reduced accordingly. The use of infiltration would also significantly reduce median export values.

Where new development occurs there is often an increase in the frequency of runoff by a factor of 20 (Wright *et al*, 1995). It is this increase in the frequency of runoff along with the addition of nutrients that may lead to the creation of an environment that favours the growth of weeds over native vegetation (Wright *et al*, 1995). Neither the Council Handbook approach or NORBE specifically require that flow frequency be maintained post-development. By indirectly targeting median pollutant values ARQ could be said to be targeting these low flows as well. However in some situations, even ARQ will not influence low flow frequency. In the case study, low flows were significantly affected by the reuse of stormwater but this was not required for compliance. Because ARQ does not explicitly address low flow frequency, it is possible that some treatment trains will be developed that still comply with ARQ, but which have significantly altered flow regimes.

The application of ARQ in its prescribed form, that is, with full translation of daily export rates into in-situ water quality values would have required a significant amount of work. The work required to undertake the translations would require the whole catchment to be modeled. Thus it is considered conservative to apply ARQ on a subdivision scale without also undertaking the translations.

4. CONCLUSIONS

The three main water quality target approaches to managing urban stormwater result in different approaches to the management of stormwater with some of these approaches more sustainable than others. It is likely that only the ARQ approach will be sustainable as it is the only approach that explicitly considers the receiving water. However, NORBE also results in a sustainable outcome where the pre-existing land use is pristine land.

In order to successfully apply ARQ to a subdivision it suggested that Councils and perhaps other regional organisations may have to undertake the rewriting of a significant part of their stormwater management plans and specifications. It may be found that Council handbook targets requiring a 45% reduction in nutrients is in fact excessive in some cases. In other cases greater retention of nutrients may be required.

ARQ may also allow a different approach to the management of land and water. The whole of catchment analyses required under ARQ when coupled with a good economic appreciation of the costs associated with stormwater management may show that far greater improvements in water quality can occur by targeting existing highly polluting land uses (such as certain types of agriculture) with funds that would otherwise be inefficiently spent targeting new development. A nexus between new development and Council required development contributions could also be easily demonstrated through an ARQ – catchment wide approach. Council's may then be able spend those contributions in the most effective manner (on land other than that which yielded the contribution).

The approaches may have an influence on which land is developed in a catchment. This may be from most degraded to least degraded. This facet of all three of the approaches is likely to lead to more sustainable outcomes as land use changes are likely to be from rural (cleared grazing land) to urban rather than from pristine to urban.

The three water quality approaches to the management of stormwater are by definition quantitative targets. They are pre--determined and provide some measure of certainty to developers. However, having pre--determined targets may not be sympathetic to the widely developing practice of IWCM, which seeks to involve the whole community, and not just the development community in the determination of performance targets. Thus in one sense the use of pre--determined targets may be avoiding a significant tenet of sustainability (that of intergenerational equity) by adopting a command and control approach. On the other hand, it is not known if the community (current generation) has been sufficiently informed and involved to assist in making decisions that will ensure intergenerational equity.

Achievement of a sustainable outcome may then require that the sustainable load approach (ARQ) be adopted as a minimum acceptable standard. This standard as a minimum would ensure intergenerational equity. One could then engage the wider community to debate the need to increase the level of protection of the aquatic ecosystems.

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