A COMPARISON OF METHODS FOR WASTEWATER SYSTEM PERFORMANCE ASSESSMENT

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ABSTRACT

Most organisations responsible for separate sanitary and combined sewer systems have target Levels of Service (LOS). Hydraulic models are frequently used to predict LOS performance and identify areas where targets are not met.

This paper compares three methods for system performance analysis, each of which has advantages and disadvantages:

- Design storms are simple to apply, however may not consider spatial variation of rainfall or back-to-back storm events.
- Long time series can be time consuming, but provide a more robust statistical understanding of how the system will perform for different conditions.
- A typical year is relatively quick to run and often uses actual rainfall; however determination of the typical year can be complex.

Modellers need to understand the system in order to understand the consequences and limitations of their choice of methodology. It is important to carry out sensitivity analysis, for example through the use of more than one method, and to understand how the models will ultimately be used to support development of potential solutions.

Current New Zealand standards leave the decision of methodology largely up to the organisation or modeller. This can lead to a lack of consistency and an inability to make meaningful comparisons of LOS.

KEYWORDS

System performance, levels of service, design storm, typical year, long time series, rainfall

1 INTRODUCTION

Most organisations responsible for wastewater and combined system networks have target Levels of Service (LOS) that they aim to achieve in terms of the performance of their systems. Common metrics include pipe capacity, surcharge, and overflow frequencies and volumes. These targets may be given for certain rainfall events; for example 'pipes should contain a 1 in 3 month Average Recurrence Interval[1] (ARI) rainfall event without surcharge'. Other targets may be given on a frequency basis; for example 'on average, the system should overflow no more than twice per year'.

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[1] ARI is defined as the average or expected value of the periods between exceedences of a given rainfall total accumulated over a given duration.

While physical monitoring is used in many areas to help understand the performance of the systems in particular areas, hydraulic computer models are frequently used to predict LOS performance, analyse the system as a whole and identify problem areas where LOS targets are not met (both now and in the future). These models are then often used as a tool to aid in the development of solutions to bring the networks up to desired LOS targets, or to help redefine appropriate LOS standards to be achieved, bearing in mind factors such as affordability, rate-payer willingness to pay, environmental considerations, etc. The physical monitoring in conjunction with the computer models allows models to be calibrated and therefore reflect the 'real life' situation.

For wastewater and stormwater networks, the analysis of whether the system meets these LOS targets requires rainfall inputs, as the performance is often determined statistically with rainfall ARI as the basis of comparison. When we say a '1 in 3 month rainfall event', how do we define this? To measure 'two spills per year', is it most appropriate to equate this to a design event or is it more appropriate to run one year of rainfall, or multiple years of rainfall to determine average system performance? Current practice in New Zealand involves a range of techniques. This paper aims to compare and contrast a selection of these.

2 EXISTING STANDARDS

The Water New Zealand "National Modelling Guidelines: Wastewater Network Modelling" (April 2009) states that the following wet weather simulations should be done to understand the performance of the system:

- Predict the peak flow rate and surcharge/spill condition for a variety of return periods. Design storms of differing durations but the same return period should be used, and the worst duration for each return period used to determine the LOS of the system. The guidelines state that standard design storms have been developed for the Auckland Region.

- Predict wet weather response using continuous simulation. The guidelines state that care should be exercised when using long time series, as the longer durations can be computationally intensive. The selection of the length of the time series is left to the modeller.

The Wastewater Planning Users Group[2] (WaPUG) "Code of Practice for the Hydraulic Modelling of Sewer Systems" (December 2002) states that synthetic design storms are normally used to predict the volume and frequency of flooding or surcharge in a sewer system, while long-term time series are normally used for Urban Pollution Management applications.

The synthetic[3] design storms referred to are generally developed in the United Kingdom using the Flood Studies Report (Natural Environment Research Council, 1975) or the "Flood Estimation Handbook" (Institute of Hydrology, 1999).

The WaPUG Code of Practice recommends that long time series used for pollution management contain at least 10 to 15 years of data, and that where a series is to be used to predict flooding the record should be at least twice as long as the frequency of the flooding. The Code of Practice states that stochastic generation of time series data is also possible.

From both of these guidelines, it can be concluded that both the design storm and long time series approaches are recommended to be used in conjunction with each other. The New Zealand guidelines leave the definition of the design storms and long time series analysis periods to the discretion of the modeller, while the WaPUG approach is somewhat more prescriptive.

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[2] WAPUG is now known as the Chartered Institution of Water and Environmental Management (CIWEM) Urban Drainage Group (UK)

[3] Synthetic design storms are artificially generated, usually using statistical techniques

Many individual local authorities and network owners/operators in New Zealand have developed their own guidelines for wastewater system performance, some of which are discussed in this paper. It is therefore currently difficult to compare expected Levels of Service across different organisations. This is particularly relevant when different standards are being assessed by a single governing/regulating body, leading to a lack of consistency and an inability to make meaningful comparisons of LOS.

3 DESIGN STORMS

One approach to the assessment of wastewater system performance is the use of design storms that equate to the target Level of Service (LOS). Design storms allow the modeller to statistically understand the performance of the network by relating it to the ARI. For example, for a target LOS of one spill per year, the one year ARI design storm may be used as a system performance tool. If the system does not spill in this event, then it can be said that it is likely to achieve the target LOS.

It is noted that the probability of a rainfall event being exceeded in any one year is defined as the Annual Exceedance Probability (AEP), and this is different to the Annual Recurrence Interval (ARI). The relationship is defined as follows: -

$$AEP = 1 - \exp\left(\frac{-1}{ARI}\right)$$

A rainfall event with an ARI of 1 year will have an AEP of 0.632 i.e. a 63% probability of being exceeded in any one year. ARIs of greater than 10 years are very closely approximated by the reciprocal of the AEP i.e. a rainfall event with an ARI of 10 years will have an AEP of 0.1 (10% probability of being exceeded in one year), and a rainfall event with an ARI of 100 years will have an AEP of 0.01 (1% probability).

Therefore, whilst the one year ARI design storm may be used as a system performance tool, if the system does not spill in this event, there is still a 63% probability that the rainfall event will be exceeded in any one year and hence a 63% probability that the target LOS may not be achieved.

3.1 SYNTHETIC STORMS

Synthetic storms are usually developed from the analysis of previous rainfall in a given area, and aim to represent a typical storm event or events. To derive a synthetic storm, the relationship between rainfall intensity, duration and frequency (probability) needs to be understood. For a given frequency or return period, as the intensity increases the duration will decrease. For example, an event with an ARI of 2 years could have an average intensity of 73mm/h over 10 minutes, or a lesser intensity of 22mm/h over a longer period of 2 hours (from Auckland City Council Model Rainstorms, Auckland City Council, 1989). The relationship between these three factors is derived from the analysis of long term rainfall records.

There are several different approaches to the development of synthetic design storms that have been used. A number of examples are discussed here.

3.1.1 AUCKLAND REGIONAL COUNCIL – TP108

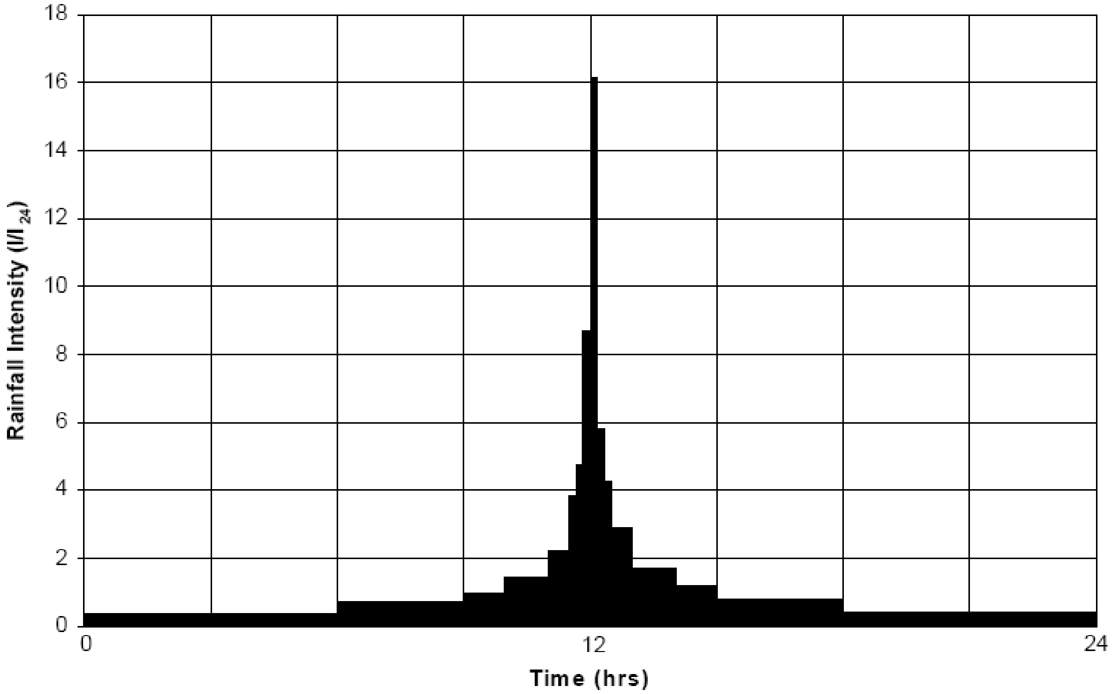
The Auckland Regional Council (ARC) "Technical Publication No. 108 – Guidelines for Stormwater Runoff Modelling in the Auckland Region" (ARC, 1999) presents a recommended method for the application of the U.S. Soil Conservation Service (SCS) rainfall-runoff model to catchments in the Auckland Region.

The ARC recommends this method for use in stormwater management design in the Auckland Region, however it is also used for wastewater system performance. The model has been designed as a standard tool to provide consistent results from different users.

Maps of design 24 hour rainfall depths are provided for the Auckland Region. A standard 24 hour pattern is provided, as shown in Figure 1, with the highest intensity rainfall at midday. This pattern was developed from statistical analysis of rain gauge data representative of the region and follows the SCS hydrograph. A range of durations from 10 minutes to 24 hours are nested within the 24 hour pattern. For ARIs of 2 to 100 years, the model is expected to be within +/-25% at a confidence interval of 90%. It should be noted that depths are only provided for ARIs of 2 years and above. Design depths for lower ARIs, as often used for wastewater system performance, need to be sourced from elsewhere. This methodology is often extrapolated and used for these lower ARIs, however it should be noted that the TP108 method has not been proven to be acceptable for these higher frequency events.

A number of other New Zealand councils use TP108 to provide the temporal pattern and runoff model for their rain events, while applying region-specific rainfall intensities. It is noted that caution should be exercised when applying the temporal pattern outside of the Auckland Region because it is based on Auckland rain gauge data, typical Auckland soil types ('clayey' [weathered mudstone and sandstone] and 'volcanic' [granular loams, and loams underlain by fractured basalt]) and relatively steep catchments typical of Auckland. Differing weather conditions in other locations, and differing rainfall runoff conditions due to differing terrain and land/soil cover may impact the rainfall runoff profiles.

Figure 1: Auckland Region 24 hour Design Storm (ARC, 1999)



3.1.2 HIRDS (NIWA)

HIRDS stands for High Intensity Rainfall Design System (NIWA, 2002), and is a computer programme that aims to provide reliable and consistent design rainfall depths for New Zealand. It can be used to estimate rainfall depths and to assess the rarity of observed storm events. The user enters the geographic location of the area of interest (as latitude and longitude) and the programme generates a table of rainfall depths against duration and frequency. Rainfall of durations from 10 minutes to 72 hours, and ARI of up to 100 years can be generated. It is noted that HIRDS provides only rainfall depths and not temporal profiles

It is noted that many local authorities in New Zealand have their own tables of rainfall depths against duration and frequency for their particular region. If available, these are generally recommended for use, although they should be similar to those generated by HIRDS, and in many cases will be derived from HIRDS.

3.1.3 AUCKLAND CITY MODEL RAINSTORMS

Model rainstorms were developed for Auckland City based on recorded data from the Albert Park raingauge (Auckland City Council, 1989). The aim of developing these rainstorms was to produce design storms that would provide floods with the same return period as the selected rainfall intensity. Seasonal variation was also taken into account, with winter and summer storms developed. This is due to the change in saturation of the ground, and therefore flood levels and runoff, between winter and summer.

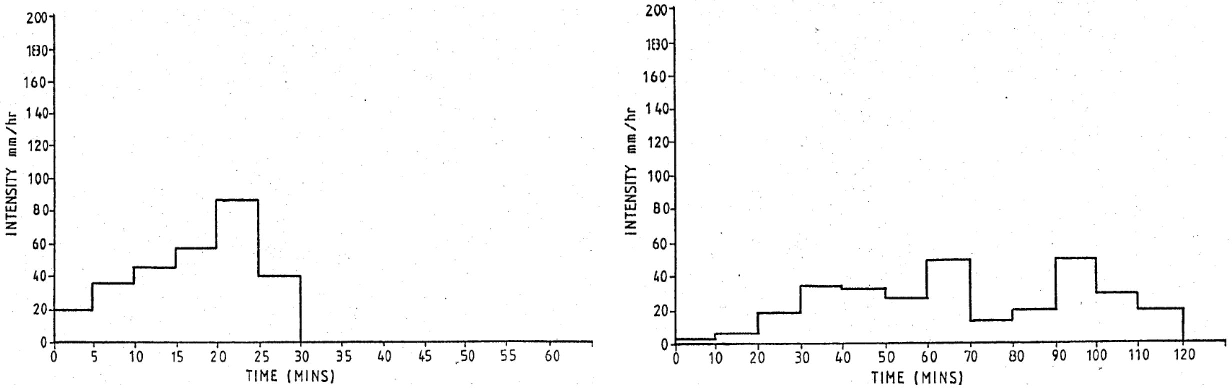
To determine the Auckland City Model Rainstorms, 20 years of Albert Park rainfall records were analysed. Temporal patterns were developed for a range of durations between 10 and 180 minutes. These patterns can be considered as typical, however it is noted that considerable variability occurs in the actual time series data.

The temporal patterns were found not to significantly differ between winter and summer, however rainfall intensities differed by between 10% for longer duration storms to up to 60% for shorter duration storms, with winter intensities being higher.

The analysis provides intensity-duration-frequency curves for return periods of between 1 week and 100 years.

The shapes of the temporal patterns developed vary depending on duration. It is significant that the 120 minute duration event has two distinct peaks, as often occurs in Auckland. See Figure 2 below for graphs of the 10 year ARI event for both 30 minute and 120 minute durations.

Figure 2: Auckland City Council 10 Year ARI Model Rainstorms (Winter temporal patterns) (Auckland City Council, 1989)



30 Minute Duration

120 Minute Duration

3.1.4 INTERNATIONAL SYNTHETIC RAINSTORMS

UNITED KINGDOM

As mentioned previously, in the United Kingdom synthetic design storms are generally developed using the Flood Studies Report (Natural Environment Research Council, 1975) or the "Flood Estimation Handbook" (Institute of Hydrology, 1999). From statistical relationships of rainfall parameters, a representative rainfall event can be generated for any location in the UK, for any duration and ARI.

Synthetic rainfall profile shapes have been developed for the 50-percentile summer storm (the storm that is more peaked than 50% of all summer storms) and the 75-percentile winter storm.

It is recommended that modellers generally use summer storms (high intensity, short duration) for flooding and flood alleviation studies, and use winter storms (low intensity, long duration) where storage or overall flow volumes are important, although it is prudent to check with both.

Certain hydraulic computer modelling software packages have in-built rainfall generators to create synthetic storms for the UK based on either the Flood Studies Report or the Flood Estimation Handbook.

AUSTRALIA

The Australian Bureau of Meteorology has undertaken a revision of the Australian Rainfall and Runoff, volume 2 reference book (Engineers Australia, National Committee for Water Engineering, 1987. Reprinted 1998). A set of accurate, consistent intensity-frequency-duration (IFD) design rainfall data, presented on a series of maps, has been derived for the whole of Australia.

As with the UK synthetic storms, certain hydraulic computer modelling software packages have in-built rainfall generators to create synthetic storms based on this data.

OTHER

Procedures and datasets have been developed for other locations around the world, and some of these have also been incorporated into certain hydraulic computer modelling software packages, allowing quick generation of synthetic design storms. Examples are as follows:

- Hong Kong Rainfall Generator
- Malaysian Rainfall Generator
- Desbordes Rainfall Generator
- QM French Rainfall Generator

3.2 ACTUAL STORMS

An alternative approach to the development of a synthetic design storm is to choose an actual measured event that is considered representative of storms experienced in the catchment.

Computer simulations/analysis using long time series data can be used to identify this design event. For example, after running 10 years of rainfall through a model, to achieve a LOS of 2 spills per year would equate to 20 spills over this 10 year period. Hence, if the 20th largest event is contained, then this LOS could be considered to be met. Using statistical analysis of the results, this 20th event can be identified and used for options development. This results in significant savings in model runtimes because only a single rainfall event needs to be considered. It should be noted that the 20th event for the whole system will probably not be the 20th event for each individual part of the system, and options developed may change the characteristics of the system.

Sydney Water specifies that a 10 year rainfall time series should be used to assess the system performance, with all overflow events for the system being ranked by total spill volume. From this summary, rainfall events should be selected to approximate the 3 month, 6 month, 1 year and 2 year storms for the purpose of establishing the approximate containment standard in different parts of the network. For example, the containment standard of 3 months relates to the rainfall that creates the 40th largest overflow volume event in 10 years of rainfall (Sydney Water, 2002).

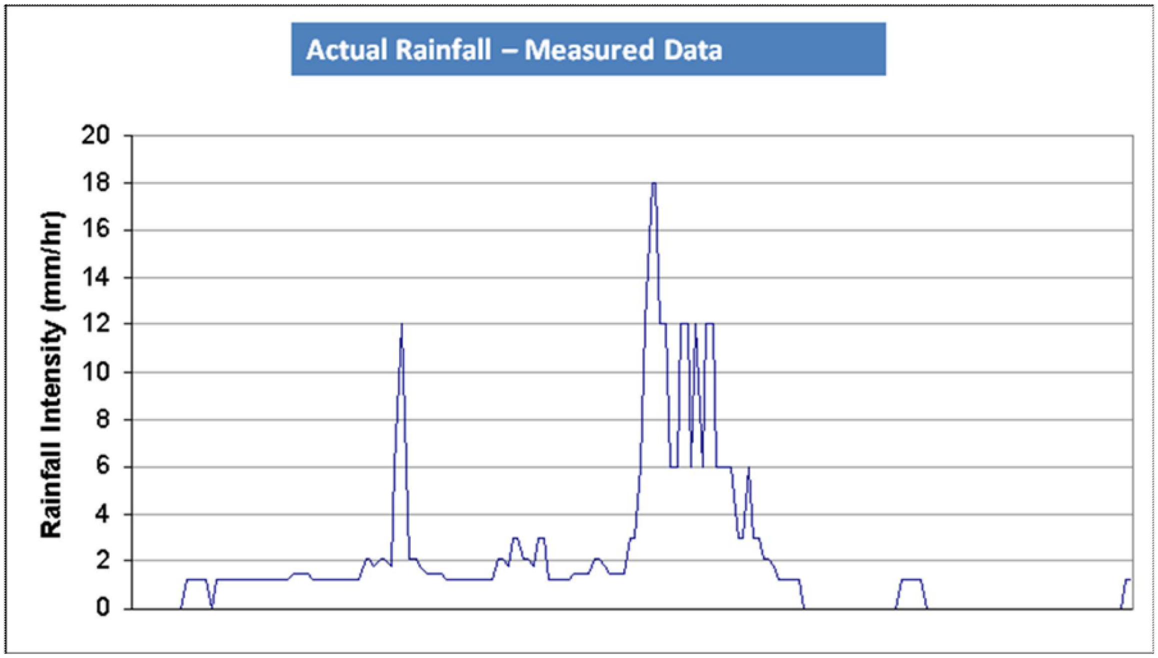
A slightly different approach that has been adopted by some network operators is to determine a ‘typical’ storm from a combination of considerations, such as:

- Statistical analysis of actual measured rainfall data
- Knowledge of the effects of the actual rainstorm on the catchment

The rainstorm could be deemed as ‘typical’ of a storm of a particular ARI, or ‘typical’ of the magnitude of storm that is considered as a benchmark LOS standard for performance of the network (e.g. for no flooding). ‘Typical’ might also mean that the rainfall variation and the duration of individual events during the time period considered might be the norm for the areas considered.

Figure 3 below shows an example of a design storm based on actual rainfall data.

Figure 3: Design Storm based on Actual Rainfall Data



3.3 USE OF DESIGN STORMS FOR SYSTEM PERFORMANCE

3.3.1 ADVANTAGES

The design storm approach has the following advantages:

- It is relatively easy to generate storm profiles, particularly if documented processes such as TP108 are followed or in-built generators within the hydraulic computer modelling software packages are used.

- It is relatively quick to complete computer simulations of single rainfall events (as compared to analyzing long time series data).

- The same temporal pattern and/or storm can be used for different catchments, meaning consistency and ease of use as a comparative tool. This is particularly useful for regulatory purposes, allowing LOS comparison on a standardized basis.

- The design storm can be used as a basis of comparison between different organizations

3.3.2 DISADVANTAGES

The design storm approach may have the following disadvantages:

- The use of synthetic storms, or ‘typical’ measured storms does not necessarily take into account the spatial variation of rainfall, particularly where synthetic patterns are developed and the same pattern is applied across the whole catchment. This can be mitigated to some extent by applying aerial reduction factors that reduce the rainfall intensities applied over large catchments. However, the influence of geographic features on weather patterns is not taken into consideration.

- Design storms may not take into account back-to-back storm events and the possibility of the system not having returned to its ‘dry’ state before the next storm arrives. This may have consequences when designing options, resulting in under-engineered schemes, particularly where storage tanks are required to empty before subsequent storms.

- Synthetic design storms use theoretical storms developed using an empirical[4] approach but then generalised for multi-location / catchment applications as opposed to actual observed rainfall events. Inaccuracies and generalizations in synthetic rainstorms may result in the model predicted LOS differing from reality.

3.3.3 POINTS TO CONSIDER

The following points should be considered when using design storms for system performance:

- Initial conditions need to be specified carefully. Assuming dry initial conditions may mean that system performance is predicted to be better than it actually is and that solutions are under-sized; conversely, wet initial conditions may result in overly conservative results.

- Design storms based on actual events need to be considered carefully, as they may not represent the critical conditions for a given catchment; for example, the critical time of concentration.

- The dataset from which design storms are generated (whether synthetic or typical) may be too small (too short a period) to have included extreme high ARI rainstorms. Naturally occurring rainfall may not agree with our assumptions because of dataset omissions. For example, in 2007 the town of Kaeo in Northland experienced two events exceeding 1/100 AEP (100 Year ARI) in the space of six months (NIWA, 2007).

- Winter and Summer storm profiles may differ significantly in temporal pattern and/or intensities. Any differences may be particular to a given region, and should be understood to determine the appropriate profile to use for the system.

4 MULTIPLE YEARS OF RAINFALL

A second possible approach is to apply multiple years of rainfall to a system model to understand the performance over a long time period. Actual or synthetic rainfall records can be used for this analysis. These can be analysed and used to understand the average performance over a long period of time – for example, a 10 year Long Time Series (LTS) simulation could predict that an overflow spills 40 times over this period, or an average of four times per year. In any given year it could spill ten times or not at all; however the long time series run allows us to understand the average performance of the system over time.

4.1 ACTUAL LTS RAINFALL RECORDS

A number of organisations specify the use of actual rainfall records to run Long Time Series analyses, with time periods ranging from five to 21 years, and in some cases more. This can depend on what historical rainfall information is available. Recorded rainfall can be directly applied to the model, either as a continuous record or as a series of sub-events that exclude dry periods.

The definition of sub-events is undertaken by considering inter-event dry periods i.e. the period of time between storm events that is subject to zero (or near zero) rainfall, and which is of sufficient duration to allow the system to return to its 'dry' state before the next storm arrives. The definition may also include an assessment of what constitutes zero rainfall i.e. rainfall below a certain depth or intensity may be ignored, being considered as inconsequential. Figure 4 shows an example of part of a long time series rainfall from which sub-events meeting certain criteria are extracted.

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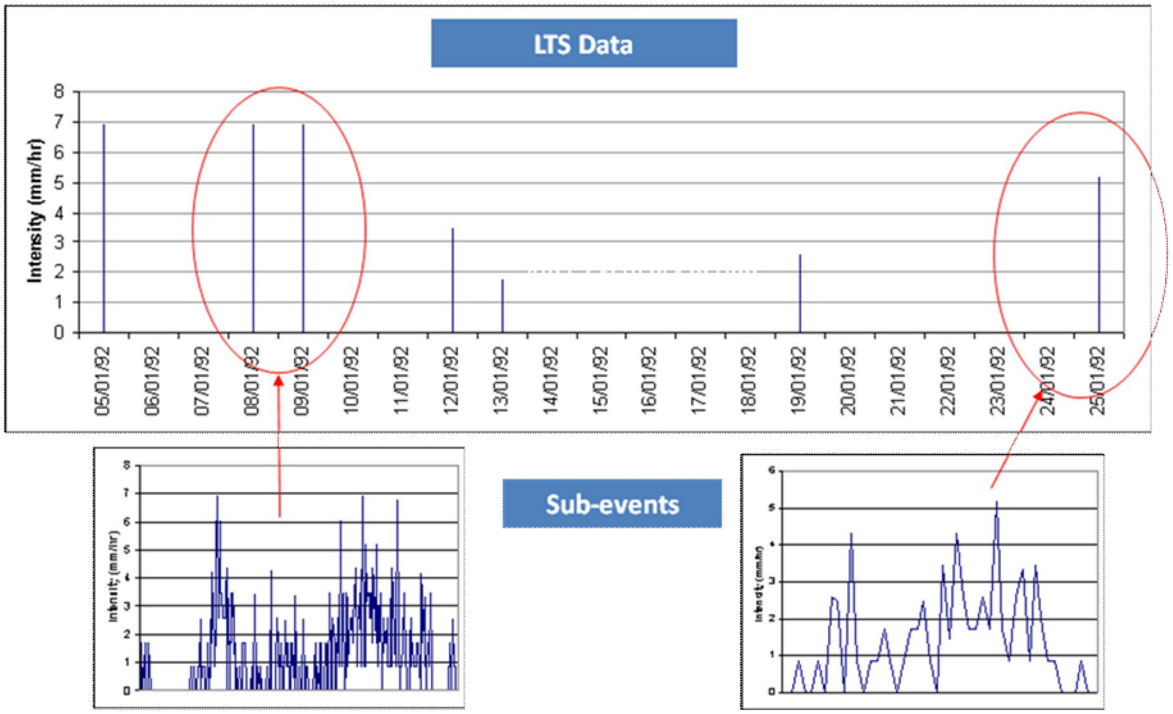
[4] An empirical approach uses observed data to develop storms rather than a purely theoretical basis.

Figure 4: Long Time Series Rainfall showing Extraction of Sub-events



There are software tools available for processing actual rainfall records, based on user-defined parameters of inter-event dry period and minimum rainfall, to generate sub-events. An example is STORMPAC (WRc).

There are also tools that can take, for example, hourly or daily measured rainfall data, and disaggregate this using statistical tools into smaller time step data series (e.g. 5 minute intervals) that are required to run detailed hydrodynamic computer simulations. This is particularly useful if historic rainfall records are only available at longer time step intervals. STORMPAC can also provide this ability.

Simulations of complete LTS data can use significant computational power. This can be reduced by simulating sub-events (i.e. not simulating dry periods). Simulation speeds can be further enhanced by moving away from detailed dynamic hydraulic analysis, to Excel or Visual Basic tools that greatly simplify representation of the system / catchments. These tools can be calibrated to gauged or modelled data (based on detailed hydraulic models), and can run long periods of 100 years or more in just seconds. An example is SIMPOL (WRc).

4.2 SYNTHETIC LTS RAINFALL

In the UK, synthetic long term time series are available for a number of regions. These are generated using stochastic tools, based on historic rainfall records. They are generalized across a range of geographic regions.

STORMPAC (WRc) can be used to generate these synthetic LTS rain datasets. The derivation of these requires inputs such as grid reference, distance from the coast, altitude and annual average rainfall.

In New Zealand, a long term ‘synthetic’ rainfall record was developed by Metrowater during the Integrated Catchment Study project. Metrowater developed 100 years of synthetic rainfall data and extracted five separate one year periods that together are representative of typical rainfall statistics for Auckland (Metrowater, 2005).

4.3 USE OF MULTIPLE YEARS OF RAINFALL FOR SYSTEM PERFORMANCE

4.3.1 ADVANTAGES

The LTS approach has the following advantages:

- With actual LTS data (as opposed to synthetic LTS data), the results of this analysis can be compared with actual measured data and field observations, so that the predicted performance in the model can be verified. This gives higher confidence when applying the rainfall series to the future conditions model.

- LTS takes into account back-to-back storm events. This is important for options development, where these events can have a large effect on storage tank and pipe sizing. Storage tanks may not have emptied fully before the next event, and the flows in the system may be higher than dry weather flows. Consequently, total peak storm flows are higher than those that would be generated from a single storm simulation, and pipes and storage therefore may need to be larger to convey / store these increased flows.

- With actual LTS data, data from different rain gauges may be able to be used. This means that spatially varying rainfall can be represented. This is particularly relevant in some areas of New Zealand where the nature of the terrain means that rainfall can vary widely across relatively small areas, and it may not be appropriate to apply the same rainfall profile to the complete catchment.

- Long term time series include a wider range of conditions than design storms, and therefore may be more likely to represent the critical conditions for the modeled catchment. As an example, they will include both winter and summer storm profiles.

- Synthetic LTS can be used for different catchments, meaning consistency and ease of use as a comparative tool. This is particularly useful for regulatory purposes, allowing LOS comparison on a standardized basis.

4.3.2 DISADVANTAGES

The LTS approach may have the following disadvantages:

- The intensity-duration-frequency relationships may change with the effect of climate change. Actual LTS analyses use historical data, and if the effects of climate change are not applied to these previous time series, predicted system performance may be better than reality.

- LTS runs can be computationally intensive, take several days to run and generate large quantities of results data. It is noted that this can be mitigated with the use of spreadsheet and/or Visual Basic tools, as discussed in Section 4.1 above.

- LTS results may not be useful when considering comparison between different organizations, except if the system performance is translated back to ARI.

4.3.3 POINTS TO CONSIDER

The following points should be considered when using multiple years of rainfall for system performance:

- Inter-event dry periods can have a significant effect on system performance if they are not properly understood. If the rainfall series is split into sub-events and dry weather excluded, if the system is not allowed to return to dry weather conditions before ending one sub-event and beginning another, then system performance can be predicted to be better than it actually is.

- If this approach is used to rank events from largest to smallest overflow volume, it should be noted that a given event (for example the 20th largest event) for the whole catchment can be different to this same event for each individual overflow point. This is due to spatial variation of rainfall and different times of concentration. The whole catchment approach is suitable to assess the effect of large scale solutions, for example new trunk lines. However, this may not provide the target LOS for all overflow points. The individual overflow point approach is particularly suitable for storage solutions, where the storage volume can be sized for each individual overflow point.

- The dataset from which the LTS data is derived (whether synthetic or typical) may be too small (too short a period) to have included extreme high ARI rainstorms. Naturally occurring rainfall may not agree with our assumptions because of dataset omissions. For example, has a 20 year long LTS included events of 100 year ARI?

5 TYPICAL YEAR

This approach analyses rainfall data from a long time period and uses statistical analysis to select a single year with a "typical" distribution of rainfall events. If the target LOS is met for this typical year, that is considered acceptable.

5.1 DERIVATION FROM ACTUAL RAINFALL

The typical year can be defined by analyzing previous rainfall records with respect to yearly rainfall depth and the nature and number of the events contained within each year. For example, Metrowater defined their typical year as 1999 (Metrowater, 2005). This year was deemed "typical" with respect to yearly rainfall depth, intensities and durations of rainfall events. The 1999 year did not contain any extreme events larger than about a 1 in 2 year ARI, therefore the results would be considered as what is "typical" for the system. The second reason for choosing this year was that it is relatively recent, and therefore model results could be validated against measurements and field observations. Lastly, there was minimal spatial variation across numerous rain gauges.

5.2 USE OF TYPICAL YEAR FOR SYSTEM PERFORMANCE

5.2.1 ADVANTAGES

The typical year approach has the following advantages, as well as those discussed in Section 4.3.1 above for the LTS approach:

- One year of rainfall is relatively quick to run compared to the LTS approach of multiple years

5.2.2 DISADVANTAGES

The typical year approach may have the following disadvantages, as well as those discussed in Section 4.3.2 above for the LTS approach:

- Determination of the typical year is a complex process involving numerous variables which quite often leads to selection of different 'typical' years by utilities in the same region. This means that this methodology is harder to use for comparative purposes.
- It can be time consuming to develop the typical year, as extensive statistical analysis may be necessary.

5.2.3 POINTS TO CONSIDER

The following points should be considered when using a typical year for system performance:

- The analysis period chosen may affect the results – for example, the typical year of the past 50 years may differ significantly from the typical of the past 10 years, due to random variation and the effects of climate change.

6 SENSITIVITY ANALYSIS

6.1 DIFFERENT METHODOLOGIES

The choice of system performance methodology can affect the results gained. This is illustrated in Section 7 below. For example, the following factors may influence the results:

- Rainfall intensities and durations
- Time of concentration of the system

- Back-to-back storms

- Effect of peak flows versus total volume, and to which of these the system is more sensitive.

As discussed in earlier sections, each methodology considers these factors in different ways. Therefore, it is important to use more than one method to understand the performance of the system. This acts as a check on the results, and can provide a range of system performance within which the *actual* performance of the system may fall.

6.2 OTHER FACTORS

There are a number of factors that system performance may be sensitive to. It is important to understand if and how these impact the predicted results. Two of these factors are discussed below, however it is noted that different systems may also be sensitive to other factors not considered here.

6.2.1 CLIMATE CHANGE

Climate change may affect the following, impacting wastewater and combined systems:

- Rainfall intensities

- Temporal patterns

- Sea levels

- Evaporation

It is recommended that a sensitivity analysis be done to understand the potential impact of these changes on system performance. This allows the organization to understand areas that are sensitive to the potential effects of climate change, and that may require more detailed study or risk analysis. Solutions can then be designed to mitigate these risks.

6.2.2 BOUNDARY CONDITIONS

Often models require boundary conditions to be applied, which may include the following:

- Inflows from upstream catchments

- Downstream water levels

- Sea level

- Evaporation

- Groundwater levels

It is important to perform a sensitivity analysis to determine which of these have significant impacts on the system. This also assists in system understanding, and can flag areas where more detailed analysis may be necessary.

7 CASE STUDY

The choice of system performance methodology can affect the understanding of the performance of the system – for example, whether it is considered that LOS targets are met or if mitigation works are necessary. Additionally, the choice of method for sizing solutions can significantly affect the sizing and therefore cost and feasibility of these solutions. The example of the Grey Lynn catchment in Auckland City is used here to illustrate the different results gained by different methodologies. The target Level of Service in this catchment is two spills per year per location. Results are given for three different Combined System Overflow (CSO) locations in this catchment.

Two different system performance methods were used to approximate 'two spills per year' and to design storage solutions. For ease of comparison, it is assumed that a storage solution will be designed to achieve two spills per year.

The design storm approach used the 1 Year TP108 event on the assumption that storing this event would achieve the target LOS. This is likely to be a conservative approach. An alternative methodology was to use a five year LTS of measured rainfall for the period 2001-2005, where storage of the 10th largest event is assumed to achieve the target LOS. Results are given in Table 1. It can be seen that the use of the 1 Year ARI TP108 design storm results in storage volumes that are significantly larger.

It is noted that both of these approaches are valid, however the differences highlight the need for sensitivity analysis and further work to determine the appropriate sizing for the solution. The model results below give the designer a range of possible sizing that should be examined to (approximately) meet the target LOS. In this case, the recommended approach would be to determine the Best Practicable sizing for the option, taking into account other considerations such as relative cost and constructability. Additionally it should be noted that any modeled system performance is only an approximation of the system. Before detailed design, it is recommended that overflows be gauged to verify the model predictions.

Table 1: Comparison of Level of Service Spill Volumes for the Grey Lynn Catchment using Different System Performance Methodologies (Maunsell, 2009)

Design Criteria	Location		
	1	2	3
Design Storm – 1 Year ARI TP108	16280m^3	970m^3	7290m^3
LTS – 2001-2005 '10th event'	11050m^3	440m^3	4450m^3

8 CONCLUSIONS

- There are currently few national criteria for wastewater system performance assessment in New Zealand, apart from the Water NZ recommendation to use both design storms and LTS methods. Many individual local authorities and network owners/operators in New Zealand have developed their own guidelines for wastewater system performance, some of which are discussed in this paper. It is, therefore, currently difficult to compare expected Levels of Service across different organisations. This is particularly relevant when different standards are being assessed by a single governing/regulating body, leading to a lack of consistency and an inability to make meaningful comparisons of LOS.

- Each method of system performance analysis has advantages and disadvantages. There is no 'one fits all' correct approach. However, it is noted that *consistency* of approach is important when comparing system performance from different studies.

- Modellers need to understand the system in order to understand the consequences of their choice of methodology – for example whether time of concentration varies across the catchment, whether back-to back storms are relevant, whether seasonal variations are important, etc.

- Key to the selection of an appropriate method is understanding how the models will ultimately be used to support development and design of potential solutions. Will the models be used to assess storage facilities? Are potential solutions only focused on peak flow criteria? Are the target levels of service based on system performance over an annual period? These questions need to be understood to ensure that the selected analysis method is appropriate for analysing and designing options.

- The modeller should ensure that the end user understands the limitations of the system performance methodology and results, and that these limitations are taken into account for future uses of the model.

- None of these methods will exactly predict the performance of the system in the future; they can only provide an indication. Therefore the use of more than one method is valuable as a check and sensitivity analysis when understanding the system and designing solutions.

- Any modelled system performance is only an approximation of the system. Before detailed design, it is recommended that gauging data be collected to verify the model predictions.

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