University of Southern Queensland
Faculty of Engineering and Surveying

Application of an Urban Runoff Model Using Surface Specific Parameters

A dissertation submitted by

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ABSTRACT

Catchment urbanisation has led to a dramatic decline waterway health. The high percentage of impervious surfaces prevalent in urban areas can affect the ecological, economic and social function of our creeks, rivers and bays. Current engineering practice aims to limit this decline using the principles of water sensitive urban design (WSUD). An essential component of this design process is the estimation of stormwater pollutant loads based on catchment characteristics. Current practice involves the estimation of pollutant loads based on land use type. As WSUD seeks to emphasise 'at source' controls there is a need to estimate for finer scale catchments. It is anticipated that the use of surface type rather than land use type to determine catchment pollutant loads will prove more accurate at a finer scale. A mass balance model developed by Brodie (2006) utilises surface type to determine pollutant loads.

This dissertation applies Brodie's mass balance model to a small catchment in Brisbane, QLD to determine the ability of the mass balance model to predict suspended solid loads. This dissertation compares the measured and predicted event mean concentrations of suspended solids over a number of storm events. The result was a poor correlation between predicted and measured data sets due to large inaccuracies in the measured rainfall and use of previously calibrated particle accumulation and washoff parameters not specific to the catchment. A major outcome involves providing comments on the further application of the mass balance model and conducting an error analysis to determine highly sensitive model parameters. The outcome is applicable to stormwater engineers and future users of the mass balance model.

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated

Kieren Peter Davis

Student Number: Q1222280

Signature

Date

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ABBREVIATIONS

ABBREVIATION	MEANING
WSUD	Water Sensitive Urban Design
SQID	Stormwater Quality Improvement Devices
NCP	Non-Coarse Particles
TSS	Total Suspended Solids
BCC	Brisbane City Council
Brisbane CBD	Brisbane Central Business District
BOM	Bureau of Meteorology
ENSO	EL Nino-Southern Oscillation
SOI	Southern Oscillation Index
HSA	Hoyland Street A inlet
HSB	Hoyland Street B inlet
HSC	Hoyland Street C inlet
HSL	Hoyland Street Level Sensor
HSO	Hoyland Street Outlet
HSOa	Hoyland Street Outlet a
HSOb	Hoyland Street Outlet b
VSS	Volatile Suspended Solids
TP	Total Phosphorous
TN	Total Nitrogen
EMC	Event Mean Concentration

DCIA	Directly Connected Impervious Area
ICIA	Indirectly Connected Impervious Area
US	United States
USGS	Unites States Geological Survey
SSC	Suspended Sediment Concentration
RDI	Rainfall Detachment Index
ADP	Antecedent Dry Period
SRM	Statistical Rational Method
AMC	Antecedent Moisture Condition
USQ	University of Southern Queensland
RCP	Reinforced Concrete Pipe
ALS	Airbourne Laser Survey

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

"We're all downstream"

Margaret and Jim Drescher, Nova Scotia

Extensive catchment urbanisation has led to a dramatic change in the natural hydrology and ecology of many urban catchments. The high percentage of impervious area prevalent in major cities and towns has produced an increase in runoff volumes and a decrease in stormwater quality. The end result is a modification of stream flow processes causing erosion and habitat degradation. It is now widely accepted that a notable relationship exists between stream degradation and impervious area.

The effects of catchment urbanisation on stormwater discharge has gained considerable awareness within the community over the past 20 years, resulting in a shift in traditional engineering approach and application to stormwater. Local governments have been placing increasing emphasis on the treatment of urban stormwater through stormwater quality improvement devices (SQIDs). More recently, the focus has moved from the broad scale application of end-of-pipe solutions to source controls such as stormwater retention and infiltration (O'Loughlin, 2007). This reflects the emergence of water sensitive urban design (WSUD), which seeks to combine all elements of the water cycle.

An essential aspect of stormwater management practice involves estimating stormwater pollutant loads based on catchment characteristics. Current engineering practice is to estimate stormwater pollutant loads from urban catchments based on land use parameters. These land use parameters are often divided based on the zoning of the land use type (eg residential, industrial). This method proves practical and reasonably accurate for larger catchments, however for smaller catchments it has been considered that stormwater loads determined from a specific land surface (eg. roofs, gassed areas) are more effective. As current practice seeks to emphasise "at source" controls, the need for accurate information on smaller catchments is increasing. This necessitates a need for accurate modelling of these smaller catchments to assist in design and planning.

A recent University of Southern Queensland research project (Brodie, 2006) has developed a simple empirically based model to estimate suspended solid loads in stormwater runoff from various urban surfaces. Non-coarse Particles (NCP) as opposed to Total Suspended Solids (TSS) were used to measure the suspended solids in the analysis. Data for the model was obtained utilising runoff samples from 40 storm events from December 2004 to January 2006 within the inner city of Toowoomba, Australia. Runoff samples were obtained using an innovative flow splitting device for 5 surface types; galvanised roof, grass, bare soil, commercial carpark and road. According to Brodie, the model was able to provide reasonable estimates (R^2 = 0.74 to 0.97) when compared to the measured loads. The model also performed well in comparison to three models used in current engineering practice; the Arithmetic Mean, Logarithmic Mean and Stochastic EMC methods.

1.1 Project Outline and Objectives

The purpose of this dissertation is to assess the effectiveness of Brodie's mass balance model in predicting the stormwater loads of total suspended solids from a small urban catchment. This catchment is located at Hoyland Street in Northern Brisbane, Australia and drains into a bioretention basin before discharging into Bald Hills Creek. The inflows to this bioretention system have been monitored as part of the WSUD monitoring program instituted by Brisbane City Council (BCC).

The catchment is significantly different in terms of climatic conditions and surface characteristics to the catchments sampled by Brodie. It is expected that significant variation in predicted and measured suspended solids will be evident over a number of storm events. The effectiveness of the mass balance model will be determined by direct comparison with the measured and modelled data, following the application of modelled runoff and measured rainfall data. The comparison will also focus on determining the extent of any relationship between the accuracy of the model and any rainfall event or catchment characteristics. This will aid in determining any major contributing factor to either the accuracy or inaccuracy of the modelled data.

Due to the nature and design of the bioretention system and monitoring arrangement, large inconsistencies in the recorded inflow data are evident. During rainfall events ponding within the system can cause backflow effects. This effectively slows the flow rate and thus causes a delay in the measured runoff hydrograph. In larger events negative inflows have been recorded due to the water level within the system being at a higher elevation than the monitoring equipment. This phenomenon has been investigated by Deletic and Fletcher (2006) and it was confirmed that backwater effects do occur at two of the three monitored inlet pipes. Despite the inconsistencies in discharge data, event specific suspended solid concentrations are available for the bioretention system and are consistent with expected results.

It was initially considered that the results of the mass balance model could be directly compared to measured suspended solids loads in order to provide a direct comparison. Due to the data inconsistencies discussed previously this is not possible and it has been necessary to model the sub-catchment event discharge in order to apply it to both the measured data and the mass balance model to determine event suspended solids loads. The sub-catchment discharges were modelled using DRAINS hydrologic and hydraulic modelling software. The total event discharge was then compared to the measured discharge for storms where no backwater effects occurred in order to calibrate the model and aid in selecting appropriate input variables.

The outline of this study is to achieve the following broad aims:

1. Conduct a literature review on the prediction of stormwater pollutant loads using urban surface characteristics, restricted to suspended solids.
2. Determine the physical characteristics of the catchment.
3. Gather rainfall, runoff and suspended solids data for the Hoyland Street catchment and select appropriate rainfall events.
4. Develop and calibrate DRAINS model.
5. Test mass balance model.
6. Compare and verify model results with measured suspended solid loads.
7. Write and submit a dissertation on the application and effectiveness of the model in predicting suspended solid loads in urban stormwater runoff.

CHAPTER 2

BACKGROUND

2.0 BACKGROUND

2.1 Climate and Geography of Bald Hills

The city of Brisbane is located in the south-east corner of Queensland, on the Brisbane River adjacent to a large shallow bay known as Moreton Bay. Bald Hills is the northernmost suburb in Brisbane (Figure 2.1) and shares its northern and western borders with the Moreton Bay Regional Council. Largely a residential suburb, Bald Hills has undergone significant development within the last 30 years with many rural allotments being subdivided and gradually taken over as a low-density residential area.

Bald Hills is situated at the confluence of the South and North Pine Rivers which subsequently flow into Moreton Bay. As a result the suburb drains into the South Pine River to it's west and Bald Hills Creek to it's east. Bald Hills Creek discharges into the environmentally sensitive Tinchi Tamba Wetlands Reserve before entering the Pine River.

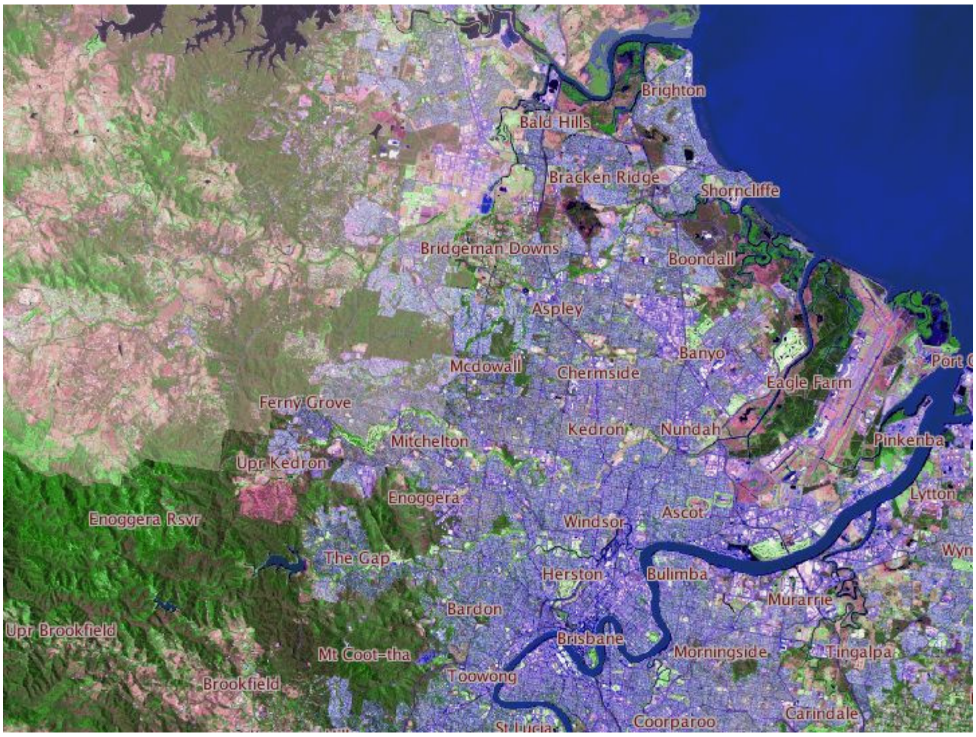

Figure 2.1 Location of Bald Hills Relative to the Brisbane CBD (Source: Brisbane City Council)

Brisbane experiences a subtropical climate with four distinct yet temperate seasons. Average temperatures range from 9.5°C to 20.9°C in the winter, and 20.6°C to 29.1°C in the summer (BOM, 2000), with maximum and minimum recorded temperatures of 39.6°C and 0.6°C respectively. Cool, clear nights are prevalent in the winter months while cloud cover is nearly twice as common in summer. Rainfall is also much greater in the summer months as is the prevalence of high intensity storms with a short duration.

Bald Hills has a typical Brisbane Climate. Figure 2.2 below displays the rainfall and temperature patterns at Sandgate Post Office, approximately 5.5 km east of Bald Hills. It can be seen that rainfall within the catchment is subject to a high degree of variation within the year, with average rainfall in the summer months over twice that of winter.

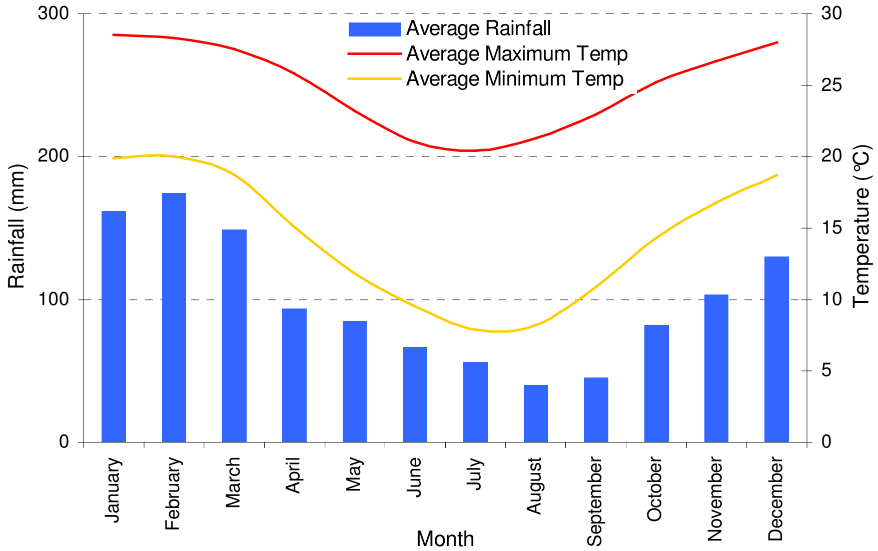

Figure 2.2 Monthly Rainfall and Temperature Averages at Sandgate Post Office (Bureau of Meteorology)

As well as the increased summer rainfall, evaporation is dramatically increased in the summer months, particularly from October to March. As seen in Figure 2.3, this is largely dependant on an associated increase in solar energy associated with seasonal variation leading to increased summer temperatures. Increased wind speeds in the warmer months create an additional transport mechanism which would also result in an increase for evaporation.

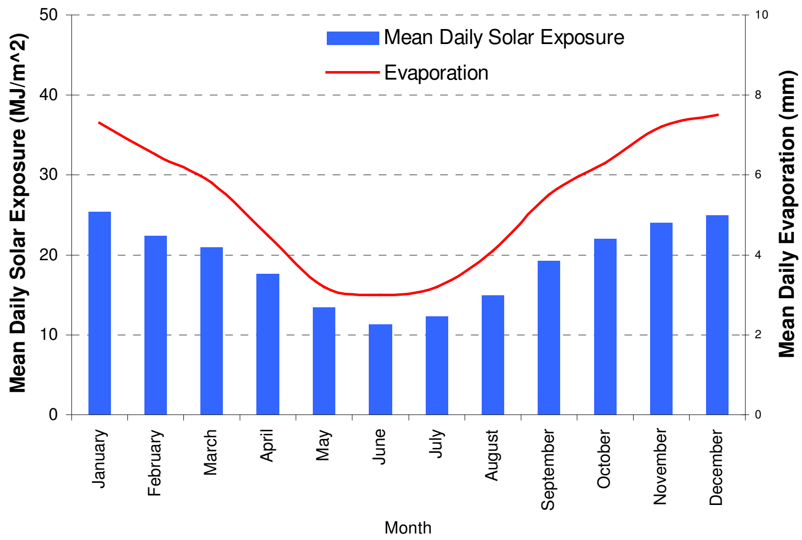

Figure 2.3 Monthly Evaporation and Solar Exposure Averages at Brisbane Airport (Bureau of Meteorology)

Distinct inter-annual rainfall variation occurs along the East Coast of Australia as a result of a phenomenon known as El Nino-Southern Oscillation (ENSO). This phenomenon is influenced by ocean temperature, ocean currents as well as the atmospheric pressure over Darwin and Tahiti. The result of an ENSO event is a large decrease in annual rainfall, which can follow a two to seven year cycle, however is extremely variable.

For Brisbane, including Bald Hills, this event results in dry winters, occasionally with no rain at all for the entire winter months. A prolonged El Nino event has recently occurred for the past five to six years resulting in a prolonged drought. Trends in the Southern Oscillation Index (SOI) indicate that this event ended in late 2007, however accurate predictions of this poorly understood phenomenon are not possible.

2.2 Hoyland Street Catchment

As previously explained, a bioretention system is located at Hoyland Street, Bald Hills and has been monitored as part of a WSUD monitoring program by the Brisbane City Council. The catchment area draining into this system is approximately 1.8ha and is located 20km North of the Brisbane CBD within the wider Bald Hills Creek catchment (BCC, 2006). Three sub-catchments drain into the system through separate inlets at the upstream end of the bioretention system.

2.2.1 Bioretention System

The Hoyland Street bioretention system is located at the intersection of Hoyland and Parer Streets, an Arterial Route connecting the Gympie Arterial Road with the Gateway Motorway (Figure 2.4). The system was constructed in late 2001 as a demonstration project for Water Sensitive Urban Design (WSUD) during a major road upgrade with a view to monitor the site for pollutant removal efficiency.

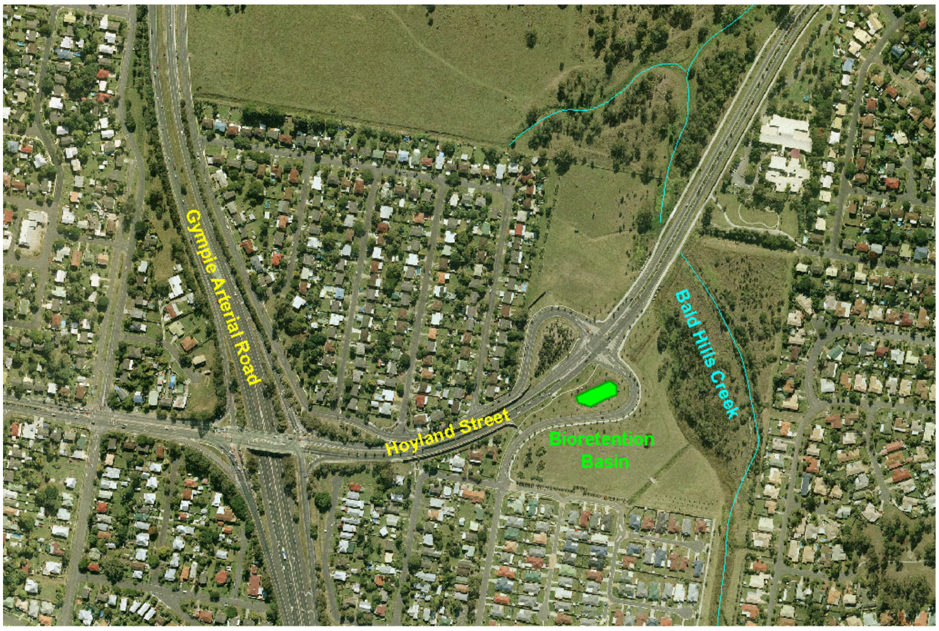

Figure 2.4 Location of Hoyland Street Bioretention Basin

A bioretention system is a vegetated area where runoff is filtered through a filter media layer as it percolates through the ground (2006, Healthy Waterways). Perforated under-drains collect the filtered stormwater before discharging into the receiving environment. Essentially runoff is treated by mechanical filtration as it passes through the filter media and dense vegetation, and also by adsorption onto the filter media as well as biological uptake by the vegetation. Bioretention basins also limit peak discharge downstream by providing significant flow attenuation.

The three sub-catchments previously described, drain into separate pipes, which in turn flow into the bioretention system. Figure 2.5 illustrates this, and clearly shows the three inlet pipes, known as HSA, HSB and HSC respectively. A row of six 150 mm slotted PVC agricultural pipes at three metre centres convey the filtered runoff into an outlet chamber at the downstream end of the system. A maintenance pipe is also located within the basin to enable cleaning of the slotted PVC pipes.

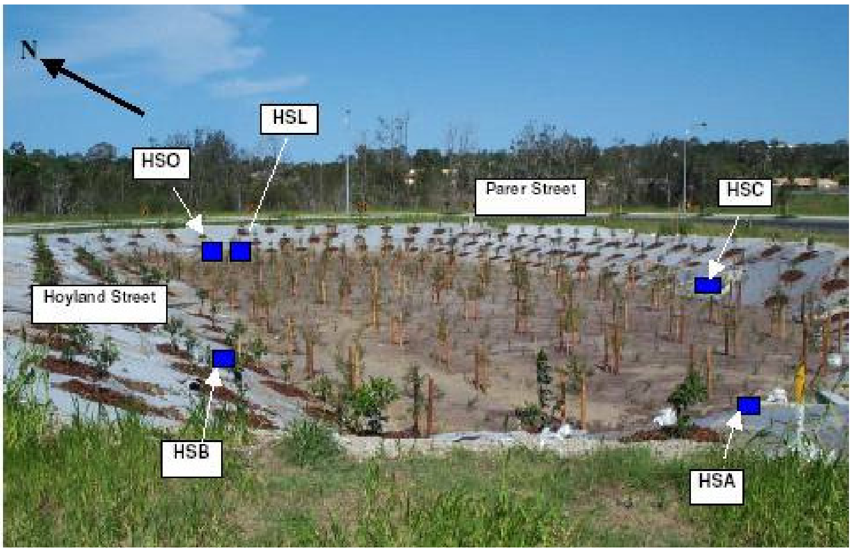

Figure 2.5 Hoyland Street following construction in January 2002 (BCC, 2006)

In addition to the perforated under-drains, a high flow bypass pit with two 675 mm outlet pipes known as HSO1 and HSO2 drain any surface water that has not infiltrated through the soil into nearby Bald Hills Creek. The pit is set 0.5 m higher than the surrounding basin allowing considerable extended detention. This configuration allows the basin to act as a fully on-line system, conveying runoff from major rainfall events directly through the basin before exiting the system through the high-flow bypass.

Planted vegetation within the system was confined to a single tree species and two ground cover species. *Melaleuca quinquenervia* (Broad-leaved paperbark) and *Lomandra longifolia* (Spiny-headed mat-rush) were planted within the basin itself, while *Pittosporum revolutum* (Sweet Pittosporum) was planted in higher densities on the batters. Figure 2.6 shows the extent of vegetative cover just two years after installation.

Figure 2.6 Hoyland Street in June 2004 (BCC, 2006)

2.2.2 Catchment Characteristics

The total catchment boundary of the bioretention system is detailed in Figure 2.7. It can be seen that the vast majority of the catchment is formed by Hoyland Street itself. Fractions of eight allotments between 500 and 800 m^2 also drain into the bioretention system as does a portion of steep grassed embankment in the upper part of the catchment and a significant portion of grassed area. Some of this grassed area drains directly into the bioretention system by overland sheet flow; however the rest of the catchment is directly connected to the bioretention by stormwater infrastructure. The bioretention basin itself comprises around 4% of the total catchment area.

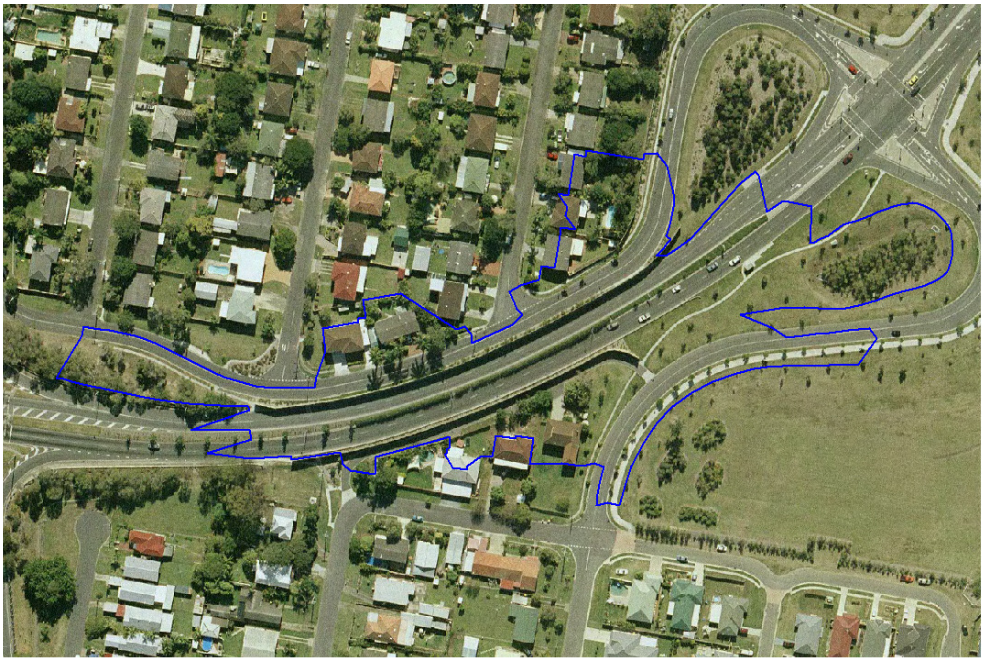

Figure 2.7 Aerial photograph depicting the Hoyland Street catchment

The upper road catchment connecting to the Gympie Road overpass is a moderately steep ramp of around 6%. This grade gradually lessens approaching the bioretention system to just over 1%. The short distance to gully pits, moderate ramp grade and distinct lack of any overland flow path indicate a relatively short time of concentration for the catchment. This coupled with the high percentage of directly connected impervious area result in inflows to the bioretention system during even small rainfall events.

2.2.3 Monitoring Data

Water quality data has been monitored at the Hoyland Street bioretention system since 2002 as part of Brisbane City Council's WSUD monitoring program in order to test the pollutant removal efficiency of the system. Recent analysis has shown that the system has a mean infiltration rate of 101 mm/h and reduces the mean TSS concentrations by 71% ranging from 32% to 88% (BCC, 2007). According to City Design (2006) samples were tested for a range of pollutants including:

- Total suspended solids (TSS),
- Volatile suspended solids (VSS),
- Total phosphorous (TP),
- Total nitrogen (TN),
- Ammonia,
- NOx,
- Ortho-P, and
- Heavy metals (zinc, lead, nickel, cadmium, chromium, copper).

Analysis of nutrient species (Ortho-P, NOx and Ammonia) was only conducted for five events between 2003 and 2006, however all other parameters were consistently tested. Testing of nutrient species required immediate chilling prior to sample collection, which could not be established in all cases.

Flow volumes were also measured at each of the three inlet pipes and outlet pipe using flow meters. In addition, a water level sensor (HSL) was located within the system close to the outlet to measure the ponded level during events. This provided an indication as to when the infiltration capacity of the soil was exceeded and subsequently when the maximum ponded level was exceeded and runoff was exiting the system via the high flow bypass pit.

As previously discussed, several deficiencies exist with the monitoring data at Hoyland Street. More specifically, errors associated with the measurement of inflow and outflow discharge as well as level and velocity. This phenomenon was described by Deletic and Fletcher (2006) and it results in an inability to establish pollutant loads for the majority of runoff events. These problems include:

- Outlet flow volume occasionally greater than inlet flow volume,
- The backing up of water in the inlet pipes causing inaccurate and sometimes negative flows to be recorded,
- The assumption that equal flow occurs in both outlet pipes was found to be false,
- High tailwater levels from Bald Hills Creek causing inaccuracies in the outflow measurements.

Deletic and Fletcher (2006) assessed the existing monitoring configuration as well as available data and recommended the calculation of pollutant loads using a catchment weighting. A major conclusion of this assessment was that the inflow and outflow data could not be reliably used to estimate pollutant loads entering or being discharged from the system. As a result, the calculation of loads using the catchment area as a weighted average was recommended.

2.2.4 Rainfall Data

Information on rainfall events within the BCC local government area is available for a large number of locations due to a widespread network of pluviometers and stream height gauges. With respect to the bioretention system, rainfall data is available from 6 pluviometers, all within 7km of the system. These pluviometers are tipping buckets with a 1mm resolution. This means that once 1mm of rain has been recorded the bucket tips and the interval between tips is recorded. Unfortunately, the closest rainfall gauge (BDR712) has not collected data for the entire monitoring period.

In addition to direct rainfall data, Rainfall contour maps are available for individual events of a specified duration. These contour maps provide an indication as to the spatial variation in rainfall during events by interpolating the rainfall at points between the rainfall gauges. Figure 2.8 below displays an example of this for a rainfall event on the 03/01/2008. These maps can prove an indispensable tool in selecting rainfall events that do not exhibit a large spatial variation between the rainfall gauge and the monitoring site.

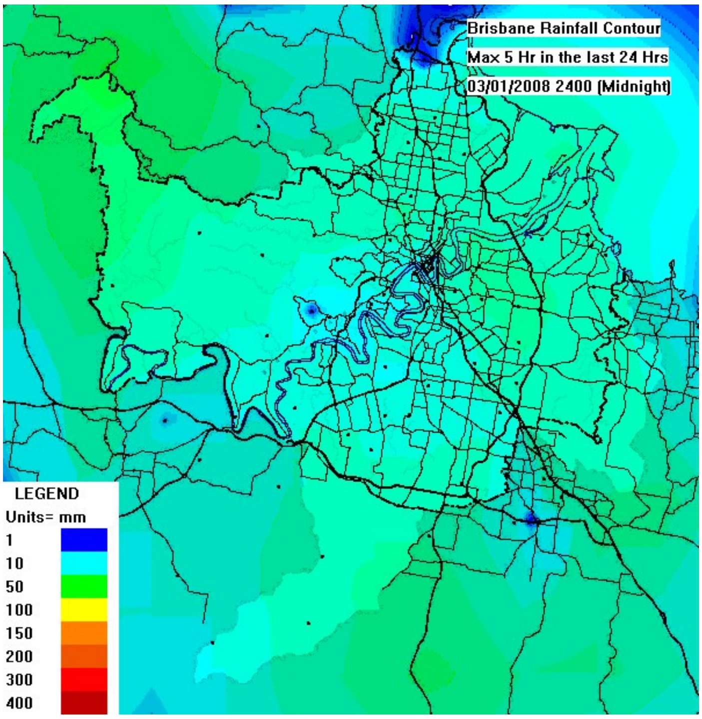

Figure 2.8 Brisbane Rainfall Contours for 03/01/2008

CHAPTER 3

LITERATURE REVIEW

3.0 LITERATURE REVIEW

3.1 Impervious and Pervious Areas

Urban catchments comprise of two distinct, hydrologically important areas that contribute to stormwater runoff through different mechanisms; impervious and pervious areas. Pervious areas allow infiltration and usually provide a greater degree of initial storage of runoff while impervious areas do not allow infiltration and usually have a small initial storage. As a result, impervious areas such as roads and roofs contribute runoff quicker and at a higher rate, whereas pervious areas such as parks and lawns require higher intensity or more prolonged rainfall to contribute similar amounts of runoff. (Boyd et al., 1993).

The connected nature of impervious area is of vital importance when describing rainfall, runoff and pollutant relationships. Directly connected impervious area (DCIA) refers to impervious areas with a dedicated connection to the drainage system such as roof runoff when conveyed directly to the street or underground drainage systems. Conversely, indirectly connected impervious area (ICIA) refers to impervious area not directly connected to the drainage system and either stored (such as with a rainwater tank) or conveyed to an additional pervious area.

Impervious and pervious areas also differ in their contribution of pollutants to receiving environments following rainfall events. The processes of accumulation and wash-off occur more frequently and easily from impervious areas. Automobiles also regularly frequent impervious areas such as roads, and drainage systems typically provide an excellent transport mechanism for pollutants. By contrast, pervious areas generally infiltrate a large portion of the total rainfall, removing pollutants in the process. This phenomenon is particularly noticeable in small rainfall events, however it has been confirmed to still occur in events up to 75 mm when comparing forested and developed catchments (Christopher et al., 1997).

In addition to runoff quality, numerous studies have established a direct relationship between the amount of impervious surface within a watershed and pollution of its surface waters (Civco and Sleavinl, 2000). The degradation is largely due to a combination of increased runoff volumes and decreased water quality (Arnold and Gibbons, 1996). However, this change in catchment hydrology can be combined with the clearing of riparian vegetation and the straightening and formalising of drainage channels to result in severely degraded receiving environments.

3.2 Urban Drainage Systems

Drainage systems in urban areas are primarily designed for the effective conveyance of runoff into a receiving environment. Receiving environments vary from dry gullies, overland flow paths, creeks, rivers, groundwater storages, lakes and oceans. In addition to runoff conveyance, urban drainage systems can also be designed to provide retention, treatment and/or reuse of stormwater and also provide surcharge from sewerage systems. Components of an urban drainage system typically comprise of:

- Property drainage,
- Street drainage,
- Trunk drainage,
- Detention systems,

- WSUD elements.

Individual allotments comprise of portions of pervious and impervious area both of which are connected to the drainage system either directly or indirectly. Pervious area generally consists of surfaces such as lawns, gardens, grassed road reserve and parks. Impervious area includes roofs, driveways, tennis courts, sheds, sealed roads and footpaths. Roofs usually comprise the largest impervious area within individual allotments. Impervious area is either DCIA in the case of roof guttering conveying runoff directly to the street, or ICIA in the case of gutters connected to rainwater tanks or backyard ‘bubbler style’ outlets that discharge onto the lawn.

Property drainage subsequently flows into a street drainage system where the cumulative effect of the discharge from individual causes flows to be increased. Streets are usually drained by a combination of gutters, inlet pits, manholes and pipes, or using surface drainage through the use of swales and other WSUD measures. The use and application of these drainage elements is closely linked to the street and property design. Design of street drainage systems in Australia generally requires the capture of small, regular rain events (1 to 5 year) within the gutter and underground drainage system, and the conveyance of large, irregular events (50 to 100 year) within the entire road reserve (Figure 3.1).

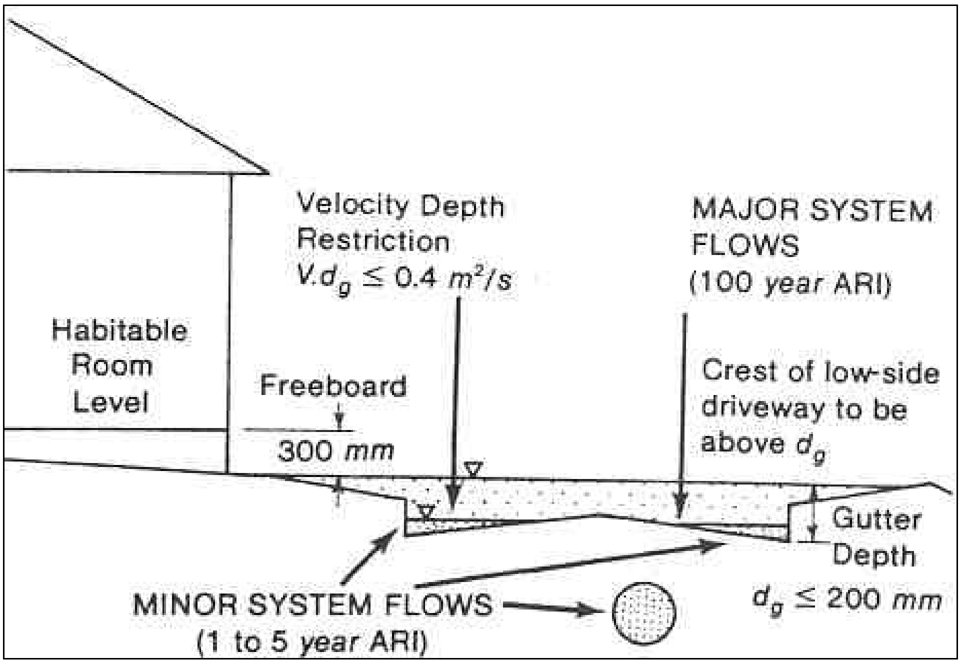

Figure 3.1 Design objectives of a street drainage system (USQ, 2003)

Trunk drainage in the form of underground pipes, open channels or a combination of both, convey the runoff from street drainage systems into the receiving environment. As with street drainage, the cumulative effects of a number of sub-areas contributing increases the size of the flowrates and thus the drainage infrastructure required.

Detention systems, otherwise known as detention basins or retarding basins are designed to store runoff volumes from a catchment for a pre-determined period of time. Detention basins are not to be confused with retention basins which are design to permanently hold water. These basins then release the runoff at a controlled rate that acts to limit the peak runoff in the downstream drainage system. The use of detention basins can be effective in areas where flooding immunity is a problem and can limit the size of trunk drainage required downstream and as a result provide cost savings. The use of detention basins is now widely regarded as an ineffective use of urban space, and additional outcomes can be achieved while integrating community, open space, biodiversity and water quality objectives using the design principles associated with WSUD.

WSUD elements are secondary design elements integrated into the four components of urban drainage systems previously mentioned. The principles of WSUD are most successfully applied at the property drainage level as the cumulative effect of increased flowrates and pollutant loads further down the drainage system limits the opportunity for its effective use. As a result, applications of WSUD are typically divided into lot scale measures when referring to property drainage and 'end of pipe' measures when referring to street and trunk drainage (Healthy Waterways, 2006). WSUD elements generally involve a combination of retention, detention, infiltration and reuse and can include:

- Swales and buffer strips,
- Bioretention systems,
- Sediment basins,
- Wetlands,
- Infiltration measures,
- Storage and reuse.

3.3 Suspended Solids

Runoff from urban areas carries a wide variety of pollutants, including sediment, nutrients, organic matter, bacteria, oil and grease, toxic substances and heavy metals (NCDWQ, 2007). Suspended solids are small particulates present in water that remain in suspension due to colloidal mixing or the motion of the liquid and are usually measured by the total suspended solids (TSS) water quality analytical measurement. Some pollutants such as phosphorous and heavy metals readily attach themselves to particulates, allowing suspended solids to act as a mobile substrate for other pollutants. TSS is not a good indictor of highly soluble pollutants from atmospheric sources such as nitrogen, which are of significant importance in urban areas.

The use of suspended solid loads as an estimate of pollution has been corroborated by numerous studies and has resulted in TSS being used as a widespread indicator of stormwater quality (Sartor et al., 1974; IEAust, 2003). However the ability of TSS to adequately measure suspended solid loads has been questioned (de Ridder et al., 2002; Brodie, 2006). The United States Geological Survey and the US Federal Highway Administration also mirror this view and have issued a policy establishing the suspended sediment concentration (SSC) as the preferred technique for runoff analysis (USGS, 2000).

This preference is largely due to the standardised nature of the SSC test and the fact that it limits bias. The TSS method involves the extraction of a sample from a container and subsequently passing the contents through a glass fibre filter that retains the solids. The mass of the retained solids is then weighed and extrapolated to the total volume to calculate the concentration. The SSC test involves calculating the mass of the entire sample negating the need for extrapolation (ASTM, 1999). This testing of the whole sample provides more accurate results especially if larger particles and fine sands are present. The presence of these particles can introduce bias if the TSS sub-sample is taken in such a way that discounts these particles, commonly through insufficient mixing times. This is particularly important if particle size distribution is an important component of the monitoring.

In order to determine pollutant loads, suspended solid concentrations obtained through either method can be multiplied by runoff. The simplest method for obtaining stormwater loads is through the use of the event mean concentration (EMC). The event mean concentration is defined as the total mass discharged divided by the total runoff volume for a defined event. This allows the mass loading to be calculated using the measured concentrations and runoff volume for individual storm events or on any defined time period.

3.4 Suspended Solids and Urban Areas

As with the majority of stormwater pollutants, suspended solid loads in receiving environments result from the accumulation and removal of particles on impervious surfaces such as streets, roofs and parking lots as well as localised soil erosion on pervious areas. As a result, the relationship between stormwater pollutants and urban areas is also applicable to suspended solid loads. Suspended solid loads are often highly correlated with the activities undertaken on the particular surface.

Suspended solids on urban surfaces undergo a cyclical process of accumulation and removal that is dependant on a number of variables. The process kinetics of accumulation and removal are often highly site specific and involve complex relationships that can be difficult to model in a changing urban environment (Ayoko, 2004). Simplified, accumulation generally occurs during periods of dry weather, and these accumulated particles are removed in periods of wet weather. Major sources of accumulation include atmospheric fallout, surface wear, soil erosion, and vehicle and tire wear.

It has been corroborated by numerous studies that the process of accumulation is not highly time dependent and occurs within a few days of wet weather (Vaze and Chiew, 2002; Deletic and Maskismovic, 1998). Brodie (2006) also discovered a 'rapid post-storm recovery' of particles on impervious surfaces and considered that the build-up of free particles reaches an equilibrium that is dependant on supply and removal process. These processes can include wind as well as activities involving cleaning surfaces such as roof, driveway and street cleaning. Numerous studies have conceded that either vehicle generated or external wind has a very significant effect on pollutant accumulation (Ball et al., 2002; Pitt et al., 2004; Vaze and Chiew, 2002). It is important to note that a number of other studies have found a relationship between the antecedent dry period (ADP) or time since last rainfall and particle load, suggesting a slower post-storm recovery (Ball et al., 1998). It has been noted by Pitt (2004) that an equilibrium accumulation condition depends on a number of environmental factors specific to the location. This suggests that post-storm recovery may occur fast or slow depending on the prevailing environmental conditions.

Accumulation has a tendency to reach an upper limit that is often dependant on the location and type of surface. This phenomenon has been noticed in a wide range of empirically based studies, which are generally highly specific to the particular environment. A typical study on the mass accumulation of TSS on eight highway sites in Southern California discovered a build-up of 0.544 g/m^3 per day (Jeong et al., 2006). Spatial variation has also been found when studying road surfaces, with over 90% of particles found within 30 cm of the kerb (Pitt et al., 2004)

As with accumulation of particles, the removal process of particles from impervious area is also quite complex. Removal is dependant on the available supply and size distribution of particulates, kinetic energy of the rainfall, capacity of runoff to mobilise particles and the surface characteristics (Pitt et al., 2004; Ayoko et al., 2004). Brodie (2006) also discovered that the use of a rainfall detachment index (RDI) improved the relationship with suspended solid loads.

Runoff from surfaces frequented by vehicles has often been the major focus of a large number of studies on surface water quality. Although road surfaces generally comprise only 30% of the DCIA of an urban catchment they represent a major source of suspended solid loads (Ball, 2002). This stems from the view that a large portion of stormwater pollutants are generated through vehicular motion and other activities associated with the use of roads. In addition, small rainfall events generate sufficient depth of flow to mobilise particles on roads that are efficiently conveyed into the drainage system.

Several studies have attempted to develop indicators to describe and predict the relationship between vehicular use and runoff quality. Borroum et al. (2003) concluded that there is a link between annual average daily traffic and highway runoff constituents. However, it was noted that the influences of accumulation and removal as well as catchment characteristics outweighed any potential direct correlation between increases in traffic volumes and resultant increases in TSS concentration. These findings were mirrored by Tomlinson et al (1999) who could not find any direct relationship between TSS concentration and factors such as traffic volume, despite large difference in median concentrations (60 to 1925 mg/L). This variability is complicated by the transport of particles, with over 95% of the sediment on any given highway originating from sources other than the vehicles themselves (Shaheen, 1975).

Parking lots and driveways are also a surface frequented by vehicles, however measured TSS concentrations tend to be lower than that of highways and urban streets. In areas of heavy commercial traffic such as service stations, suspended solid loads can be high. Rabanal and Gizzard (2000) monitored runoff from several commercial sites and discovered that while loads were variable, the highest were encountered at service stations when compared to restaurants and office parking lots. Results from Neary et al (2002) also proved that loads were extremely variable with smaller catchments providing the most irregularity.

Roofs comprise a significant portion of the impervious area of urban catchments however sediment concentrations are generally lower than roads due to differing processes of accumulation and removal. The majority of particles in roof runoff are fallout from atmospheric build-up and as a result the ambient concentration of atmospheric particles has a major influence, as does the roof surface. Brodie (2006) measured event mean concentrations of TSS at approximately 15 times smaller than road runoff. In a review of worldwide literature Duncan (1995) found TSS concentrations in urban areas approximately 10 times smaller for roofs than road runoff respectively.

Despite the large number of studies focussing on road runoff, pervious surfaces can contribute large volumes of sediment and are generally regarded as the largest source of sediment in waterways. This is highly dependant on vegetative cover and is largely due to localised soil erosion (Ball, 2002). Brodie (2006) discovered that for areas of bare soil, TSS concentrations were similar to that of road surfaces however runoff was less due to the pervious nature of the surface. This is due to the fact that bare soil detaches easily from a surface when subjected to rainfall, a characteristic that has been confirmed by numerous studies (Kinnel, 1997). Other studies have found a closer correlation between soil erosion and runoff compared to soil erosion and rainfall (Linhong, 2007). Grassed areas typically have the lowest sediment load due to the ability of the surface to trap particles and the higher energy required to detach particles. In fact, grassed surfaces in the form of swales are commonly used as a stormwater treatment system to reduce sediment concentration to background levels.

3.5 Urban Stormwater Drainage Models

A variety of models exist for the prediction of the stormwater runoff from both a quality and quantity perspective. This review has been restricted to models that are used in the analysis of urban drainage systems and in particular the DRAINS modelling software that will be used in this project.

A variety of urban drainage computer models are used for the design and investigation of drainage systems both in Australia and internationally. A review undertaken by Dayaratne (2000) determined that the most popular computer models used for drainage design include:

- ILSAX / DRAINS (Watercom, 2000),
- RAFTS (WP Software, 1991),
- RAT-HGL (WP Software, 1992),
- CIVILCAD (Surveying and Engineering Software, 1997),
- RORB (Laurenson and Mein, 1990),
- SWMM (U.S. EPA, 1992),
- WBNM (Boyd et al., 2000),
- HEC-RAS (Hydraulic Engineering Centre, 2000),

Many of these computer models use hydrologic and hydraulic calculations involving loss modelling, and interchangeable pipe and overland flow routing. These models differ in their time structure and can be described as either event-based or continuous. Continuous models calculate losses through continual soil moisture and evaporation computations on a daily basis. Event-based models are required to be constructed for a specific event, and generally do not take into account the effects of evaporation. Soil moisture accounting in event-based models is also limited, with inputs usually requiring some degree of user subjectiveness.

In addition to computer models, a procedure known as the statistical rational method (SRM) has widespread usage for the determination of peak discharge in simple situations. The SRM is known to incorrectly determine discharge in catchments where different land uses, irregular shaped catchments and inconsistent topography complicate calculations. This method also relies on a number of major assumptions that can limit its application.

DRAINS is a rainfall-runoff simulation program with uses in designing and analysing urban drainage systems. DRAINS combines hydrological and hydraulic calculations including routing in an event-based format. DRAINS can utilise either a modified version of the SRM that incorporates continuing soil losses during rainfall events or the ILSAX hydrologic model for calculation of discharge. In the ILSAX model a catchment is divided into a number of sub-catchments which are further subdivided into three sub-areas (Figure 3.2); a paved area directly connected to the drainage system (DCIA), pervious area, and a supplementary impervious area not directly connected to the drainage system (ICIA). This approach allows separate hydrological parameters to be applied to each surface with the resultant hydrograph from each sub-catchment a sum of the hydrograph in each sub-area (O'Loughlin and Stack, 2008).

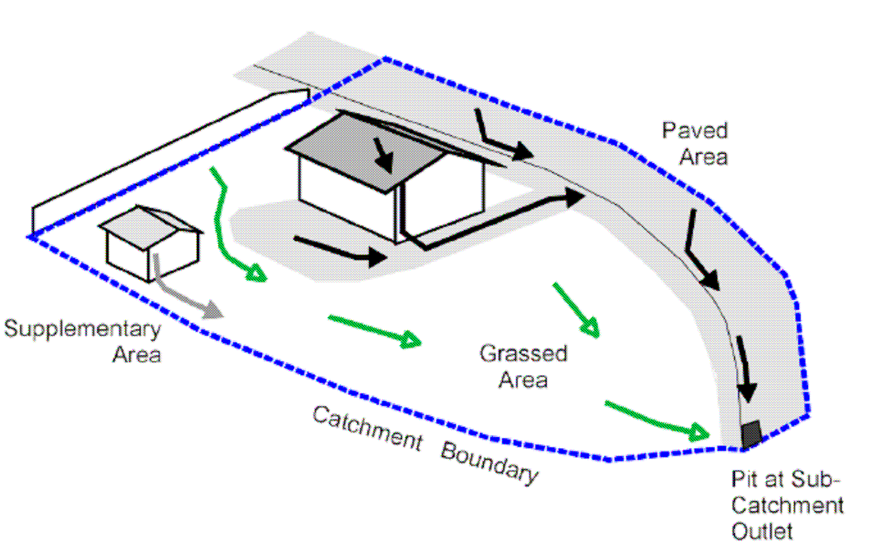

Figure 3.2 ILSAX catchment model land-use types (O'Loughlin and Stack, 2008)

To apply infiltration losses, the ILSAX model utilises an initial and continuing loss approach using Horton infiltration curves. The initial losses are specified by the modeller for each sub-area while the continuing losses for pervious area are calculated from the infiltration curves. These curves are based on a starting antecedent moisture condition (AMC) that is determined from the amount of rainfall in the past five days. The infiltration capacity is then a function of the time after the start of the rainfall event (Figure 3.3). The Horton curves have been developed by the U.S. Department of Agriculture and tested widely in North America. The determination of soil type is the subjective choice of the modeller and it has been suggested that the use of U.S. soil classifications to characterise Australian catchments is somewhat untested (Dayaratne, 2000).

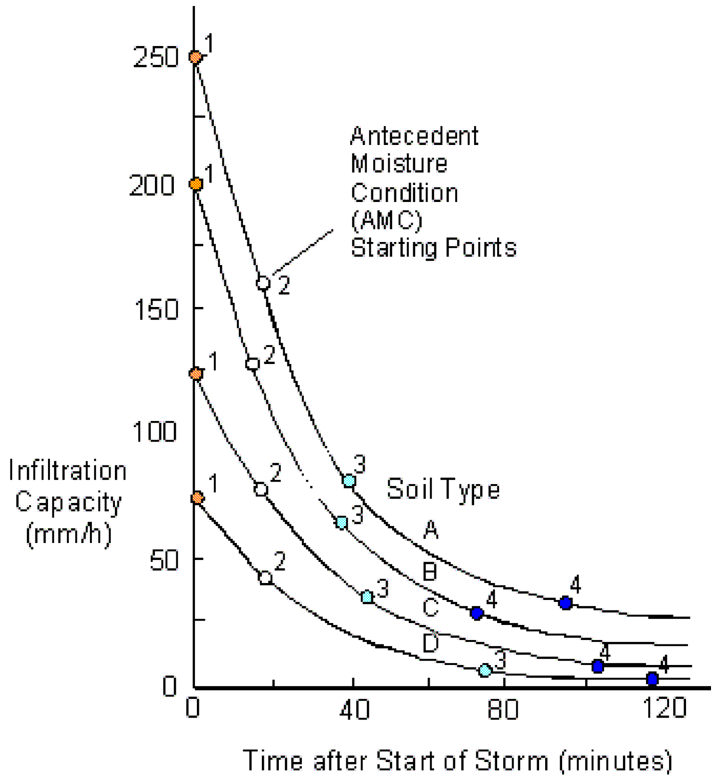

Figure 3.3 Horton Infiltration Curves (O'Loughlin and Stack, 2008)

The summing and routing of individual sub-areas is then combined with hydraulic computations from which lag times are determined and the discharge at individual nodes calculated (Figure 3.4). The routing through pit and pipe systems occurs in conjunction with surface overflows and additional input from adjacent sub-areas. These complex interactions can result in very different results when comparing storms with different durations and rainfall intensities. DRAINS also incorporates a link with HEC-RAS software to model flow relationships through open channel systems before discharging into the receiving environment. (O'Loughlin and Stack, 2008).

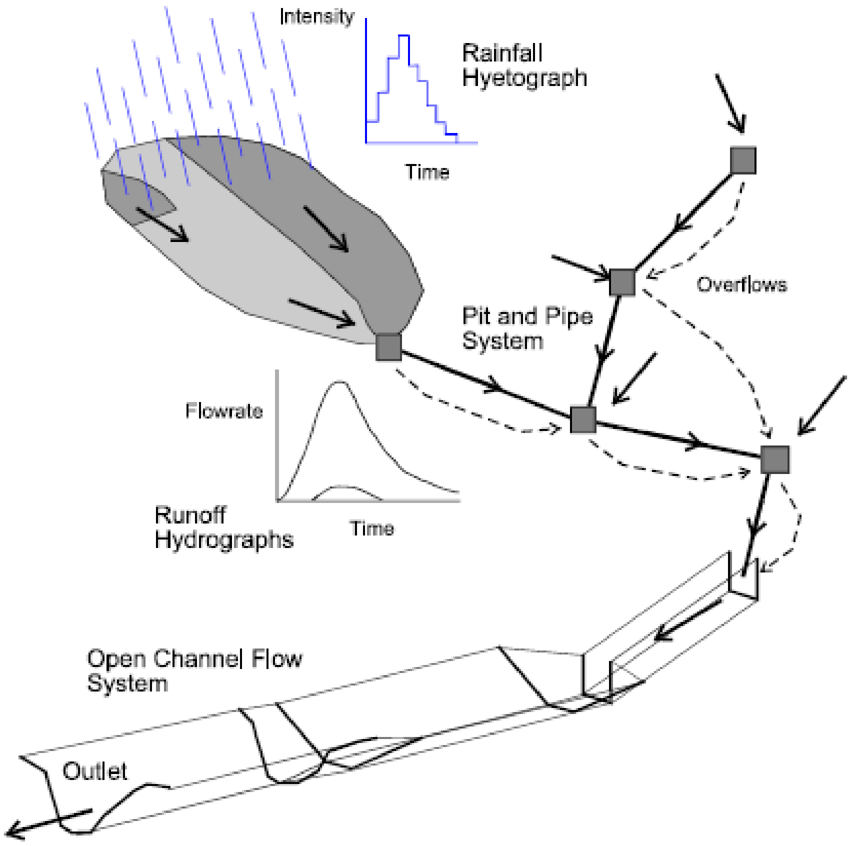

Figure 3.4 Representation of complete DRAINS modelling process (O'Loughlin and Stack, 2008)

CHAPTER 4

DATA COLLECTION AND ANALYSIS

4.0 DATA COLLECTION AND ANALYSIS

4.1 Drainage System

Data available to describe the drainage system has been collected from BCC spatial information software known as iBimap, ‘as constructed’ plans as well as on-site site visits. Information was obtained from iBimap and compared with available plans before a number of site visits were conducted to confirm the accuracy of this data. Council iBimap records along with plans were found to be in error and measurements were taken to correct the information.

Given the size of the Hoyland Street catchment, the drainage is not overly complex and typical of a pit and pipe drainage system. On-grade and sag inlets capture runoff which is conveyed in pipes through a series of pits that subsequently discharge into the bioretention system. Overland flow paths from each catchment area do not discharge into the bioretention system when pit capacities are reached. The entire drainage system has been constructed in 2002 as part of the aforementioned Hoyland Street connection linking Gympie Road and Bracken Ridge Road.

The iBimap software displays stormwater infrastructure visually and has the option of linking to background metadata where a variety of detailed information is available available. This process involved in entering stormwater infrastructure into the iBimap system creates inconsistencies in how gully pits are linked to the trunk drainage system. The result of this is that for gully pits are shown as linked directly to the closest adjacent stormwater pipe. In addition, no metadata is available for gully pit connections such as size of pipe of invert levels. Despite this shortcoming, metadata includes a variety of information, however data pertaining directly to drainage system analysis includes:

- Eastings and Northings of pits and chambers,
- Surface levels and invert levels of pits and chambers,
- Chamber and pit sizes and types,
- Pipe lengths,
- Downstream and upstream pipe invert levels,
- Pipe sizes and types, and
- Number of pipe barrels

As constructed plans of the Hoyland Street connection include detailed drainage construction plans that have been amended following construction. Surface and piped drainage plans as well as catchment plans are available in Appendix C. A review of these plans identified the discrepancy between the orientation of gully pits and connecting pipes with iBimap. This was evident in the upper portion of HSA catchment where two on-grade inlets at the corner of Coriander and Kluver Street were displayed as being directed in opposing directions. A number of pipe and pit invert levels as shown in iBimap were inconsistent with the detailed plans.

Site visits conducted in May and June 2007 concluded that both sources of information were incorrect and that the two gullies drained into a 375 mm diameter reinforced concrete pipe (RCP) toward the North, external to the Hoyland Street catchment. Discrepancies between pit and pip levels were also checked which confirmed the accuracy of the drainage plans. A number of discrepancies in the surface drainage regime as indicated on the plans were also noted including road crossfall and locations of road crowns. These were noted and new measurements taken using a digital level.

Figure 4.1 below, indicates the location of all amended stormwater infrastructure within and external to the Hoyland Street catchment (Appendix D). Manholes are represented by circles, gully pits are represented by squares and the extent of the catchment area is represented by the blue line. It can be seen that the majority of the catchment runoff is captured by gully pits on and adjacent to Hoyland Street and conveyed into a branched trunk drainage system before discharging into the bioretention system through HSA. HSB collects a small portion of the road runoff downstream of the HSA network while HSC collects a large portion of the road runoff south of the bioretention system through a single gully pit.

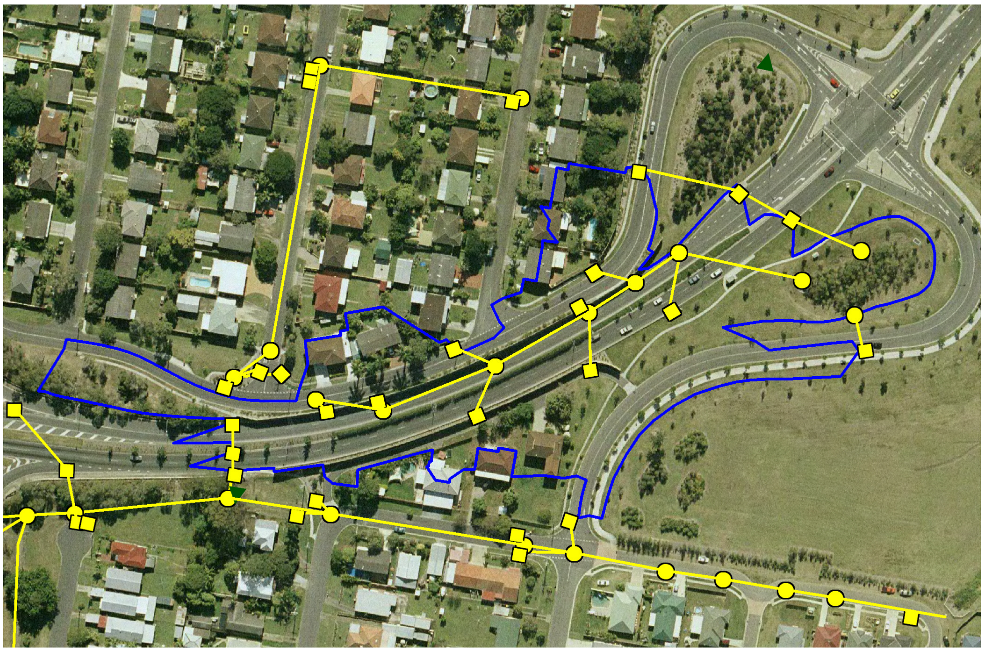

Figure 4.1 Location of Stormwater Infrastructure within the Hoyland Street catchment

4.2 Catchment Characteristics

The vast majority of the Hoyland Street catchment is comprised of road runoff which discharges through piped drainage directly into the Hoyland Street system. A portion of rainfall also enters the bioretention system directly as well as sheet flow runoff from the grassed area surrounding the bioretention system. Figure 4.2 depicts the HSA, HSB and HSC catchments discharging into the Hoyland Street bioretention system (reproduced in Appendix E).

Figure 4.2 Catchments discharging into the Hoyland Street bioretention system

Catchment areas have been delineated using MapInfo version 8.0 GIS software using a combination of aerial photography, contours, detail plans and airborne laser survey (ALS) data. Site visits also proved beneficial to determine the extent of directly connected roof area, supplementary area as well as other lot based connections. Initial rough catchments were defined using high-resolution 2005 aerial photography and 0.5 m contours. These catchments were subsequently refined to determine hydrological characteristics for DRAINS and surface characteristics for the mass balance model. This was achieved with the use of detail plans as well as ALS data. ALS data has been obtained from scanning conducted from 15 to 20 June 2002 and surface levels to a 1 mm resolution (±200 mm) are directly available at 1 m intervals. The use of this data proved necessary in the delineation of the boundary between catchments on very flat ground adjacent to the bioretention system and to the south of the catchment. The detailed 'as constructed' plans provided valuable information on the road grading and location of crowns. The 2002 and 2005 data sets have been assumed as applicable to the catchment conditions over the entire monitoring period.

The HSA catchment at 1.034 ha is the largest catchment discharging into the bioretention system. DCIA, pervious and supplementary areas comprise approximately 54%, 43% and 3% respectively. While not the largest percentage, this represents the greatest area of pervious and supplementary area in all catchments. The effect of this pervious and supplementary area is the delay of the runoff contribution from these areas. In many rainfall events it has been discovered that this results in a second peak, where the DCIA produces an initial runoff response that is followed by the other contributions well after the peak. The large elongated catchment shape also tended to result in an extended falling limb of measured hydrographs.

Table 4.1 Hoyland Street catchment hydrological characteristics

Catchment	DCIA	Pervious	Supplementary	TOTAL
	Area	Area	Area	Total Area
	ha	ha	ha	ha
HSA	0.564 54.56 %	0.440 42.55 %	0.030 2.89 %	1.034
HSB	0.147 64.60 %	0.074 32.64 %	0.006 2.76 %	0.228
HSC	0.102 34.35 %	0.150 50.41 %	0.045 15.24 %	0.297
HSO	0.000 0.00 %	0.249 96.39 %	0.009 3.61 %	0.258
TOTAL	0.813 44.76 %	0.912 50.24 %	0.091 5.00 %	1.816

HSB catchment represents the smallest catchment at 0.228 ha with the largest portion of impervious area. DCIA, pervious and supplementary areas comprise approximately 64%, 33% and 3% respectively. The high imperviousness of the catchment and proximity to the bioretention basin results in a fast runoff response. In the majority of consistent runoff events, HSB recorded the earliest response time and time to peak runoff. The relatively uniform, rectangular catchment shape as well as the high imperviousness also tended to result in a faster, almost linear falling limb of the hydrograph.

HSC catchment is slightly larger than HSB at 0.297 ha with the majority of the catchment as pervious area. DCIA, pervious and supplementary areas comprise approximately 34%, 51% and 15% respectively. As a result HSC has the largest proportion of pervious and supplementary area of all catchments, due to its proximity to adjacent parkland and bikeways. Recorded hydrographs tend to exhibit a more traditional ‘bell curve’ shape when compared to HSA and HSB. This may be due to the crescent shape and flat grade of the catchment providing additional lag time. The flat grade may also be the contributing factor behind the comparatively slow response times evident in measured hydrographs despite the proximity of the catchment to the bioretention system and the very short length of connecting pipe.

4.3 Rainfall Data

Hyetographs for rainfall events within the BCC local government area are available for locations citywide due to an extensive network of pluviometers combined with a real-time data management system. As previously explained, rainfall data is available from 6 pluviometers that are within 7 km of the Hoyland Street bioretention system (Table 4.2). Unfortunately data is not available for the entire monitoring period at all pluviometer locations.

All pluviometers are of a tipping bucket design with a 1 mm resolution allowing small rainfall events to be recorded. The closest rainfall gauge (BDR712) has not collected data for the entire monitoring period. Subsequent investigations indicated that the data obtained from this gauge was questionable and was taken offline in 2003 due to error with the gauge itself. Plots of the remaining rainfall gauges when compared to three samples of runoff indicated that pluviometer BDT839 and MBR752 provided the best correlation with runoff response. Pluviometer BDR839 located at the Bracken Ridge reservoir, 1.7 km from the catchment was subsequently chosen due to its closer proximity to the catchment. A total of 16 storms were available that produced catchment runoff.

Table 4.2 Pluviometers within 7km of the Bioretention System (Brisbane City Council)

Location	Pluviometer	Distance to Site (km)	Collection Period	
			From	To
Bald Hills Ck at Bracken Ridge Rd, Bracken Ridge	BDR712	1152	7/06/1994	21/11/2003
Bracken Ridge Reservoir, Jude St Bracken Ridge	BDR839	1772	21/02/2005	Present
Moreton Bay at Brighton Bowls Club	MBR752	4761	1/12/1999	Present
Albany Ck at Pinnaroo Cemetery,	A_R842	4102	22/03/2005	Present
Cabbage Tree Ck at Braun St, Deagon	C _R560	4642	11/06/1994	Present
Little Cabbage Tree Ck at Aspley Reservoir, Aspley	LCR566	6264	22/06/1994	Present

Given the size of the catchment and the distance of rainfall gauges from the centroid of the catchment, difficulties arise in the applicability of the measured rainfall data to the modelling of runoff. Ideally a pluviometer should be located as close as possible to the centroid of a catchment to enable meaningful correlation with the timing and volume of runoff. This is largely due to the spatial variation in rainfall events and the relatively small size of the catchment.

Due to the questionable nature of the applicability of the rainfall data to the Hoyland Street catchment, other techniques have been employed to 'weed out' inconsistent data and only use event with an acceptable correlation with rainfall. As a first pass, the rainfall contour maps previously mentioned were used where available to determine any noticeable discrepancies in the spatial variation of rainfall in proximity to the gauges and catchment. This resulted in a total of five events being removed due to obvious variability in the rainfall patterns. While this test proved inherently subjective, a method was required to quickly eliminate inconsistent data. Subsequent plots comparing two of these storms to measured runoff confirmed that the volume and timing of these events did not correlate at all to runoff.

Events suitable for the modelling and calibration of the DRAINS model should exhibit a high degree of correlation with the timing and intensity of rainfall. In order to maintain data integrity and it was necessary to analyse the rainfall patterns and available runoff hydrographs for each specific event. This process involved the graphical representation of discharge (L/min) and rainfall (mm) for storms and individual burst events. Hydrographs for HAS, HSB and HSC inlet pipes as well as HSOa and HSOb outlet pipes were plotted from the start of the rainfall to the final recession of the longest recorded hydrograph. This intensive screening process provided the ability to select events that indicated a direct and quantifiable correlation with measured runoff. Additional data collected to improve event selection and subsequent DRAINS analysis included the:

- Time period,
- Total precipitation,
- Precipitation in past five days,
- Precipitation in past twelve hours, and
- AMC condition.

Figure 4.3 displays the output of this process for Storm 6, burst event 4. The complete rainfall-runoff analysis graphs for individual events are available in Appendix B. It was discovered that only two events were suitable for calibration with the DRAINS due to the large data inconsistencies previously described; storm 2 (event 2) and storm 3 (event 1). The vast majority of the events exhibited runoff hydrographs that did not correlate at all to rainfall, indicating that rainfall was not occurring in the catchment at the same time as gauge BDR839. HSC was found to be the outlet with minimal error due to negative flowrates and in some situation HSB also provided acceptable hydrograph responses. The exercise did provide insight into each typical catchment response with HSA providing a dual peak hydrograph for most events indicating a definite lag between the pervious and impervious area contribution times.

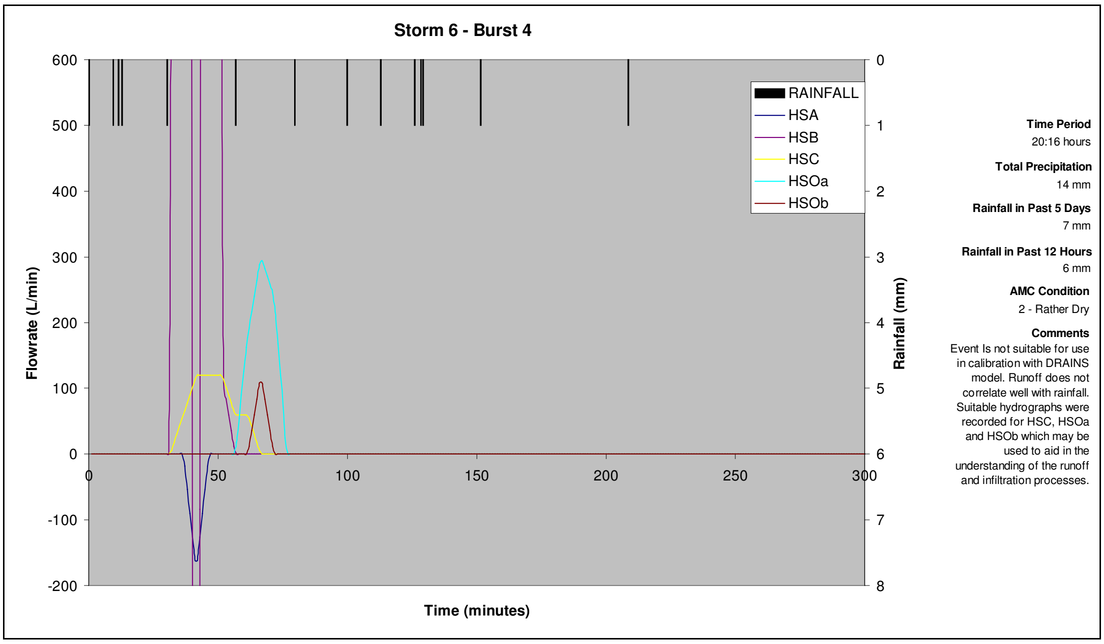

Figure 4.3 Measured rainfall-runoff screening graph for Storm 6, Event 4.

For application of the mass balance model a larger number of events proved acceptable, since event averages are required as opposed to whole of event relationships. A good correlation between measured rainfall volume and runoff volume should be evident for the specific storm event. Since the specific hydrograph response is not as important a total of 11 events (Appendix B) were suitable for application to the mass balance model.

4.3.1 Storm 1

Storm 2 occurred from 12:31am to 6:40am on 12/03/2006 to 6:40pm and consisted of a single burst event. This event is not suitable for use in calibration with DRAINS model. A correlation with the rainfall is evident however the timing indicates gauge and monitoring data inconsistencies. Hydrograph shapes are consistent with an expected response however the relative magnitude of each response is inconsistent with catchment characteristics. The measured runoff shows a response in HSC catchment in excess of the contribution in HSA and HSB, which is unlikely to be correct.

4.3.2 Storm 2

Storm 2 occurred from 1:44am 23/03/2006 to 10:21pm 24/03/2006 and consisted of a total of 4 events with a single suitable modelling event observed. Event 1 is not suitable for use in calibration of DRAINS model. This is due to the low runoff response that that would be expected from a dry catchment. The data also features negative flowrates for HSB and HSA. Event 2 is suitable for use in calibration with DRAINS model. A high correlation between rainfall and runoff is evident. Suitable hydrographs were recorded for HSC, HSOa and HSOb. The data also features negative flowrates for HSA and HSB. Event 3 is not suitable for use in calibration with DRAINS model. Correlation between rainfall and runoff is evident however not consistent. Event 4 is not suitable for use in calibration with DRAINS model. A high rainfall-runoff correlation is apparent, however wildly exaggerated hydrographs and negative flowrates are also features of this data.

4.3.3 Storm 3

Storm 3 occurred from 10:25am to 3:43pm on 31/03/2006 and consisted of a single burst event, which also provided a suitable modelling event. Event 1 is suitable for use in calibration of DRAINS model. There is a high correlation between rainfall and runoff. A suitable hydrograph was recorded for HSC however wildly exaggerated hydrographs and negative flowrates are also features of this data.

4.3.4 Storm 4

Storm 4 occurred from 6:00pm on 04/04/2006 to 4:18am on 06/04/2006 and consisted of 2 burst events, both of which were not suitable for calibration of the DRAINS model. Event 1 is not suitable for use in calibration with DRAINS model however can provide insight into the time of concentration for low flows. Although HSB is exaggerated, HSA appears relatively accurate and exhibits a high degree of correlation with the rainfall. Event 2 is not suitable for calibration. Flowrates are only available for HSA and are obviously inaccurate.

4.3.5 Storm 5

Storm 5 occurred from 5:02pm to 11:42pm on 30/04/2006 and consisted of 2 burst events, both of which were not suitable for calibration of the DRAINS model. Event 1 is not suitable for use in calibration with DRAINS model however can provide insight into the time of concentration for low flows. Although HSB is exaggerated, HSA appears relatively accurate and exhibits a high degree of correlation with the rainfall. Event 2 is not suitable for use in calibration with DRAINS model. While the runoff appears to correlate well to the first two events, a third rainfall event does not produce any runoff. The data may be used to aid in the understanding of the runoff response for catchment C and the initial response for catchment A.

4.3.6 Storm 6

Storm 6 occurred from 4:25pm on 09/06/2006 to 11:41pm 11/06/2006 and consisted of 4 burst events, none of which were not suitable for calibration of the DRAINS model. Events 1 and 2 are not suitable for use in calibration with DRAINS model. Runoff correlates very poorly with rainfall. Event 3 is not suitable for use in calibration with DRAINS model. Runoff appears to occur before the rainfall is registered suggesting a poor correlation. Hydrographs for HSC and HSOa appear to be consistent with an expected response. Event 4 is not suitable for use in calibration with DRAINS model. Runoff does not correlate well with rainfall. Suitable hydrographs were recorded for HSC, HSOa and HSOb, which may be used to aid in the understanding of the runoff and infiltration processes.

4.3.7 Storm 7

Storm 7 occurred from 1:13pm to 11:17 pm on 26/06/2006 and consisted of a single burst event. This event is not suitable for use in calibration with DRAINS model. A very poor correlation between rainfall and runoff is evident

4.3.8 Storm 8

Storm 8 occurred from 10:26pm on 29/06/2006 to 12:22am 30/06/2006 and consisted of a single burst event. This event is not suitable for use in calibration with DRAINS model. No runoff has been recorded despite rainfall occurring at the gauge. This was perhaps due to a dry catchment condition limiting runoff.

4.3.9 Storm 9

Storm 9 occurred from 1:50am to 6:42am on 4:25pm on 16/07/2006 and consisted of a single burst event. This event is not suitable for use in calibration with DRAINS model. Poor correlation with rainfall is evident and wildly varying negative and positive flowrates indicate instrument error.

4.3.10 Storm 10

Storm 10 occurred from 1:41am to 6:32am on 25/07/2006 and consisted of a single burst event. This event is not suitable for use in calibration with DRAINS model. Poor correlation with rainfall is evident. This is coupled with negative flowrates for both HSA and HSB. Instrument error has caused no suitable hydrograph to be recorded for HSC, HSOa and HSOb. The two distinct responses for HSA indicate separate pervious and impervious area responses and may provide information regarding the pervious area time of concentration for input into the DRAINS model.

4.3.11 Storm 11

Storm 11 occurred from 12:49am on 28/07/2006 to 12:01am on 29/07/2006 and consisted of 2 burst events, none of which were not suitable for calibration of the DRAINS model. Event 1 is not suitable for use in calibration with DRAINS model. Poor correlation with rainfall is evident. Runoff has only been measured at HSA, where negative flowrates are a feature. Event 2 Event is also not suitable for use in calibration with DRAINS model. Very poor correlation with the start of the rainfall event is evident. Runoff has only been measured at HSA, where the hydrograph shape is not indicative of a typical catchment response.

4.4 Monitored TSS Data

Suspended solid concentrations and loads for a large number of storm events between 2002 and 2006 are available for the bioretention system and have been testing using the TSS method. Monitoring ceased in 2006 due to the inconsistencies in flow measuring data previously discussed resulting in an inability to calculate loads. Data quality of TSS concentration samples however is expected to be good and will be used for the selected events.

Discrete flow-weighted water quality samples have been collected using 'Sigma 900 Max' automatic samplers. Samples were collected at each inlet pipe (HSA, HSB, and HSC) as well as one of the outlet pipes (HSO). This single monitoring of the two outlet pipes made the assumption that equal flows would occur in both pipes. The sampler is triggered by flows of $0.01m^3/s$ for the inlet pipes and $0.05m^3/s$ for the outlet pipe. Samples of 500mL were gathered for every consecutive $12.5m^3$ of runoff. As a result the sampling time and quantity varies with the inflow volume, and is unique for each storm event. Table 4.3 below displays the sampling configuration and characteristics for the bioretention system.

Table 4.3 Hoyland Street bioretention system sampling locations and characteristics

Site ID	Full Site Name and Sampler Location	Sampler Type	Trigger Volume (m^3/s)	Volume between Collections (m^3)
HSA	Western inlet pipe draining Catchment A	SIGMA 900MAX with integral flow meter	0.01	12.5
HSB	Northern inlet pipe draining Catchment B	SIGMA 900MAX with integral flow meter	0.01	12.5
HSC	Southern inlet pipe draining Catchment C	SIGMA 900MAX with integral flow meter	0.01	12.5
HSO	Outlet pipe	SIGMA 900MAX with integral flow meter	0.05	12.5
HSL	Level Sensor, adjacent to outlet pipe.	Greenspan PS310 level logger	N/A	N/A

Table 4.4 below indicated the average TSS concentrations from each catchment over the extent of the monitoring period. Table 4.5 indicates TSS event mean concentrations for available events. HSA exhibits the highest mean TSS concentration of 74.6 mg/L which is followed by HSC with 56 mg/L and HSB with 50 mg/L. This distribution of concentrations is consistent with the surface types in each catchment as well as the dominant activity of each surface.

Table 4.4 Hoyland Street TSS inflow concentration (average over monitoring period)

	Site	TSS mg/L
HSA	Mean	74.639
	Median	58.214
	C.V. (StdDev/Mean)	22.125
	Minimum	137.400
	Maximum	0.605
	10%ile	34.013
	90%ile	136.440
HSB	Mean	50.065
	Median	42.498
	C.V. (StdDev/Mean)	16.667
	Minimum	160.000
	Maximum	0.847
	10%ile	18.227
	90%ile	78.640
HSC	Mean	55.992
	Median	46.500
	C.V. (StdDev/Mean)	14.800
	Minimum	98.000
	Maximum	0.514
	10%ile	28.705
	90%ile	96.200

The significance of Hoyland Street as a regional link between Gympie Road and Bracken Ridge Road results in high traffic volumes. In addition to traffic volumes, the steep grade of Hoyland Street as traffic approaches the intersection is likely to result in increased brake dust and tire wear accumulation in HSA catchment. The location of a sound barrier on both sides of this narrow ramp is likely to limit the ability for wind to remove accumulated particles. Traffic also needs to slow and turn 90 degrees on Parer Street approaching Hoyland Street in catchment HSC. The relatively straight sections of road draining into HSB may slow or limit the extent of pollutant accumulation, despite this catchment having the largest percentage of impervious area. Given that HSA catchment is at a steep grade, this may also provide an additional removal mechanism for particles when comparing to the flat catchments of HSB and HSC. As a result the relative distribution of TSS concentration appears to be consistent with surface type as well as use.

Table 4.5 Monitored rainfall events and TSS event mean concentrations

	Inlet Pipe	TSS mg/L
8/12/06	HSA	69
	HSB	76
	HSC	60
4/01/06	HSA	190
	HSB	130
	HSC	220
12/02/06	HSA	170
	HSB	50
	HSC	180
17/02/06	HSA	69
	HSB	76
	HSC	60
2/03/06	HSA	100
	HSB	320
	HSC	140
5/03/06	HSA	31
	HSB	32
	HSC	15
23/03/06	HSA	190
	HSB	260
	HSC	170

CHAPTER 5

MODEL CALIBRATION AND APPLICATION

5.0 MODEL CALIBRATION AND APPLICATION

5.1 DRAINS MODEL

5.1.1 Model Structure

To set up the DRAINS model structure, catchment subdivision is necessary into the pervious, DCIA and ICIA sub-areas as previously explained. This catchment subdivision occurs at the catchment draining into each gully pit. A number of catchment, A through to N, were delineated and each sub-area plotted. These surfaces can be seen in Appendix I.

Flow paths as well as estimates for the DRAINS parameters then require input into the model. In addition, pipe and gully characteristics as well as rainfall characteristics and soil types as well as the AMC are required. The resultant characteristics output file is shown in Appendix G. The display of the set up DRAINS model structure following a model run is shown in Appendix H.

5.1.2 Sensitivity Analysis

A major limit of the DRAINS modelling software is that it does not have the ability to calibrate a modelled hydrograph based on measured data. The ability to calibrate the model to the measured data to obtain accurate event volumes is essential in determining the event pollutant loads. As such, a subjective trial and error approach was undertaken, where a number of variables were modified and the results recorded. As a result of this analysis the most sensitive variables for a number of criteria were obtained and were altered to provide a better fit of the model.

Due to the nature of trial and error calibration a comparison between the goodness of fit of measured and modelled hydrographs will invariably lead to the model having a tendency toward a particular hydrograph aspect. These can include peak discharge, hydrograph shape, hydrograph recession and runoff volume.

An additional degree of subjectiveness involves the limit of the sensitivity analysis. Since accurate measured hydrographs are only available for HSC (Deletic and Fletcher, 2006) and due to the limit of available events that correlate with rainfall the sensitivity analysis can only be applied to catchment HSC. As a result, the outcome of the analysis will require the selection of parameters not only for catchment HSC but also for catchment HSA and HSB. Consequently, this method assumes that the parameters that require calibration in HSC are also the parameters that require calibration in the other two catchments as well. While this approach is far from ideal, it is necessary due to the aforementioned inconsistencies in measured runoff data. This sensitivity analysis was applied to burst 2 of storm 2 as it proved the most ideal event for calibration due to a high correlation with rainfall and runoff.

Table 5.1 DRAINS parameters for catchment HSC

Catchment HSC				
Storm 2: Burst Event 2				
Total Area	ha	0.297		
		Paved	Supplementary	Grassed
Percentage of Area	%	34.35	15.24	50.41
Additional Time	min	**0**	**5**	**15**
Flow Path Length	m	150	2	29
Flow Path Slope	%	**1**	**1.7**	**1.7**
Flow Path Roughness		**0.015**	**0.015**	**0.13**
Area Depression Storage	mm	**1.5**	**1**	**3**
Lag Time	min	**10**	-	-

Pressure Loss Coefficient (Ku)	**4**

Soil Type	**4**
AMC	2
Storm	2
Burst	2
Intensity averaging	5 min

Table 5.1 above displays the parameters required by DRAINS to model the catchment. Parameters that can be modified and will be subjected to the sensitivity analysis are shown in bold red. The sensitivity analysis required successive runs of DRAINS and the resultant hydrograph output was recorded. A total of 73 runs were performed analysing 15 parameters with a minimum of five runs for each parameter to graphically represent trends. The sensitivity of each parameter to changes in peak runoff, total volume, time to peak, and correlation (R), which attempts to measure hydrograph shape, were recorded. A search and move approach was trailed for each initial adjustment to determine an appropriate direction of movement. Hydrograph aspects for each parameter were also graphed if they proved sensitive. A discussion on each parameter

below is supplemented with the summary results table and graphed relationships in Appendix J and Appendix K respectively.

Impervious Area Lag Time

Impervious area lag time showed a decreasing correlation and decreasing peak discharge with an associated increase in value. Time to peak also increased with additional lag time as would be expected. The parameter did not have any impact on runoff volumes. This indicates that any modification to the existing value of 0 is likely to result in a less accurate model. This would be expected as there are very few obstructions to flow in the kerb and channel in the catchment.

Impervious Area Flow Path Slope

The impervious area lag time exhibited a decreasing time to peak and an increase in peak discharge with an associated increase in value. This response is expected as an increase in the grade of an impervious area with minimal surface roughness will increase velocities. The parameter did not have any impact on runoff volumes.

Impervious Area Roughness

The impervious area roughness value which relates directly to the Manning's roughness value provided a decrease in peak discharge with an increase in value. Time to peak also increased which indicates that the modification to the roughness coefficient has the opposite response to the flow path slope previously discussed. The parameter had no impact on runoff volumes.

Impervious Area Depression Storage

This depression storage parameter displayed a rapid linear decrease in runoff volume as a result of increasing the size of the storage. This is typical of a model response whereby more runoff is being detained resulting in less reaching the catchment outlet. No change in peak runoff or time to peak was noticed however correlation remained almost unchanged indicating that the modification to this parameter does not appreciably change the hydrograph shape.

Supplementary Area Additional Time

Modification to the supplementary area additional time resulted in changes to all hydrograph features. An increase in this value decreased total runoff and peak discharge and increased time to peak. Despite this a slight increase in correlation was apparent for reasons unknown.

Supplementary Area Flow Path Slope and Roughness

Modifications to both these parameters did not appreciably change the hydrograph features. A very slight increase in time to peak was noticeable with a decrease in slope and an increase in roughness, similar to the impervious parameters.

Supplementary Area Depression Storage

This storage parameter, as expected, resulted in a decrease in total runoff volume with an increase in value. The modification to this parameter did not affect other hydrograph features and correlation remained almost unchanged.

Supplementary Area Lag Time

The lag time factor decreased peak runoff and increased time to peak when it was increased. As this variable, results in modifications to the time component only, no change was evident in total runoff volumes.

Grassed Area Additional Time

The grassed area additional time parameter proved highly sensitive to modification. An increase in time produced a large decrease in total runoff and peak discharge. This is undoubtedly due to increased contact time on the pervious surface resulting in an increase in infiltration.

Grassed Area Flow Path Slope and Roughness

The response of this variable was similar to the effect on impervious area however the magnitude was more pronounced. Total runoff as well as peak discharge was increased with a decrease in surface roughness or an increase in grade. Conversely, time to peak decreased with an increase in surface roughness and a decrease in grade. This may be due to the cumulative effect of overlapping hydrographs.

Grassed Area Depression Storage

Depression storage in pervious area proved highly sensitive, with a rapid linear increase in total runoff and peak discharge with a decrease in storage size. The depression storage factor had no appreciable impact on time to peak, and exhibited a mild increase in correlation with an increase in storage size.

Pit Loss Coefficient

As expected the pit loss coefficient had no impact on any hydrograph parameters. This is likely to be due to the fact that there is only one pit in the HSC catchment. The sensitivity of the model to a catchment such as HSA with over 15 pits may prove different.

Soil Type

Modifications to the soil type had negligible impact on the model for soil types 1 to 3. However the use of soil type 4 dramatically increased total runoff. As the soil type is already at 4 this may have no impact on the calibration process.

5.1.3 Calibration and Testing

The most important parameter to achieve is the mass balance of runoff volume. It would be ideal to also correlate time to peak, peak discharge and overall hydrograph shape however that is not the aim of this exercise as only total loads are required. The following parameters were found to affect the mass balance of flows in order of sensitivity:

1. Soil Type
2. Grassed Area Depression Storage
3. Grassed Area Additional Time
4. Grassed Area Flow Path Roughness
5. Paved Area Depression Storage
6. Grassed Area Flow Path Slope
7. Supplementary Area Additional Time
8. Supplementary Area Depression Storage

The model initially predicted a mass balance of $22.7m^3$ for Storm 2 Burst 2, while the measured hydrograph indicated a mass balance of $26m^3$. Thus any modification to the variables needs to result in an associated increase in the total runoff. While soil type was the most sensitive variable, any further change in the soil type would lead to a further decrease in total runoff (since the soil type is already at 4). A modification to the grassed area flow path roughness or slope will also result in a modification to the peak discharge as well as time to peak.

Since Grassed, paved and supplementary area depression storages has no appreciable impact on other features of the hydrograph, these variables will be modified to achieve mass balance of flows. New values include 2 mm, 0.5 mm and 0.5 mm respectively. In addition, the grassed area additional time ha been reduced from 15 minutes to 10 minutes. A re-run of the model following the modification of these parameters produced a total runoff volume of 24.7 m^3 suggesting an accuracy of 5%. Figure 5.2 displays the calibrated hydrograph for catchment HSC.

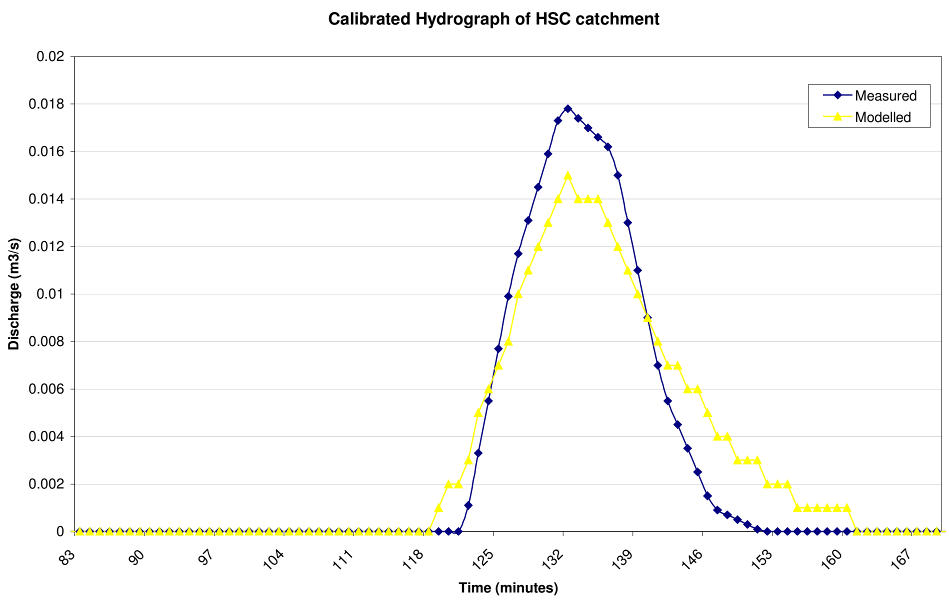

Figure 5.1 Measured and modelled hydrographs for HSC catchment following calibration

As a result of this process the HSA and HSB catchments were modified to match the new parameters accordingly with a few exceptions. The upper portion of catchment HSA in sub-catchment A has retained a grassed area additional time of 15 minutes due to the vegetated nature of the area. This differs markedly from the well-mown grassed area that was contributing to HSC. Grassed and supplementary area additional times have also retained high values where a prolonged flow path through backyards or across lawns indicates the necessity for a higher value. Unfortunately with now residential area contributing to HSC the effects of these parameters could not be tested.

5.1.4 Modelled Runoff and Pollutant Loads

In order to determine runoff volume the DRAINS model was run for the seven available monitored events described in the previous chapter with event specific rainfall. The discharges were collated and are presented below in Table 5.2.

Table 5.2 Measured TSS concentration combined with modelled runoff to calculate TSS load

	Inlet Pipe	TSS Concentration mg/L	Modelled Runoff m^3	TSS Load g
8/12/06	HSA	69	4.60	317.40
	HSB	76	1.30	98.80
	HSC	60	0.90	54.00
4/01/06	HSA	190	18.70	3553.00
	HSB	130	5.20	676.00
	HSC	220	3.60	792.00
12/02/06	HSA	170	22.30	3791.00
	HSB	50	6.10	305.00
	HSC	180	4.20	756.00
17/02/06	HSA	69	0.90	62.10
	HSB	76	0.20	15.20
	HSC	60	0.20	12.00
2/03/06	HSA	100	10.50	1050.00
	HSB	320	2.90	928.00
	HSC	140	2.00	280.00
5/03/06	HSA	31	7.10	220.10
	HSB	32	2.90	92.80
	HSC	15	2.00	30.00
23/03/06	HSA	190	14.30	2717.00
	HSB	260	2.70	702.00
	HSC	170	3.90	663.00

5.1 MASS BALANCE MODEL

5.2.1 Model Application

To apply Brodie's (2006) mass balance model it is necessary to determine the surface characteristics of the catchment and measured rainfall characteristics. As mentioned, the surface characteristics to be applied to the mass balance model differ to the application of the DRAINS model in that surface types are required as opposed to hydrological areas. As a result a different division of catchments and determination of surface types based on pollutant generation characteristics is required. Obviously road areas have been modelled as road surfaces and roof areas have been modelled as roof surfaces. However grassed areas as indicated by Brodie (2006) have been also assumed as any pervious surface in the catchment including gardens, backyards, trees and median strips. In addition driveways and footpaths have been modelled as carpark area. No bare soil was observed in aerial photography or during site visits and as such has not been included in the mass balance model. The proportion of each surface type in the major catchments is shown below in Table 5.3.

Table 5.3 Surface characteristics of the Hoyland Street catchment for input into the mass balance model.

Catchment	Road	Carpark	Roof	Grass	TOTAL
	Area	Area	Area	Area	Total Area
	ha	ha	ha	ha	ha
HSA	0.536 51.86 %	0.029 2.83 %	0.029 2.76 %	0.440 42.55 %	1.03
HSB	0.147 64.60 %	0.001 0.49 %	0.005 2.27 %	0.074 32.64 %	0.23
HSC	0.102 34.35 %	0.045 15.24 %	0.000 0.00 %	0.150 50.41 %	0.30
HSO	0.000 0.00 %	0.009 3.61 %	0.000 0.00 %	0.249 96.39 %	0.26
TOTAL	0.79 43.23 %	0.08 4.68 %	0.03 1.86 %	0.91 50.24 %	1.82

In addition to determining the catchment surface characteristics a number of other variables specific to each individual rainfall event are required. These rainfall parameters include:

- Total antecedent rainfall (mm);
- Antecedent rainfall period (hours);
- Storm duration (hours);
- Rainfall depth (mm);
- Mean intensity (mm/hour);
- Peak 6 minute intensity (mm/hour);
- Interburst period (hours);
- Square of the peak 6 minute intensity ($mm^2/hour^2$);
- Sum of the square of all 6 minute intensities ($mm^2/hour^2$);

A fundamental basis of the mass balance model is that the main drivers for particle washoff are rain power and transport of particles along the lateral drain. Transport along the lateral drain is assumed a function of the peak intensity while particle washoff is assumed a function of the sum of the square of all intensities and the rainfall depth. The rainfall depth is also used to calculate the discharge from each surface. The total and time between antecedent rainfall is used to calculate the dry weather accumulation of particles on each surface. Wet weather accumulation is calculated from the length of the interburst period (the period between peak intensities in an individual storm). A hyetograph of each rainfall event has been graphed in order to determine each of these variables. The hyetograph for storm of 05/03/2006 has been reproduced in Figure 5.2 below, while the hyetographs for all storms are available in Appendix L.

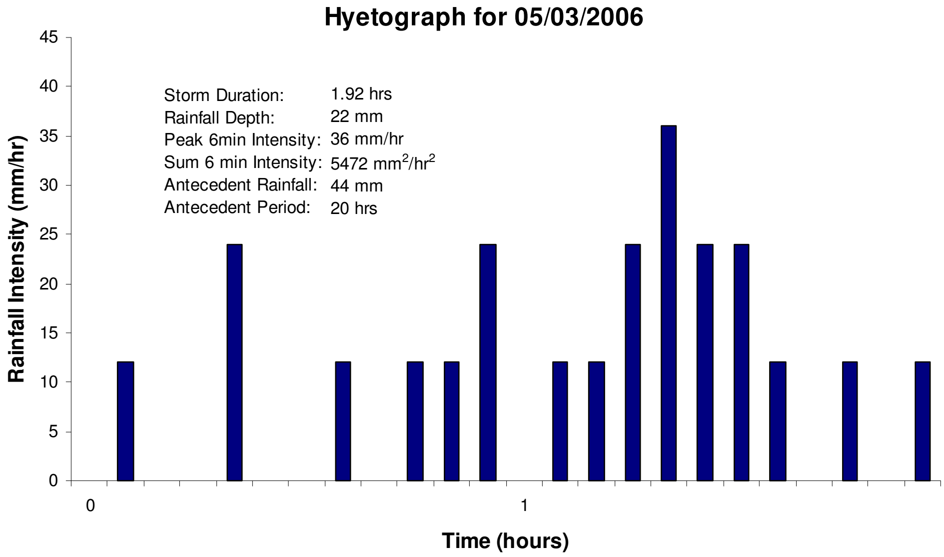

Figure 5.2 Hyetograph and mass balance model parameters for storm 05/03/2006

All accumulation, transport and washoff parameters that were calibrated by Brodie (2006) to Toowoomba conditions have been assumed as applicable to the Hoyland Street catchment. The simple linear approximation for grassed surfaces where the load is equal to 40 times the runoff depth has also been used. The use of these pre-calibrated parameters is expected to introduce inaccuracy into the EMC predictions of the mass balance model, however it is not the purpose of this dissertation to calibrate the mass balance model to the conditions of the Hoyland Street Catchment.

5.2.2 Modelled Event Mean Concentration and Runoff

Application of the mass balance model revealed that NCP EMCs as predicted by the mass balance model did not correlate well with the measured EMCs. The results also revealed that the surface discharge as predicted by the mass balance model did not correlate well with the subcatchment discharge produced by the calibrated DRAINS model. Mass balance model spreadsheets for catchments HSA, HSB and HSC are available in Appendix M.

Figure 5.3 below illustrates the poor correlation between modelled and predicted EMCs. All data points are spread horizontally or vertically from the ideal dotted 1:1 line. This indicates that the mass balance model may be systematically over and underestimating the NCP EMC. For event with a small TSS EMC a large NCP EMC is produced, and vice versa. It appears that either the mass balance model is not estimating the EMC, data collection for the EMC was inadequate, or there is some bias in the measured EMC.

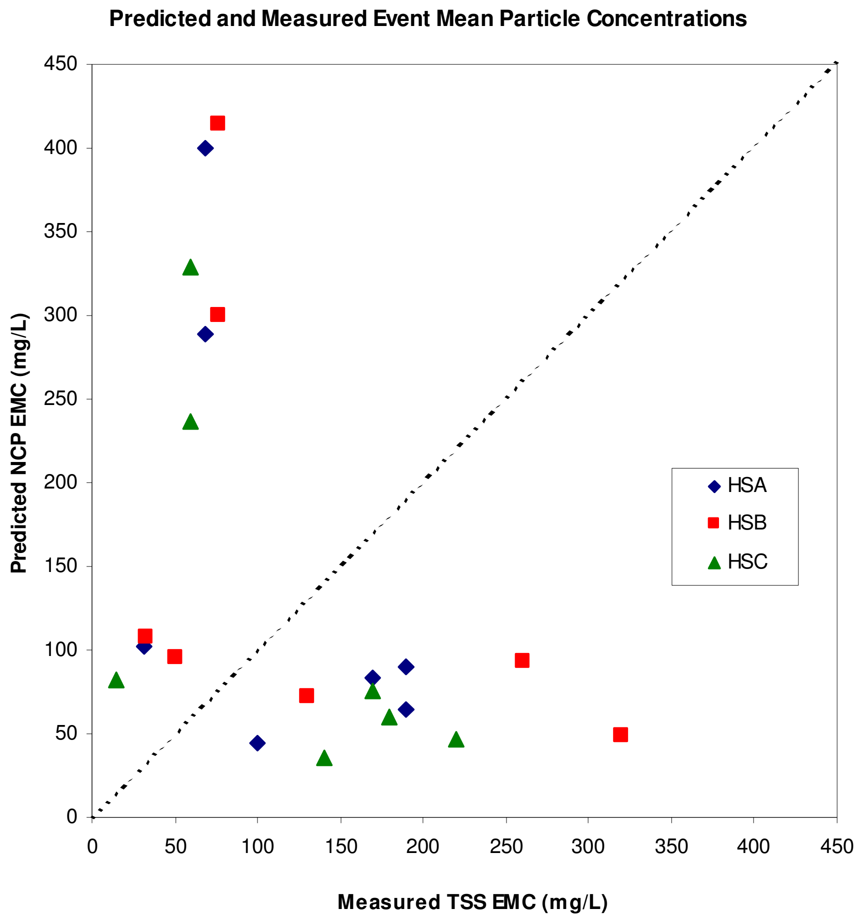

Figure 5.3 Event means for modelled NCP and measured TSS concentrations

In addition to the inaccurate prediction of particle concentrations, total event runoff volume was dramatically overestimated using the simple hydrologic calculations of the mass balance model. Figure 5.4 below illustrates this overestimation. This has resulted in a similar overestimation of event NCP load as can be seen in Figure 5.5. Given that the same rainfall data was used, the systematic overestimation of runoff when compared to the calibrated DRAINS model may represent an error in the assumptions underlying the mass balance hydrologic calculations or in the DRAINS modelling process.

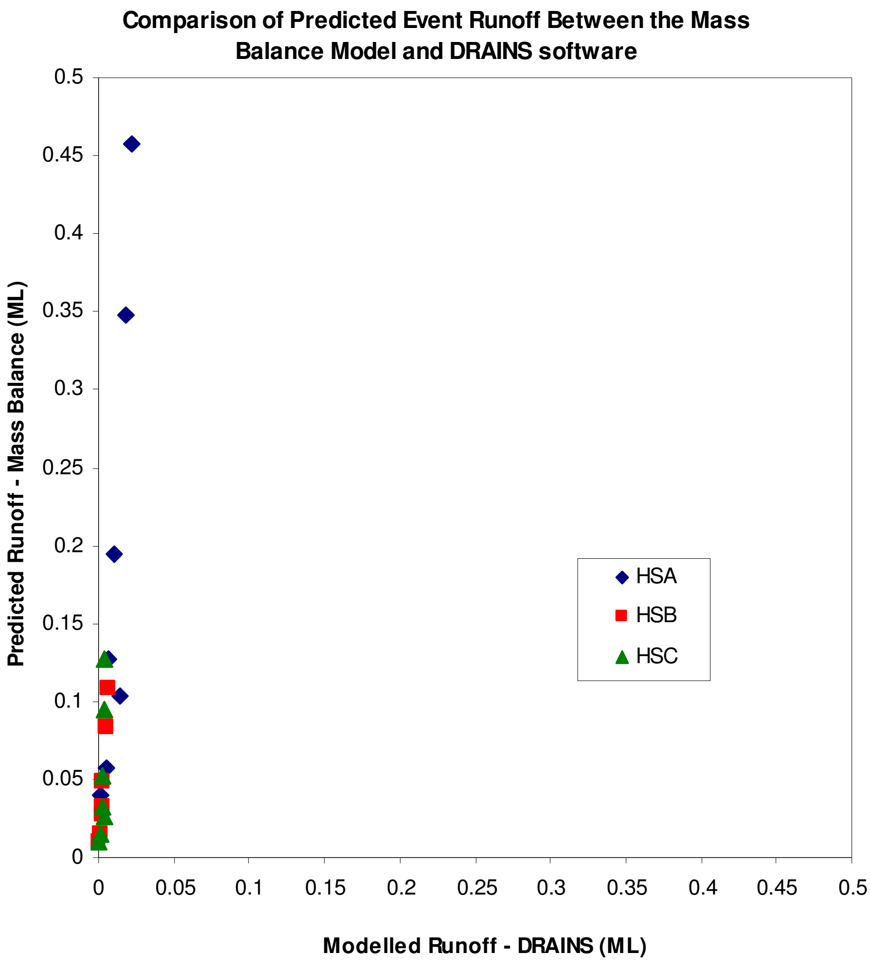

Figure 5.4 Event means for runoff volume produced by the mass balance model and the DRAINS software

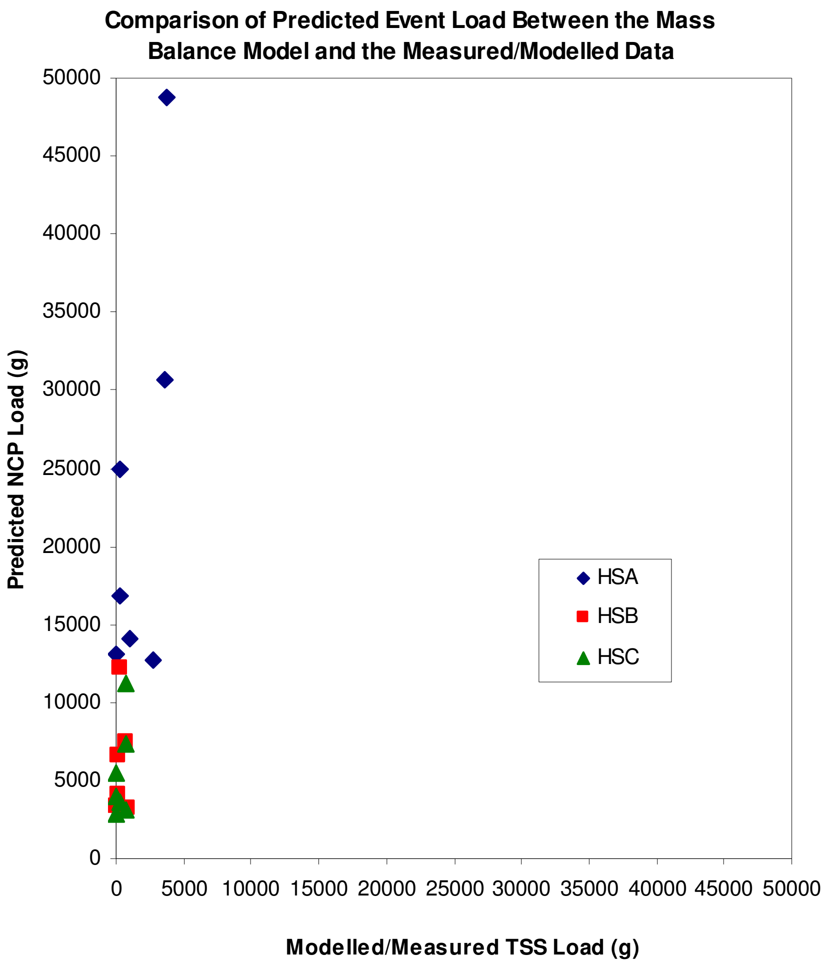

Figure 5.5 Event means for modelled NCP and measured/modelled TSS loads

5.2.3 Error Analysis

The mass balance model is calibrated using accumulation, transport and washoff parameters derived from experiments conducted by Brodie (2006) in Toowoomba. While it is not a part of this dissertation to calibrate the mass balance model, given the inherent data limitations and inaccuracies, some analysis of the sensitivity of these parameters is warranted. Figure 5.3 and 5.4 only provide a visual guide to the matching of modelled and measured data.

Calculated parameters from storm events also provide a source for error. The determination of the magnitude of this error may aid in understanding the source of error in the data. Given the fine scale determination of catchment surface characteristics and the likelihood of a direct linear correlation when modified, changes to surface areas were not included in the analysis.

The error analysis involved modification to the mass balance model parameters in order to determine the associated magnitude of error in predicted and measured EMCs. Each parameter was multiplied individually using a factor of 0.5 and 3 while other parameters were kept constant. Increasing and decreasing the size of the value aided in the determination of a direction of greatest sensitivity and whether the relationship was linear. As defined below, the two error statistics used are the cumulative EMC error (CEMCE) and the maximum EMC error (MEMCE).

$$CEMCE = \frac{\Sigma EMC_P - \Sigma EMC_M}{\Sigma EMC_M}$$

$$MEMCE = \text{Absolute Max } \frac{EMC_P - EMC_M}{EMC_M}$$

Where: EMC_P = Predicted event mean concentration

EMC_M = Measured event mean concentration

This error analysis was completed for each catchment and parameter individually. The detailed results from this analysis can be seen in Appendix N, however a summary is shown in Figure 5.6 below and indicates a large variation in the change in total error due to the application of the multiplication factors. Rainfall depth proved the most sensitive parameter and resulted in a median change in total error of 267% for cumulative error and 78% for maximum error. Maximum free particle load prior to the storm was the second most sensitive, with a median change in total error of 119% and 36% respectively. The highly sensitive nature of these parameters could account for some of the error present in the results. The parameters tested are listed below in order of the cumulative EMC error displayed (insensitive parameters excluded):

1. Rainfall Depth;
2. Maximum Free Particle Load Prior to Storm;
3. Particle Washoff Multiplier for Grassed Areas;
4. Maximum Detained Particle Load Prior to Storm;
5. Dry Weather Accumulation Rate of Detained Particles Before the Storm;
6. Antecedent Rainfall Period;

7. Interburst Period;
8. Wet Weather Accumulation Rate of Free Particles During the Storm;
9. Peak 6 min Intensity;
10. Sum of the Square of all 6 min Intensities;
11. Storm Duration;
12. Maximum Free Particle Load During Storm;
13. Dry Weather Loss Rate of Retained Particles in the Drain Before the Storm;

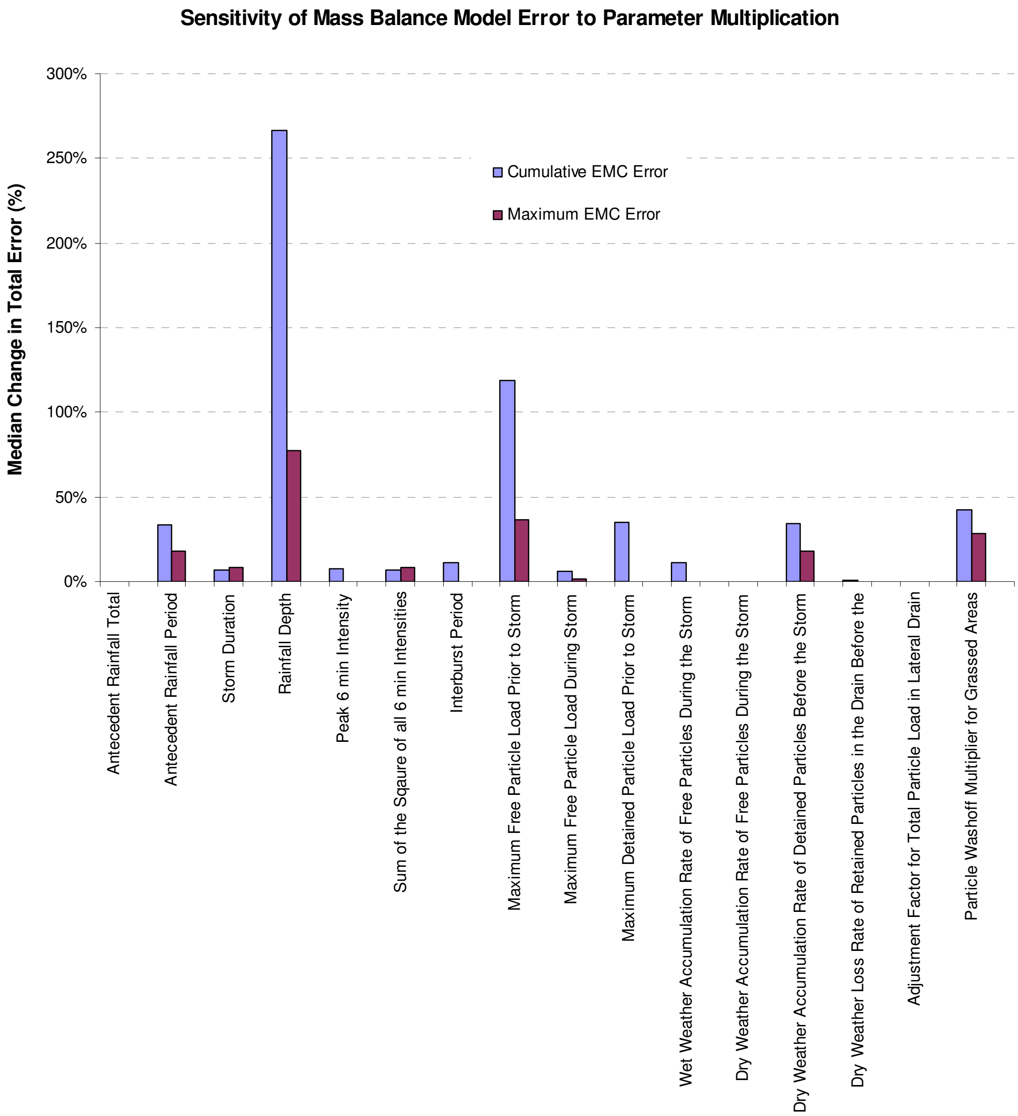

Figure 5.6 Results from error analysis of mass balance model

CHAPTER 6

DISCUSSION

6.0 DISCUSSION

6.1 DISCUSSION

Major sources of error in available data have resulted in a very poor prediction of event mean concentrations of non-coarse particles when compared to measured data. This, combined with a poor prediction of runoff has led to an inability to predict event loads of non-coarse particles. As a result an error analysis was undertaken which revealed that the major cause of the error might have been due to inaccurate rainfall depth and unavailable data for the maximum free particle load prior the storm event.

The difficulty in obtaining accurate and relevant rainfall data proved a time-intensive exercise that limited available events and may have introduced error into the models. The pluviometric gauge used to obtain rainfall data was located 1.7 km from the catchment itself. Given the small size of the catchment it was likely in many instances that runoff was not occurring in the catchment while rainfall was registering at the gauge. The distinct lack of rainfall events that correlated well with recorded runoff confirmed this assumption.

Measured event mean concentrations of suspended solids were determined using the TSS method, while the mass balance model predicted suspended solid concentrations in non-coarse particles using the SSC method. Literature suggests that the SSC method provides a more accurate measurement of suspended solid concentrations and the two can differ markedly in some instances. Initial error was anticipated as a result of the contrast between techniques, however the extent of the error will not be known.

The availability of measured runoff volumes also proved unreliable due to a poorly functioning monitoring system. This necessitated the need for rainfall runoff-modelling using DRAINS hydraulic and hydrologic software. Due the inconsistencies with the measured runoff hydrographs in HSA and HSB, catchment HSC was used to calibrate the DRAINS model. Due to poor correlation with rainfall only two events were available for calibration with the DRAINS model.

The use of the parameters calibrated from HSC during a single storm event may have also introduced significant error into the runoff volume calculations. HSC catchment differs markedly from other catchments in that the entire catchment drains to a single pit and into the bioretention system. HSC catchment also consists mostly of road surface of constant grade and no roof area. The pervious area in the catchment drains directly to the road with a small time of concentration. This is in contrast HSA and HSB, where there is a significant lag time between impervious and pervious area runoff to the point that two separate peaks are often evident.

Selection of surface types for input into the mass balance model may have also introduced error. As there are no surfaces in the mass balance model to describe footpaths or densely vegetated areas such as gardens and trees, carpark surfaces and grassed areas were selected. In the Hoyland Street catchment these surfaces are also indirectly connected to the drainage system flowing over grassed lawns or along property boundaries before discharging into the stormwater system. As a result the mass balance model is likely to have overestimated the pollutant generation from these surfaces. A number of ICIA surfaces represented as garden sheds and roofs draining into 'bubbler style' outlets onto grassed surfaces were represented as roofed area by the mass balance model. This may have also been a source or error in the runoff volume calculation as the mass balance model represents these surfaces as draining directly into the stormwater system.

6.2 FURTHER APPLICATION OF MASS BALANCE MODEL

As shown in Chapter 6, the most sensitive parameter to error in predicting the EMC from each catchment using the mass balance model proved to be the rainfall depth. In addition, the antecedent rainfall period proved somewhat sensitive with a mean cumulative error of 34% given a 50% movement in value. This highlights the need for an accurate rainfall data series when using the mass balance model to predict event mean concentration.

While Brodie (2006) confirmed the accuracy of the mass balance model in comparison to other new and well-established techniques, the practical limitations of data availability to limit model error may prevent more widespread use. While established networks of rainfall gauges are prevalent in many major cities, they are seldom within 2km of each other, generally due to the historical need for calibration of models in much larger catchments. The time-intensive screening process required to 'weed out' events that do not correlate with runoff may prove a barrier, given the widespread industry and local government acceptance of far more easily applied yet inaccurate models (eg. MUSIC). Many of these models have been calibrated and are recommended for larger catchments. As the mass balance model using surface specific parameters has the potential to provide ease of use and greater accuracy at the smaller scale, these barriers to use may be especially applicable.

The particle accumulation and washoff parameters my also represent an additional obstruction to widespread use due to the uncertainty in applying the parameters to different environmental conditions in different catchments. The error analysis confirmed that the maximum free particle load prior to the storm proved highly sensitive to error with a 50% increase in the variable producing a 117% increase in mean cumulative error. Other variables proved somewhat sensitive including the maximum detained particle load prior to the storm, the accumulation rate of detained particles prior to the storm, and the particle washoff multiplier for grassed areas. A mean cumulative error of 35%, 34% and 43% respectively was observed. Given the number of these variables and their sensitivity, calibration for potential users would prove difficult. In addition, no guidance is provided in the selection of these parameters. Testing of the mass balance model on additional catchments, and calibrating to determine appropriate values for parameters would prove wholly beneficial.

The accurate calculation of event mean and annual loads can prove an indispensable planning, design and maintenance tool. The runoff volume determination through hydrologic computations is limited to simple linear functions in the mass balance model. While this may be accurate for impervious surfaces, the relationship between rainfall and runoff in pervious surfaces is generally more complex. However, the application of the mass balance model to smaller mostly impervious catchments may invalidate this assumption. Integration with existing hydrologic software may provide ease of use and greater accuracy. The prevalence of already established hydraulic runoff routing models for urban stormwater planning in major cities may also provide runoff volumes. A number of design storms could be run through the hydraulic model to determine a curve of rainfall versus runoff volume, and provide a relationship directly based on rainfall. The hydrologic calculations performed by the model could be expanded to improve runoff volume prediction and as a result load prediction, however this could be balanced against the necessity to do so.

A wide range of surfaces types and configurations are present in urban and suburban areas, each with differing pollutant accumulation and washoff characteristics. The choice of surface type in the mass balance model is limited to five major surface types each of which is assumed to drain directly to the stormwater system. The reality of urban surfaces may include footpaths, brick and porous paving, vegetated surfaces and tiled roofs which may drain onto a combination of each other before reaching the stormwater system. Additional monitoring of different surface types and configurations could improve the accuracy and applicability of the mass balance model, however increasing complexity for limited increases in accuracy may invalidate the need.

The mass balance model has been proven to more accurately predict event mean concentrations and loads than a number of models available and in general use

(Brodie, 2006). The inability to correlate the measured and predicted NCP concentrations and loads is likely to be a result of inaccurate data and the unavailability of particle washoff and accumulation parameters specific to the Hoyland Street catchment. An error analysis undertaken confirms that these are the largest sources of cumulative and maximum error. However as a result of the application, insight has been gathered into the application of the mass balance model and potential areas for improvement.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

A major component of this dissertation was comparing the measured EMC with the predictions of the mass balance model to determine the efficacy of the model in calculating suspended solid concentrations and loads. This was achieved, however the result was a very poor correlation between data sets. This was primarily due to limitations with measured rainfall and runoff data. The use of particle accumulation and washoff parameters calibrated to Toowoomba may have also increased the error. As a result a major exercise of this dissertation was to:

- Limit already inherent error in the data by minimising any introduced error;
- Conduct an error analysis to determine likely causes of error;
- Provide feedback on the application and limitations of the mass balance model.

While the ability of the mass balance model to predict suspended solid concentrations and loads could not be fully tested, several limitations to the widespread use of the mass balance model were discussed. These limitations are focussed on the ease of application and calibration of the model. The major limitation to further use of the model to determine suspended solid EMCs involves the lack of available rainfall data that correlates well with runoff. Incorrect screening of rainfall events can introduce large cumulative errors into the model results.

6.2 RECOMMENDATIONS

Recommendations pertaining to the future monitoring of WSUD devices:

- Pluviometric gauges should be located within the catchment or as close as possible to the centroid of the catchment.
- Consideration should be given to the monitoring of WSUD devices in the design phase to limit the potential for inaccurate measurements.

Recommendations pertaining to the future use of the mass balance model:

- Surface types for input into the mass balance model should be selected carefully and take into account the nature of the surface type and its runoff configuration. Further monitoring of NCP EMCs on different surface types and configurations may be warranted.
- For the calculation of event specific loads and concentrations, rainfall gauges should be as close as possible to the centroid of the catchment to be modelled. If this is not possible a detailed analysis of the correlation between rainfall and runoff should be undertaken.
- Consideration should be given to the results of the error analysis, particularly the ability of inaccurate rainfall measurements to introduce error.
- The sensitive nature of the pollutant accumulation and washoff characteristics should be noted. Further monitoring may prove necessary to determine the variance of these parameters with different environmental conditions.
- Guidance should be provided on the selection of appropriate particle accumulation and washoff parameters for different urban surfaces.

- For complex catchments considerable pervious area, consideration should be given for the use of hydrologic/hydraulic software models for the determination of event runoff volume.

CHAPTER 8

BIBLIOGRAPHY

8.0 BIBLIOGRAPHY

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APPENDICES

Appendix A

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: KIEREN DAVIS

TOPIC: Application of an Urban Runoff Model using Surface Specific Parameters

SUPERVISOR: Ian Brodie

PROJECT AIM: Apply a mass balance urban runoff model to a specific catchment/s based on surface type and compare and evaluate its effectiveness in predicting the loads of suspended solids.

PROGRAMME: (**Issue B, 22 March 2007**)

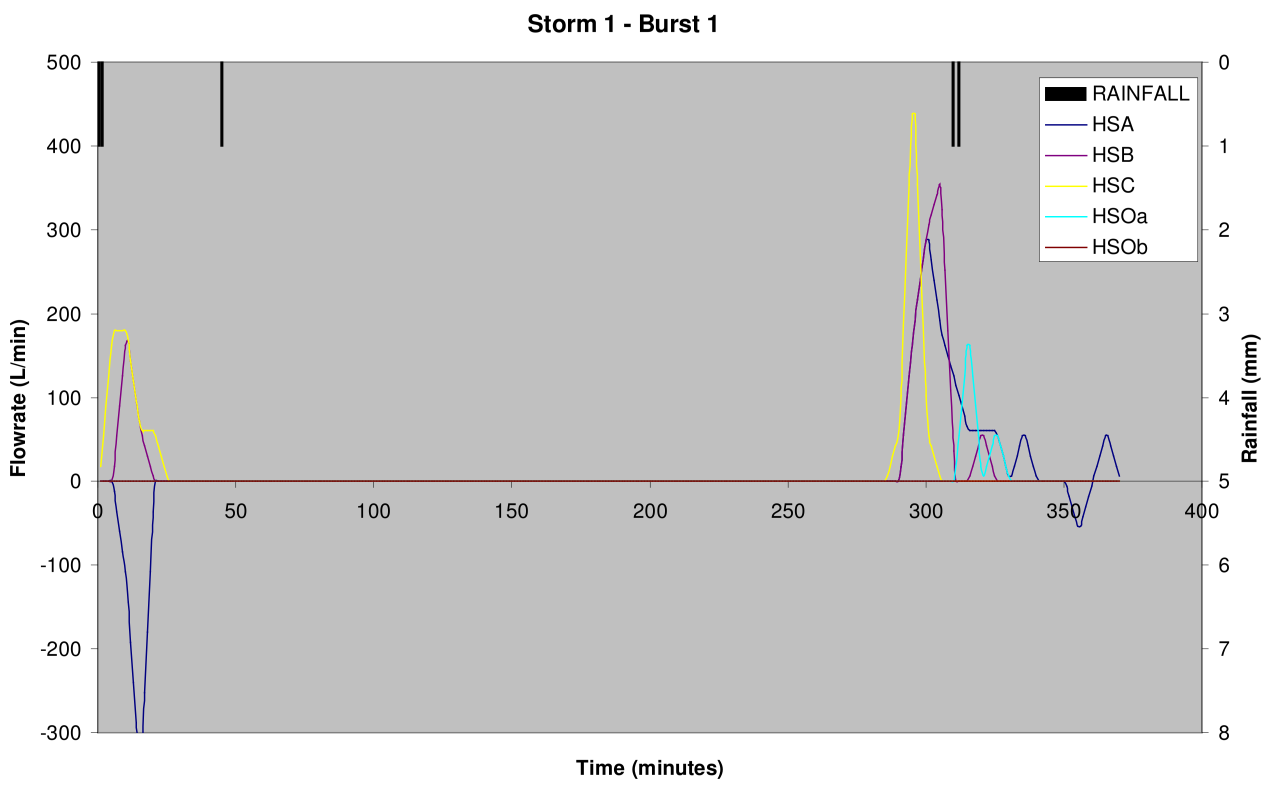
1. Conduct a literature review on the prediction of suspended solids in stormwater using urban surface data.
2. Gather rainfall and water quality data relating to a specific catchment/s.
3. Determine the surface characteristics of the catchment.
4. Customise and test the Mass Balance Model spreadsheet.
5. Calibrate the model for a number of design storms
6. Compare and verify the model results with the real-life specific catchment data.
7. Write and submit a dissertation on the application and effectiveness of the model in predicting the quality of urban stormwater runoff.

AGREED ______________________ (student) ______________________ (supervisor)

Date: / / 2007 Date: / / 2007

Co-examiner:______________________

APPENDIX B: Rainfall Runoff Analysis Graphs



Time Period
6:09 hours

Total Precipitation
4 mm

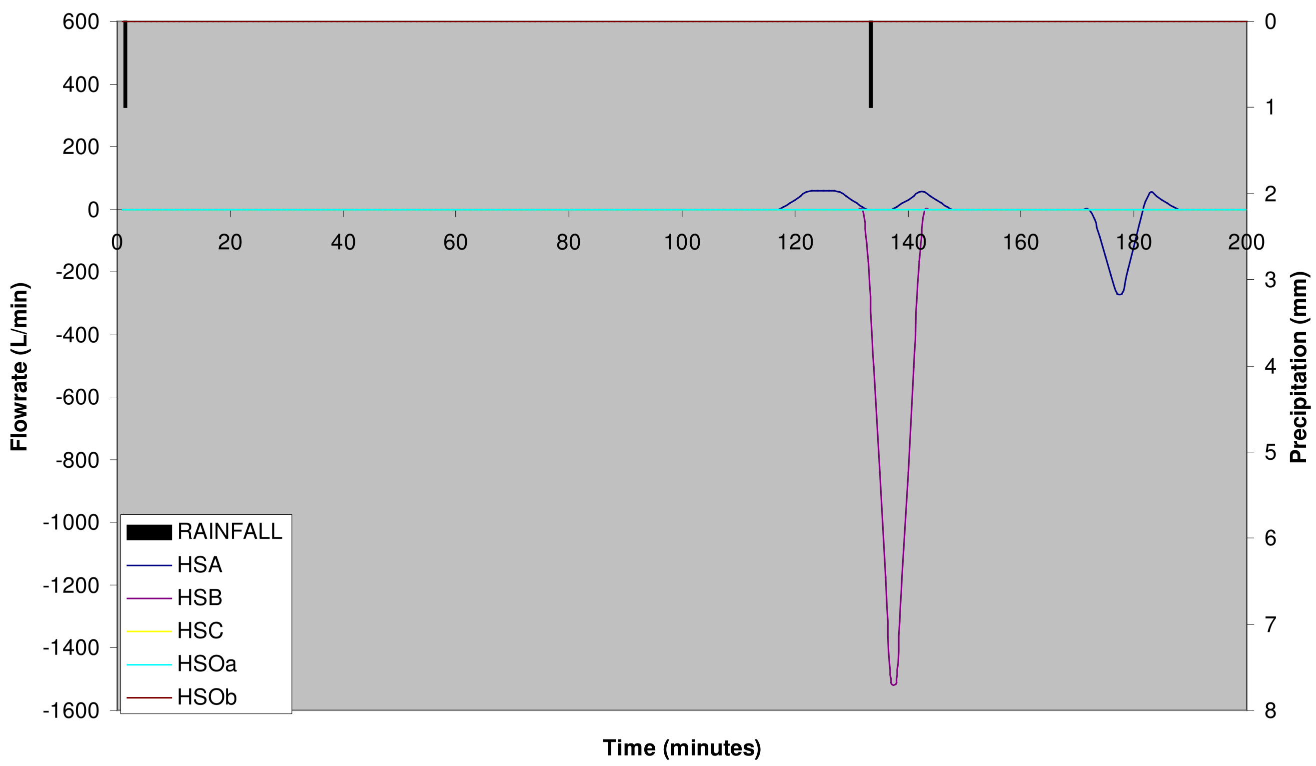
Rainfall in Past 5 Days
0 mm

Rainfall in Past 12 Hours
0 mm

AMC Condition
1 - Completely Dry

Comments
Event Is not suitable for use in calibration with DRAINS model. A correlation with the rainfall is evident howwever the timing indicates gauge and monitoring data inconsistencies. Hydrograph shapes are consistent with an expected respones however the reltive magnitude of each response is inconsistnt with catchment characteristics.

Storm 2 - Burst 1



Time Period
3:06 Hours

Total Precipitation
2 mm

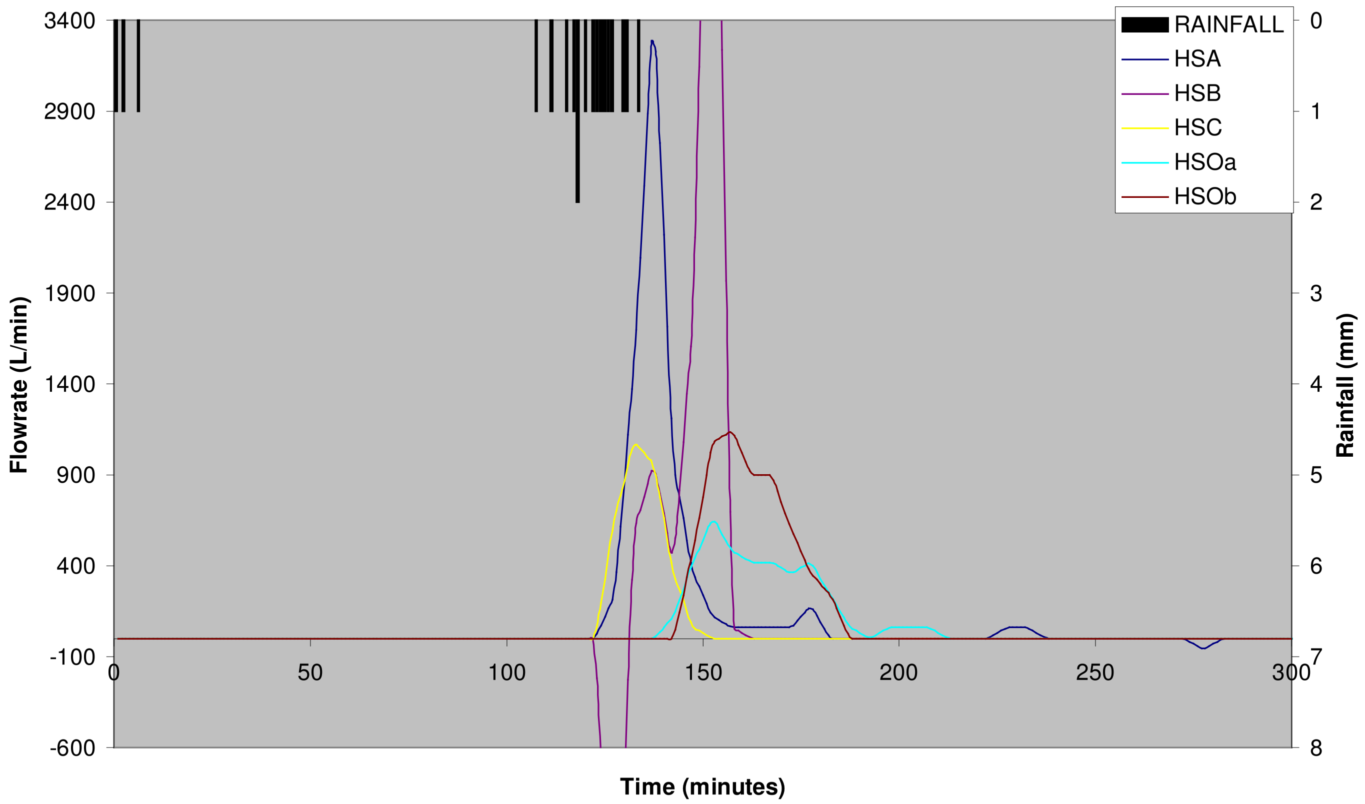
Rainfall in Past 5 Days
0 mm

Rainfall in Past 12 Hours
0 mm

AMC Condition
1 - Completely Dry

Comments
Event Is not suitable for use in calibration of DRAINS model. This is due to the low runoff response which that would be expected from a dry catchment. The data also features negative flowrates for HSB and HSA.

Storm 2 - Burst 2



Time Period
4:42 hours

Total Precipitation
19 mm

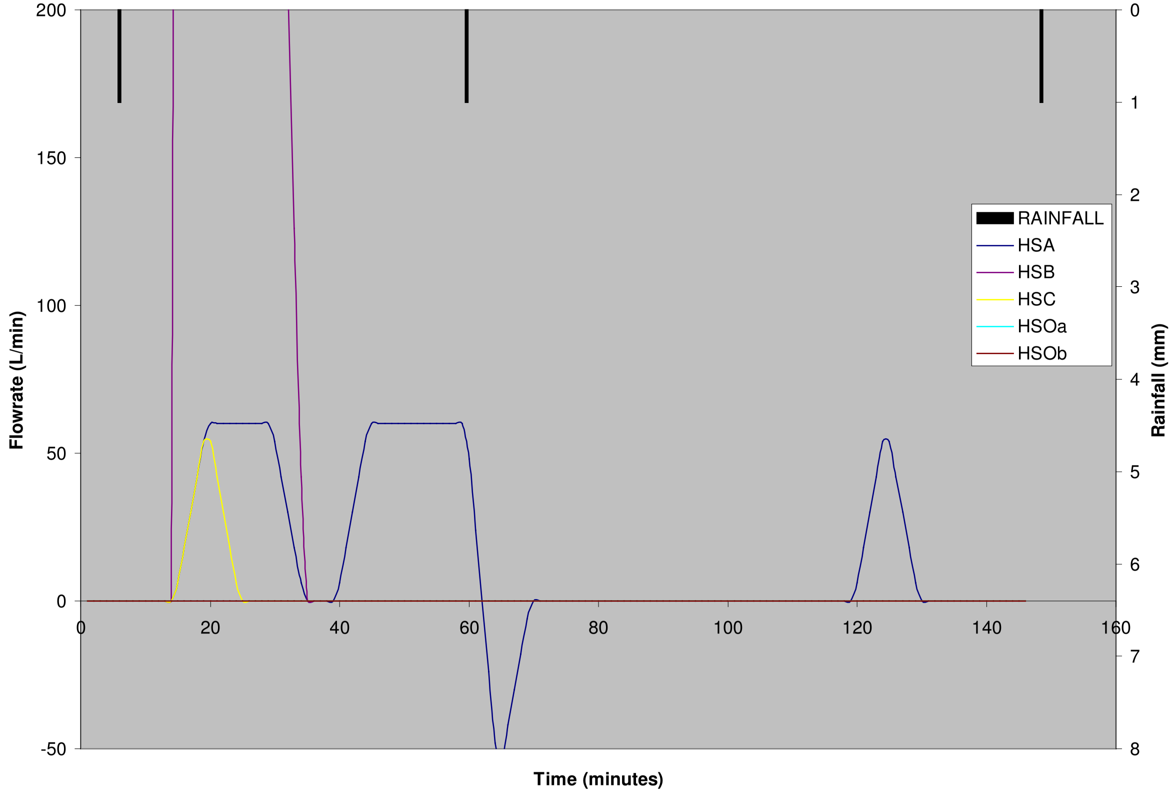
Rainfall in Past 5 Days
2 mm

Rainfall in Past 12 Hours
0 mm

AMC Condition
2 - Rather Dry

Comments
Event Is suitable for use in calibration with DRAINS model. A high correlation between rainfall and runoff is evident. Suitable hydrographs were recorded for HSC, HSOa and HSOb. The data also features negative flowrates for HSA and HSB.

Storm 2 - Burst 3



Time Period
2:03 hours

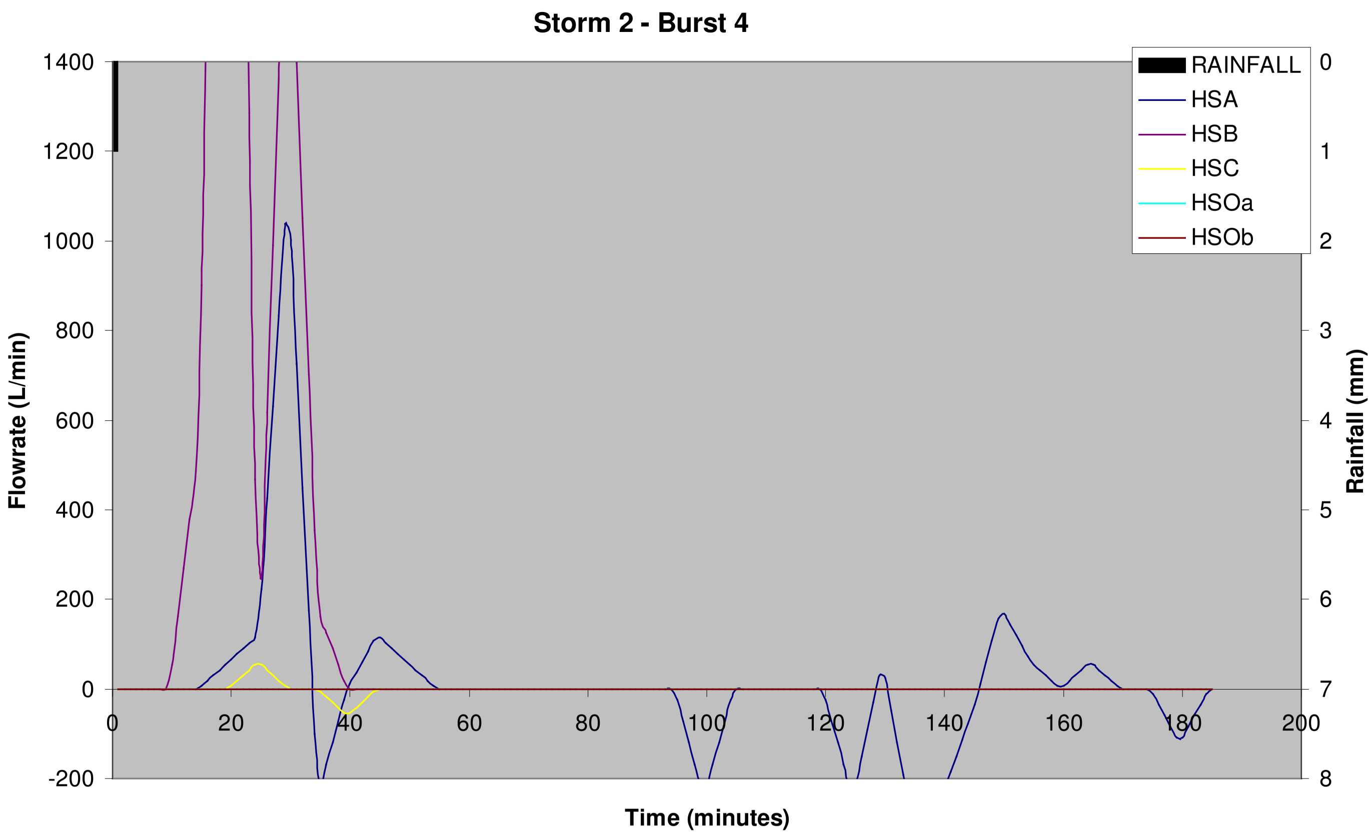
Total Precipitation
3 mm

Rainfall in Past 5
21 mm

Rainfall in Past 12
19 mm

AMC Condition
3 - Rather Wet

Comments
Event Is not suitable suitable for use in calibration with DRAINS model. Correlation between rainfall and runoff is evident however not consistent.



Time Period
3:04 hours

Total Precipitation
1 mm

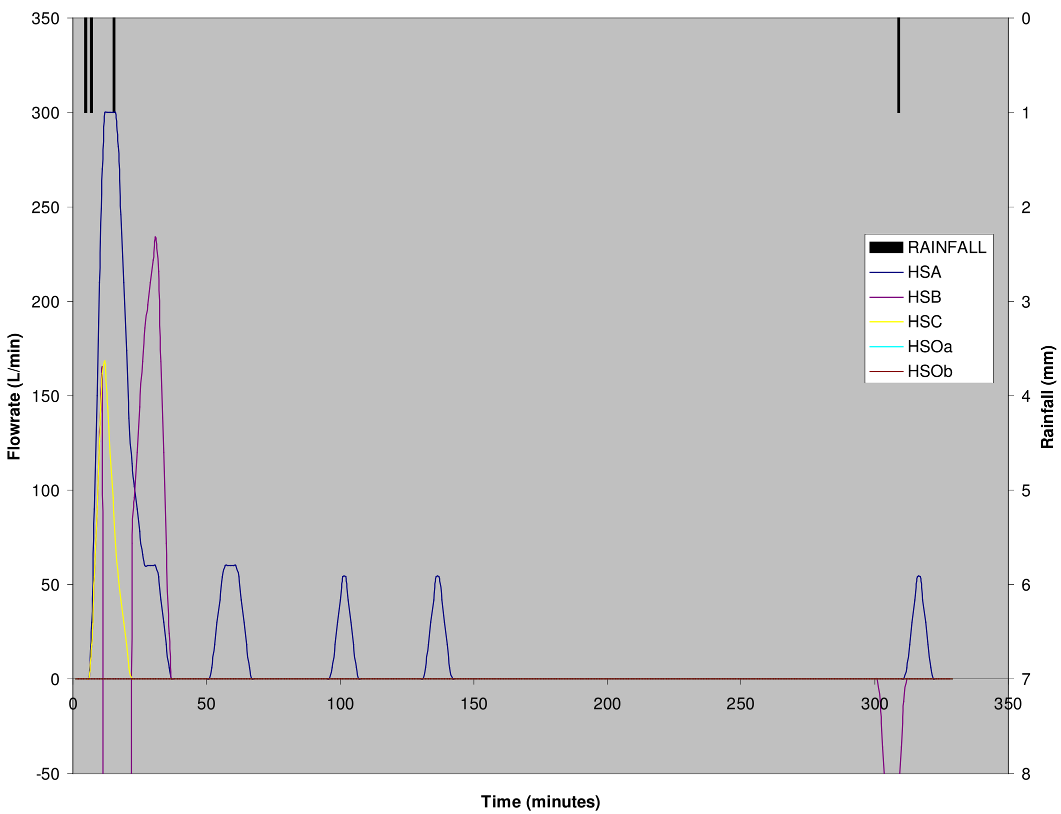
Rainfall in Past 5 Days
25 mm

Rainfall in Past 12 Hours
3 mm

AMC Condition
4 - Saturated

Comments
Event Is not suitable for use in calibration with DRAINS model. A high rainfall-runoff correlation is apparent, however wildly exaggerated hydrogrpahs and negative flowrates are also features of this data

Storm 3 - Burst 1



Time Period

5:17 Hours

Total Precipitation

4 mm

Rainfall in Past 5 Days

0 mm

Rainfall in Past 12 Hours

0 mm

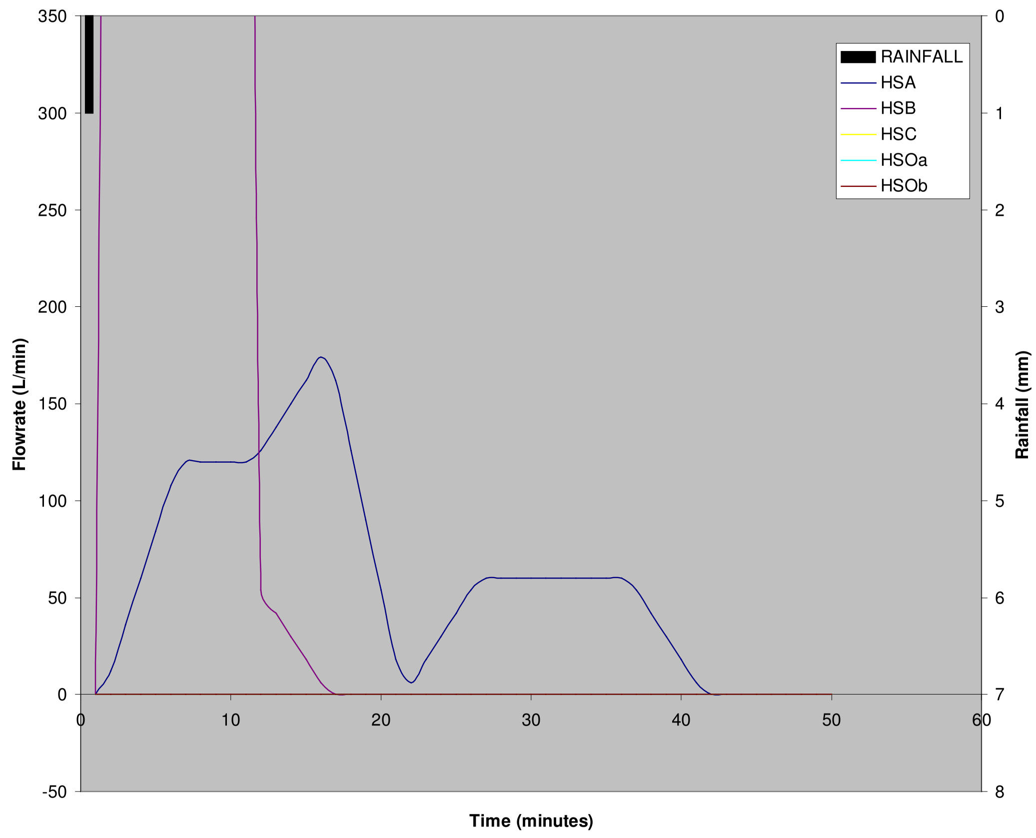
AMC Condition

1 - Completely Dry

Comments

Event Is suitable for use in calibration of DRAINS model. There is a high correlation between rainfall and runoff. A suitable hydrograph was recorded for HSC

Storm 4 - Burst 1



Time Period

0:40 hours

Total Precipitation

1 mm

Rainfall in Past 5

4 mm

Rainfall in Past 12

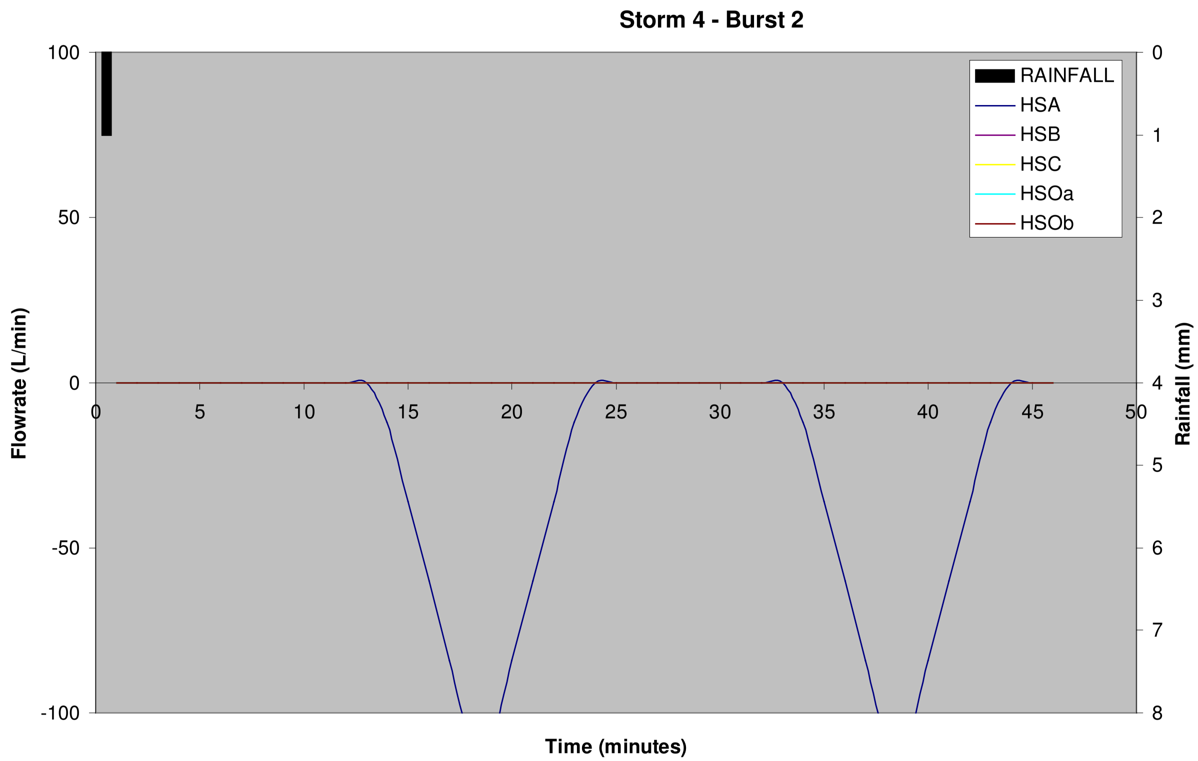
0 mm

AMC Condition

2 - Rather Dry

Comments

Event Is not suitable for use in calibration with DRAINS model however can provide insight into the time of concentration for low flows. Although HSB is exaggerated, HSA appears relatively accurate and exhibits a high degree of correlation with the rainfall.



Time Period
0:40 hours

Total Precipitation
1 mm

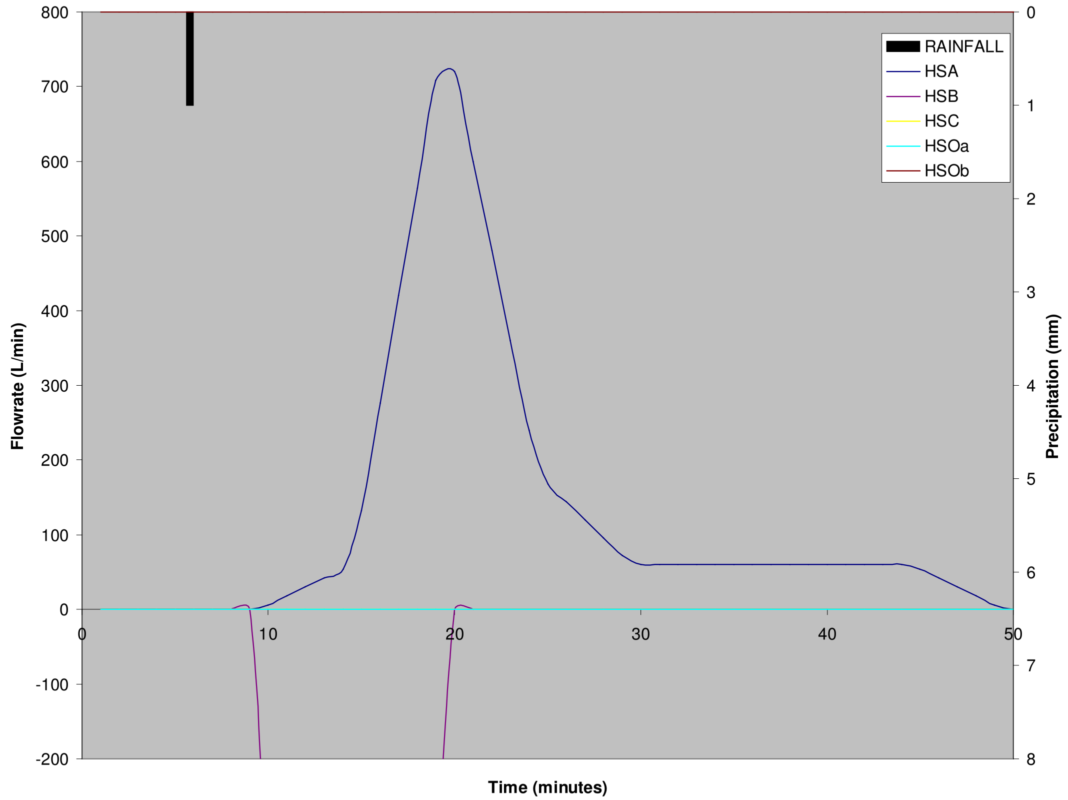
Rainfall in Past 5 Days
4 mm

Rainfall in Past 12 Hours
0 mm

AMC Condition
2 - Rather Dry

Comments
Event Is not suitable for calibration. Flowrates are only available for HSA and are obviously innacurate.

Storm 5 - Burst 1



Time Period
0:44 Hours

Total Precipitation
1 mm

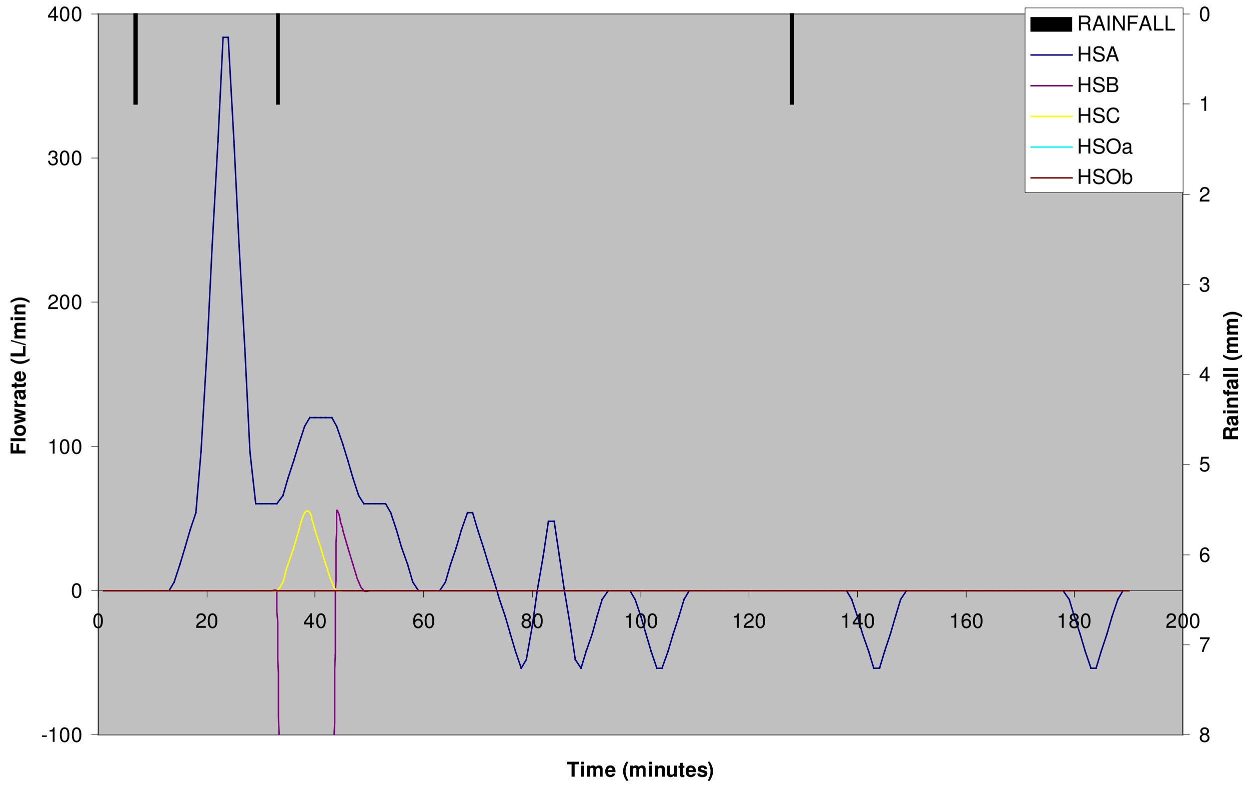
Rainfall in Past 5 Days
0 mm

Rainfall in Past 12 Hours
0 mm

AMC Condition
1 - Completely Dry

Comments
Event Is not suitable for use in calibration with DRAINS model however can provide insight into the time of concentration for low flows. Although HSB is exaggerated, HSA appears relatively accurate and exhibits a high degree of correlation with the rainfall.

Storm 5 - Burst 2



Time Period

3:02 Hours

Total Precipitation

3 mm

Rainfall in Past 5 Days

1 mm

Rainfall in Past 12 Hours

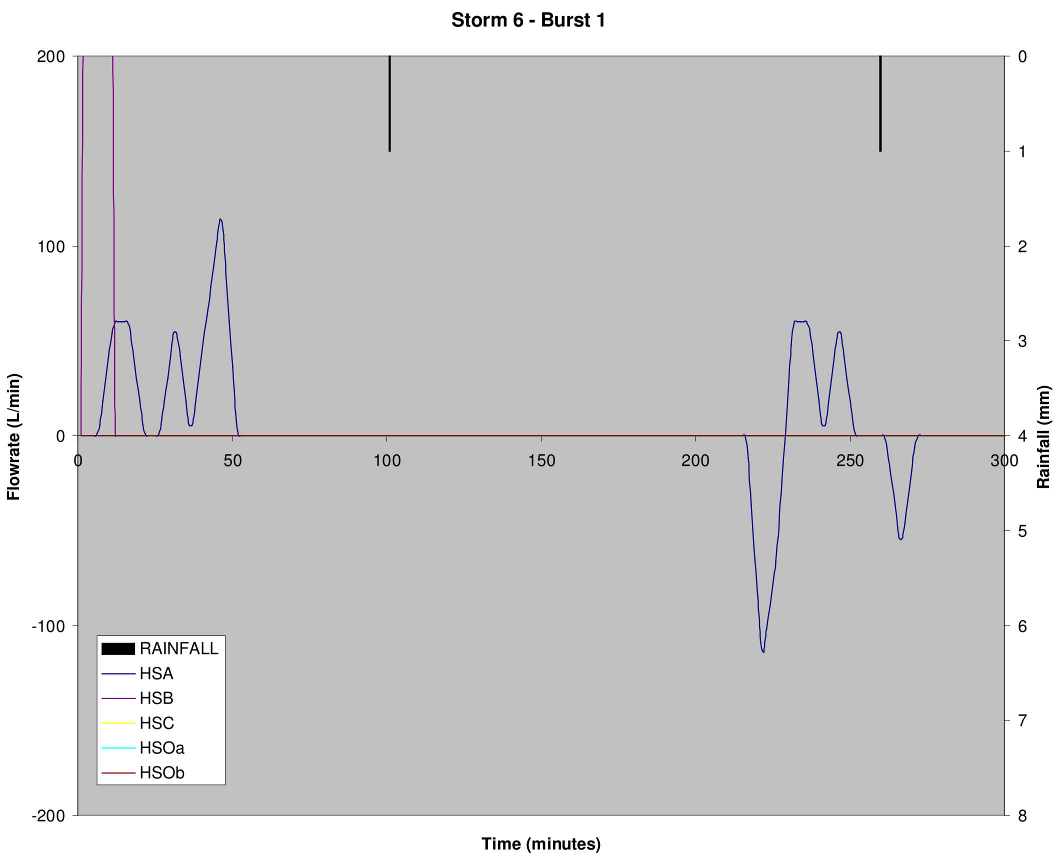
1 mm

AMC Condition

2 - Rather Dry

Comments

Event Is not suitable for use in calibration with DRAINS model. While the runoff appears to correlate well to the first two events, a third rainfall event does not produce any runoff. The data may be used to aid in the understanding of the runoff response for catchment C and the initial response for catchment A



Time Period
5:59 hours

Total Precipitation
2 mm

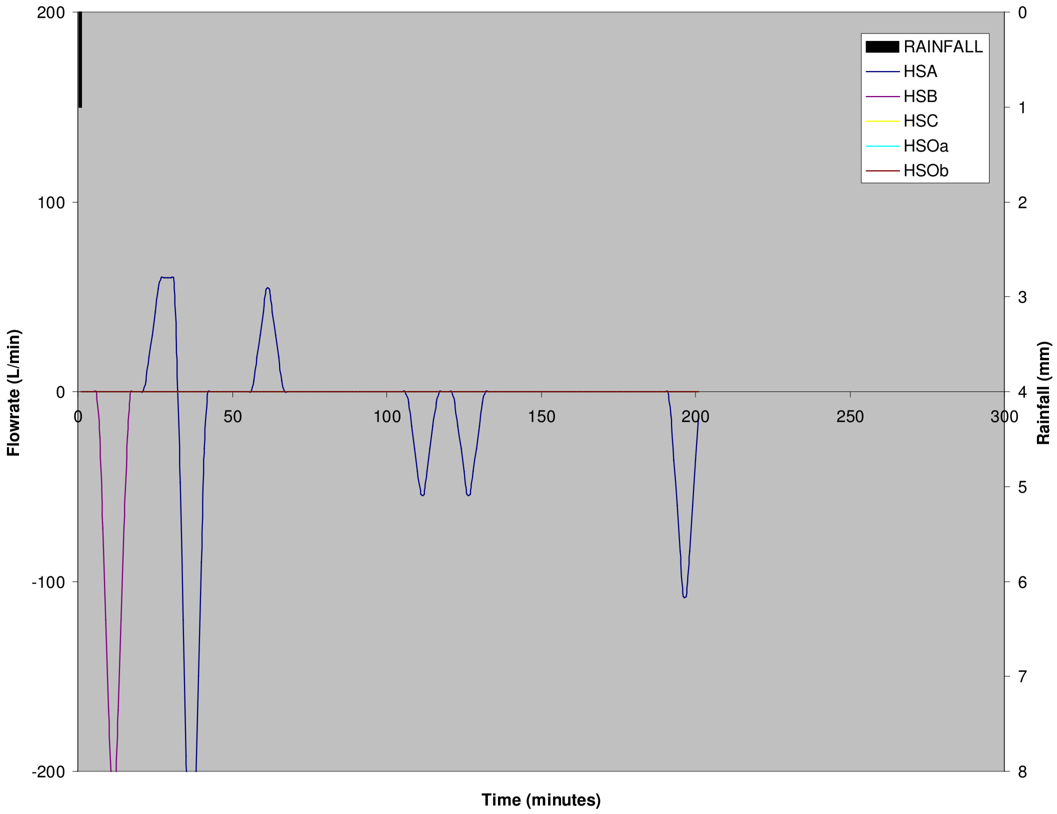
Rainfall in Past 5 Days
1 mm

Rainfall in Past 12 Hours
0 mm

AMC Condition
2 - Rather Dry

Comments
Event Is not suitable for use in calibration with DRAINS model. Runoff correlates very poorly wih rainfall.

Storm 6 - Burst 2



Time Period
3:20 hours

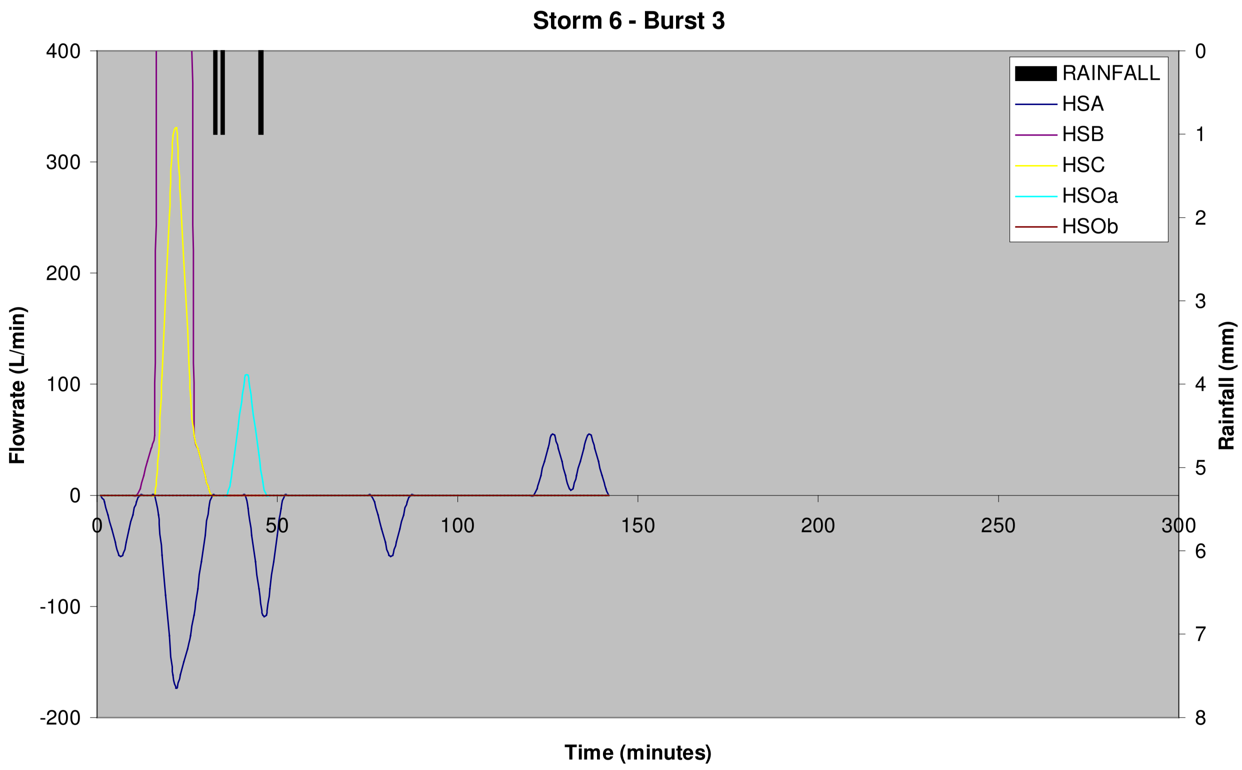
Total Precipitation
1 mm

Rainfall in Past 5 Days
3 mm

Rainfall in Past 12 Hours
2 mm

AMC Condition
2 - Rather Dry

Comments
Event Is not suitable for use in calibration with DRAINS model. Runoff correlates very poorly wih rainfall.



Time Period
2:11 hours

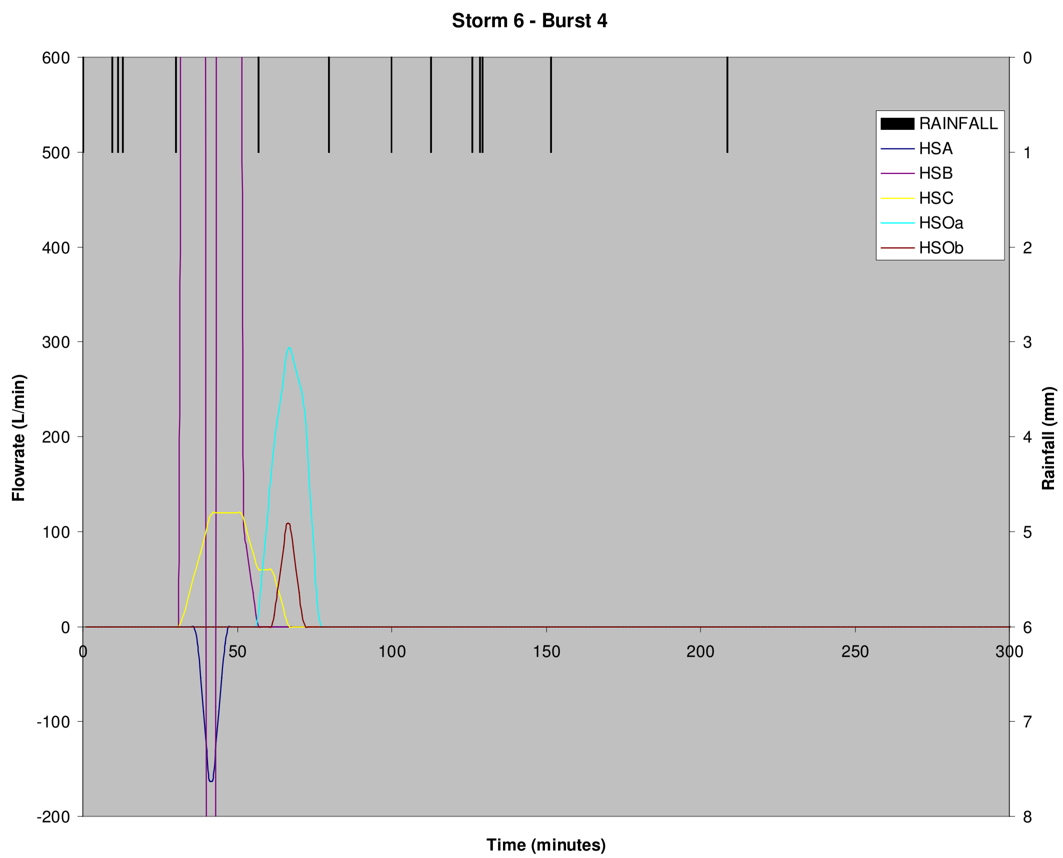
Total Precipitation
3 mm

Rainfall in Past 5 Days
4 mm

Rainfall in Past 12 Hours
1 mm

AMC Condition
2 - Rather Dry

Comments
Event Is not suitable for use in calibration with DRAINS model. Runoff appears to occur before the rainfall is registered suggeting a poor correlation. Hydrographs for HSC and HSOa appear to be consistent with an expected response.



Time Period
20:16 hours

Total Precipitation
14 mm

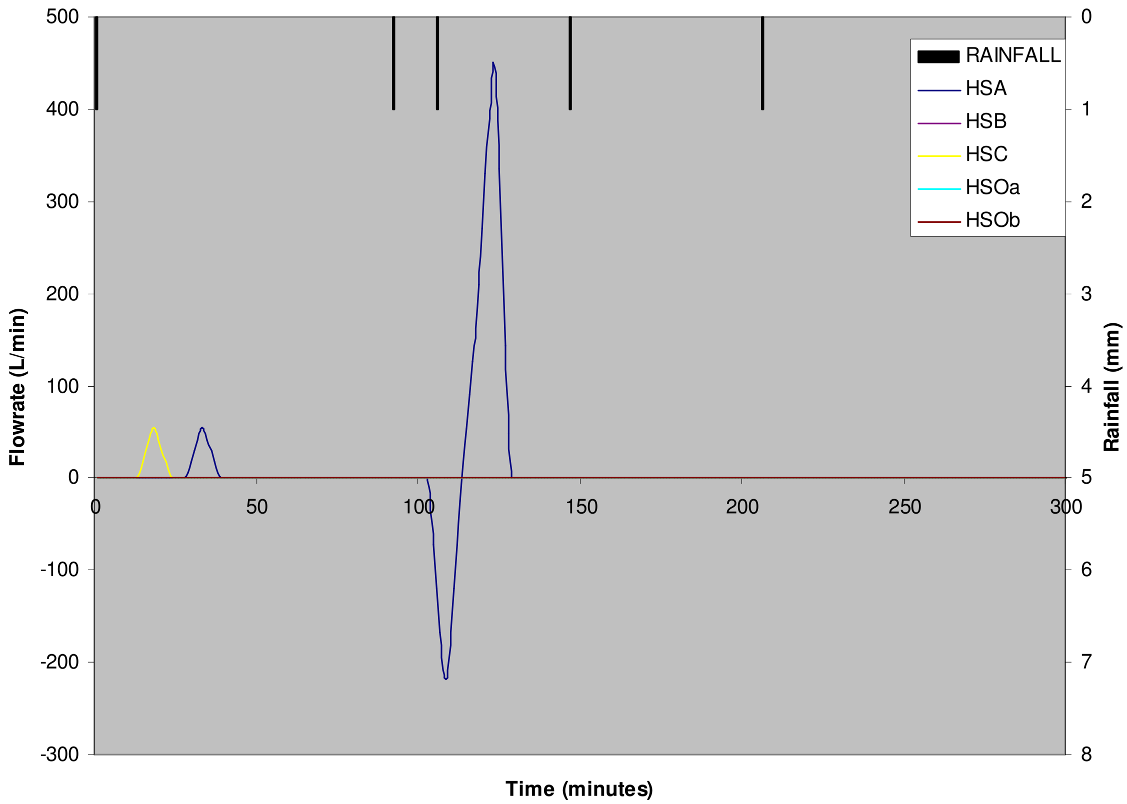
Rainfall in Past 5 Days
7 mm

Rainfall in Past 12 Hours
6 mm

AMC Condition
2 - Rather Dry

Comments
Event Is not suitable for use in calibration with DRAINS model. Runoff does not correlate well with rainfall. Suitable hydrographs were recorded for HSC, HSOa and HSOb which may be used to aid in the understanding of the runoff and infiltration processes.

Storm 7 - Burst 1



Time Peric
19:13 hou

Total Precipitati
5 n

Rainfall in Past 5 Day
1 n

Rainfall in Past 12 Hou
0 n

AMC Conditic
2 - Rather D

Comment
Event is not suitable fc
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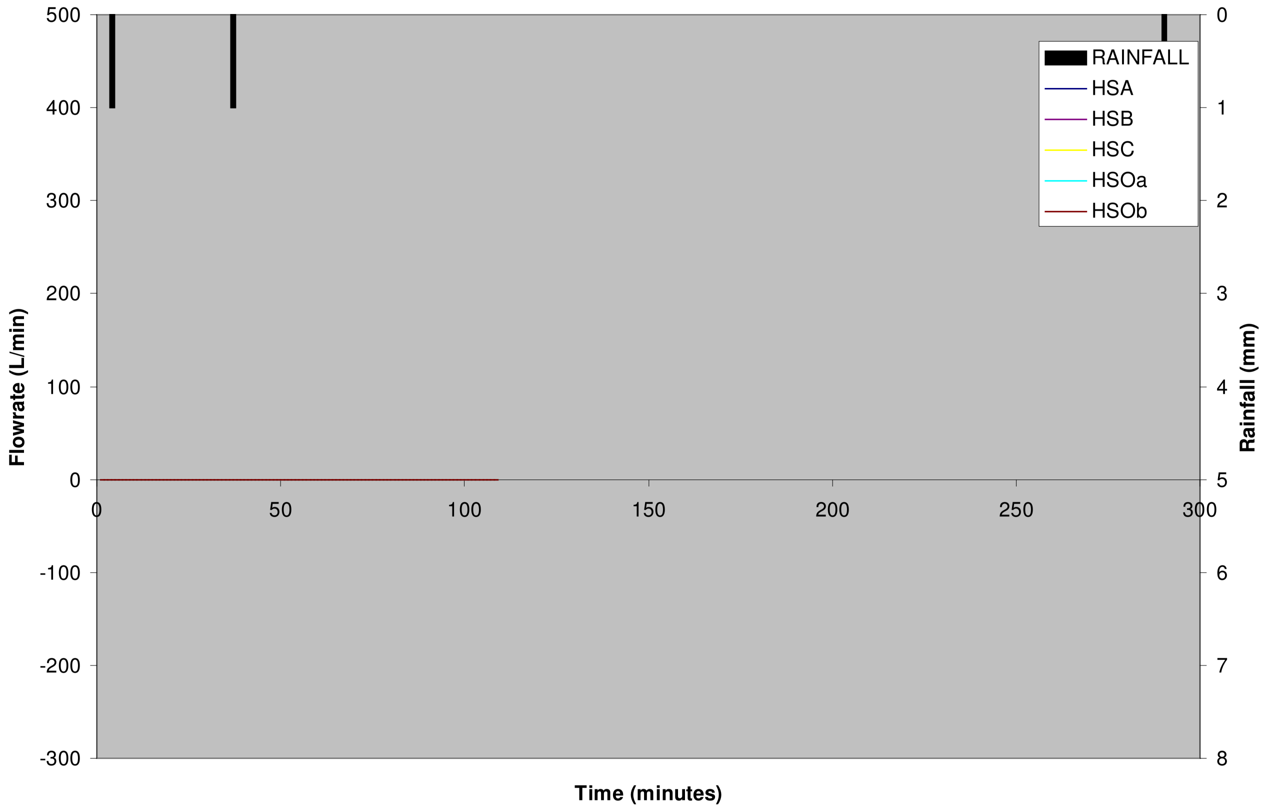
runoff is evider

Storm 8 - Burst 1



Time Period
22:36 hours

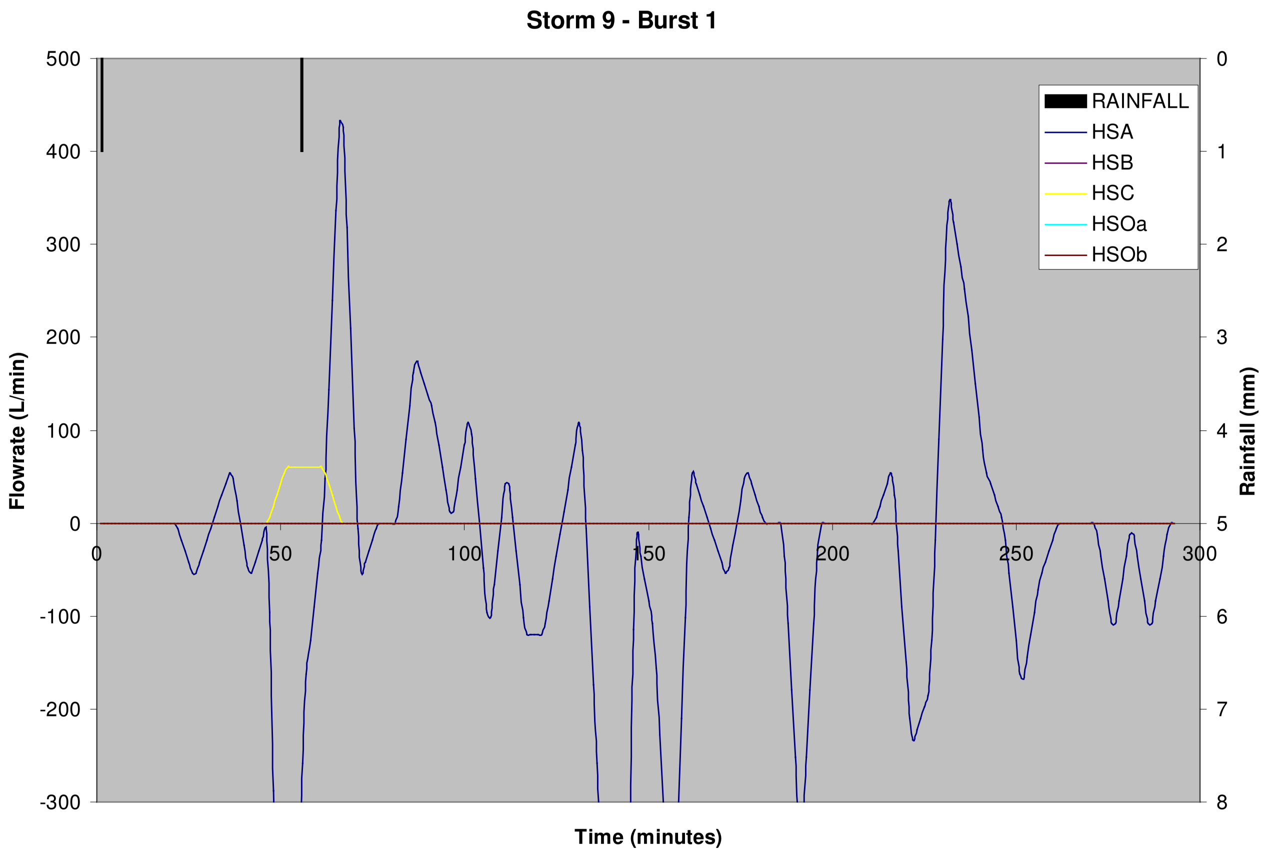
Total Precipitation
3 mm

Rainfall in Past 5 Days
0 mm

Rainfall in Past 12 Hours
0 mm

AMC Condition
1 - Completely Dry

Comments
Event Is not suitable for use in calibration with DRAINS model. No runoff has been recorded despite rainfall occuring at the guage. This was perhaps due to a dry catchment condition limiting runoff.



Time Period
4:52 hours

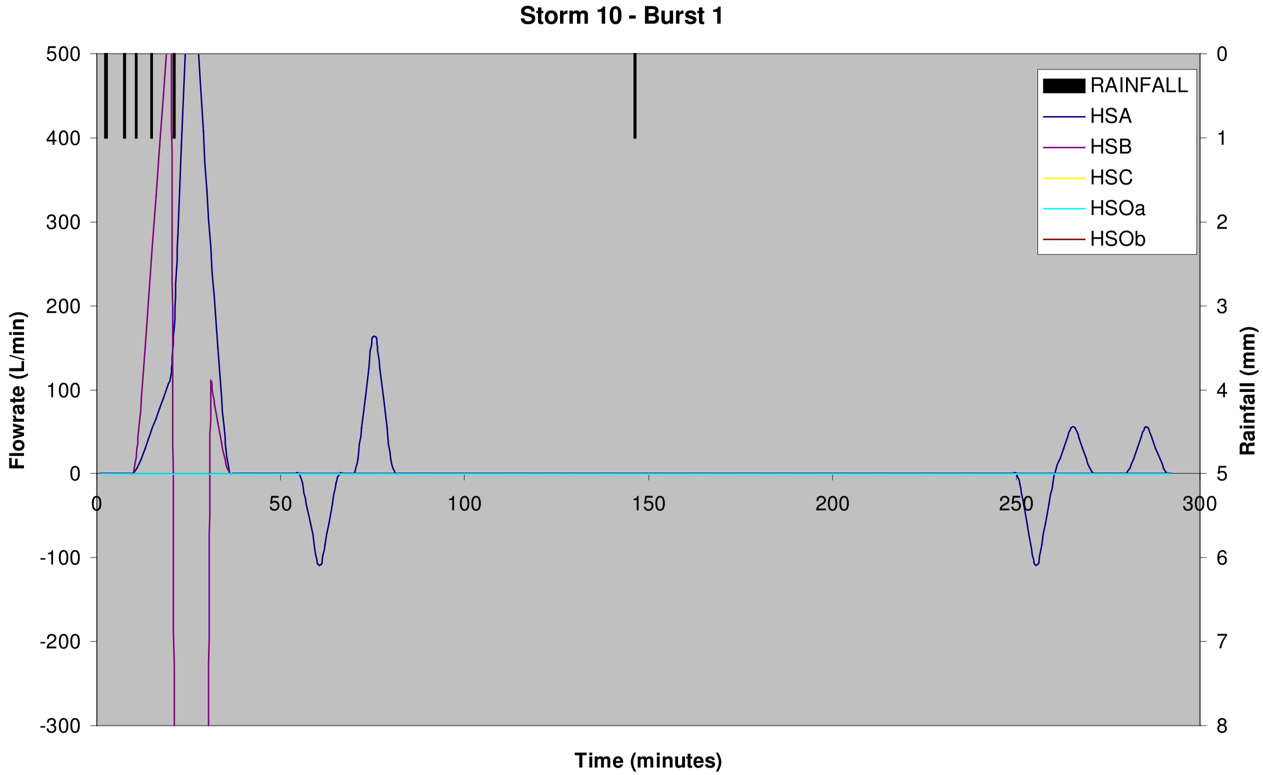
Total Precipitation
2 mm

Rainfall in Past 5 Days
0 mm

Rainfall in Past 12 Hours
0 mm

AMC Condition
1 - Completely Dry

Comments
Event Is not suitable for use in calibration with DRAINS model. Poor correlation with rainfall is evident and wildly varying negative and positive flowrates indicate instrument error.



Time Period
4:51 hours

Total Precipitation
6 mm

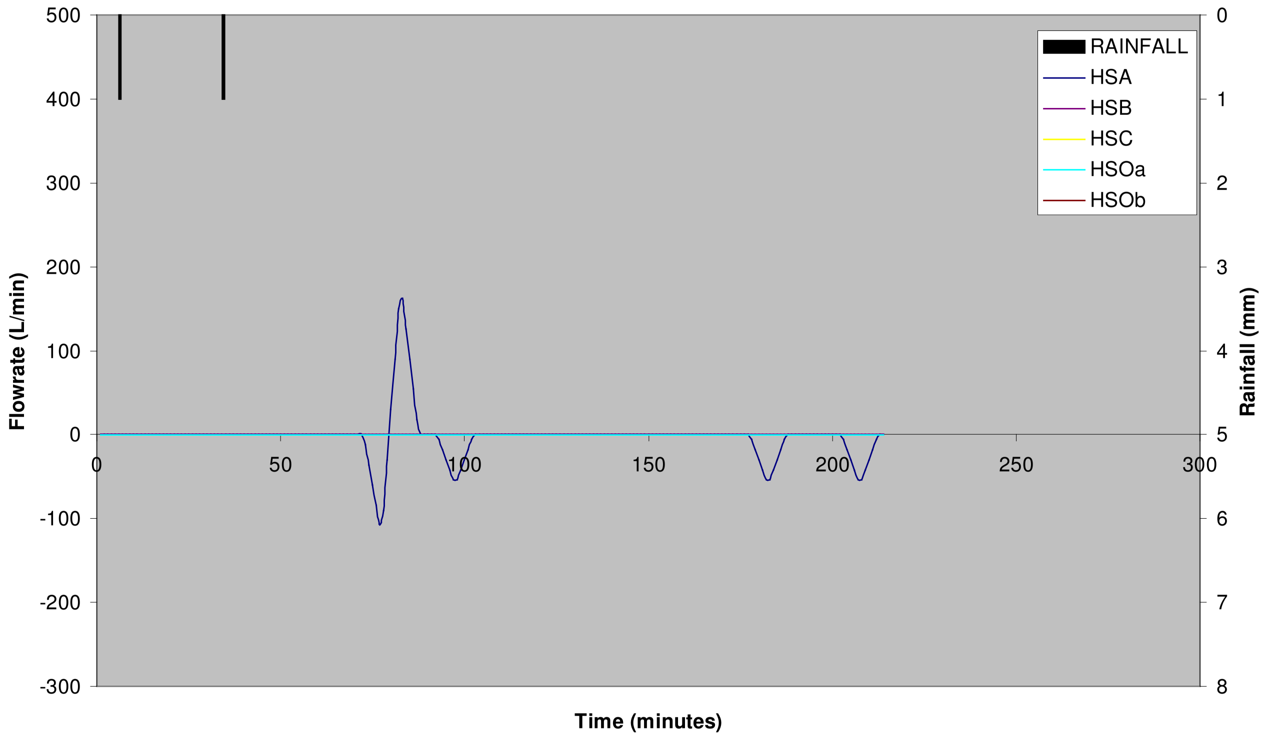
Rainfall in Past 5 Days
0 mm

Rainfall in Past 12 Hours
0 mm

AMC Condition
1 - Completely Dry

Comments
Event Is not suitable for use in calibration with DRAINS model. Poor correlation with rainfall is evident. This is coupled with negative flowrates for bith HAS and HSB. Instrument error has caused no suitable hydrograph to be recorded for HSC, HSOa and HSOb.

Storm 11 - Burst 1



Time Period
3:15 hours

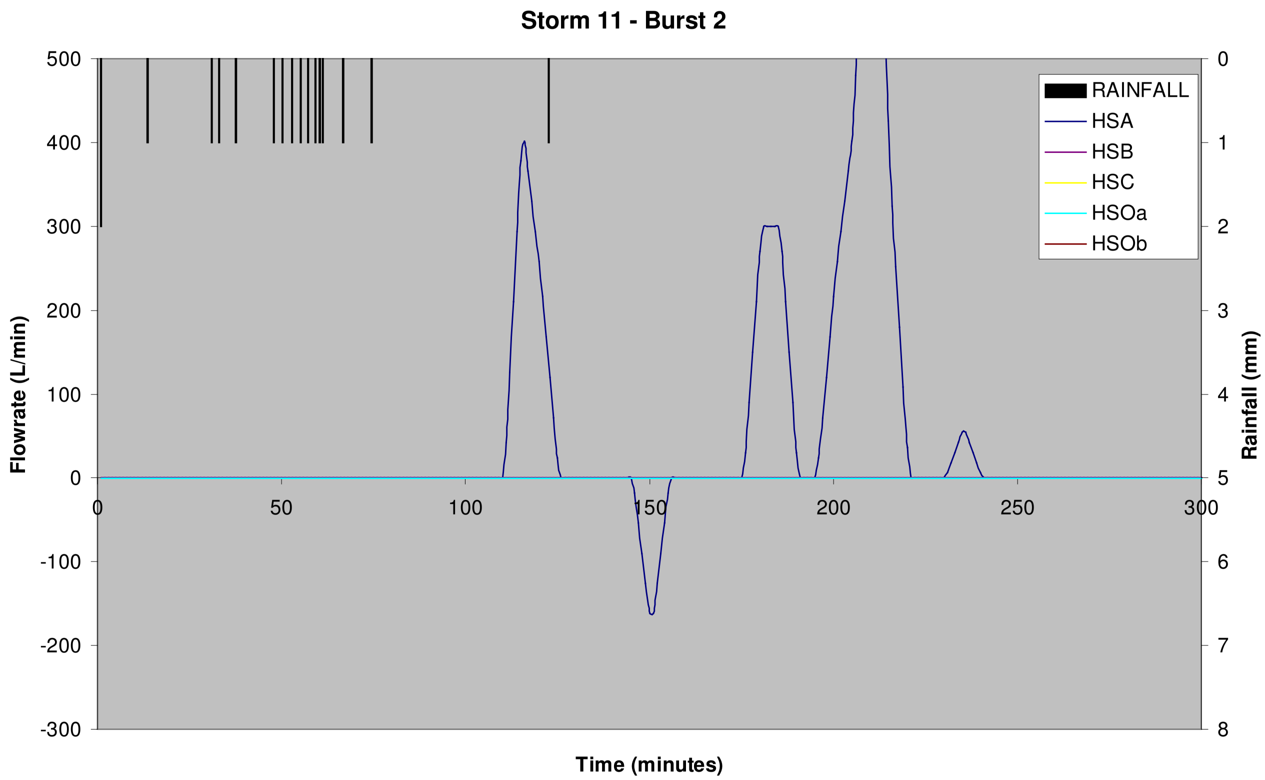
Total Precipitation
2 mm

Rainfall in Past 5 Days
0 mm

Rainfall in Past 12 Hours
0 mm

AMC Condition
1 - Completely Dry

Comments
Event Is not suitable for use in calibration with DRAINS model. Poor correlation with rainfall is evident. Runoff has only been measured at HSA, where negative flowrates are a feature.



Time Period
3:15 hours

Total Precipitation
2 mm

Rainfall in Past 5 Days
0 mm

Rainfall in Past 12 Hours
0 mm

AMC Condition
1 - Completely Dry

Comments
Event Is not suitable for use in calibration with DRAINS model. Very poor correlation with the start of the rainfall event is evident. Runoff has only been measured at HSA, where the hydrogrpah shape is not indicative of a typcial catchmnet response.

APPENDIX C: Hoyland Street Connection Drawings

(irrelevant sections omitted)

HOYLAND STREET CONNECTION

Brisbane City

City Design

GYMPIE RD
TO
BRACKEN RIDGE RD

DRAWING INDEX

DRAWING INDEX, LOCALITY PLAN AND NOTES	9905412-001
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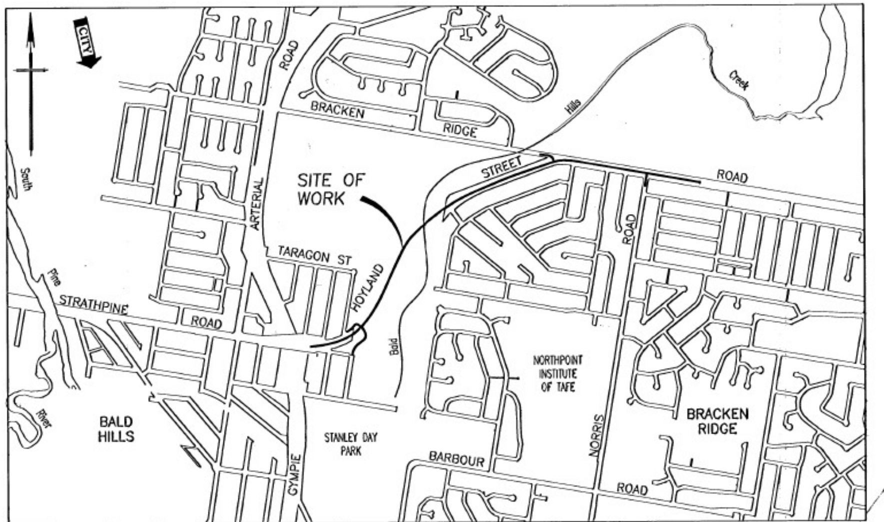
CULVERT WORKS AND DETAILS SHEET 2 OF 3	9905412-202
CULVERT WORKS AND DETAILS SHEET 3 OF 3	9905412-203



LOCALITY PLAN

UBD. MAP REF: 109 M-2

PAVEMENT DETAILS

REFER TO 9905412-020 FOR PAVEMENT DETAILS

GENERAL NOTES

1. REFER TO BRISBANE CITY COUNCIL 'DEPARTMENT OF WORKS - STANDARD DRAWINGS' WS9-1 FOR LINE STYLES AND WS9-2 FOR DRAWING SYMBOLS.
2. THE PAVEMENT THICKNESS SHOWN ON THE DRAWINGS MAY BE VARIED BY DIRECTION, IN WRITING, OF THE SUPERINTENDENT AFTER THE EXAMINATION AND/OR TESTING OF THE ROAD SUBGRADE. THE CONTRACTOR SHALL IN ALL CASES CONFIRM THE PAVEMENT THICKNESS BEFORE PROCEEDING WITH THE FINAL FORMATION OF THE ROAD SUBGRADE.
3. THE QUANTITIES OF IMPORTED FILL AND SPOIL IN THE SCHEDULE HAVE BEEN CALCULATED ALLOWING A FIFTEEN PERCENT (15%) COMPACTION LOSS FOR 'EARTHWORKS ON LEADS'.
4. THE QUANTITY FOR EARTHWORKS TO SPOIL GIVEN IN THE SCHEDULE IS THE VOLUME IN THE SOLID BEFORE EXTRACTION.
5. ALL GULLIES ARE TO BE TYPE A AS PER WS 52-1 AND 52-2 WITH 375 DIA. PIPE CONNECTION UNLESS OTHERWISE SHOWN.(FOR LINTEL TYPE, REFER TO GULLY SETOUT TABLE.)
6. GULLIES AND CONNECTIONS HAVE BEEN ALLOWED FOR IN THE SCHEDULE AS SHOWN ON THE DRAWINGS, BUT THE ACTUAL POSITION OF GULLIES MAY BE VARIED BY THE SUPERINTENDENT ON THE SITE.
7. FOR STORMWATER PIPE TRENCH WIDTHS , REFER WS 50-1.
8. NOTWITHSTANDING THAT THE PRESENT AND/OR PROPOSED POSITIONS OF PUBLIC UTILITIES, FITTINGS, PIPES, POLES, MANHOLES, ETC. MAY BE INDICATED ON THE DRAWINGS, NO RESPONSIBILITY WILL BE ACCEPTED BY THE PRINCIPAL FOR THE ACCURACY OF THE REPRESENTATION OR THE OMISSION THEREOF.
9. CONTACT ENERGEX FOR THE EXACT LOCATION OF UNDERGROUND CABLES (PHONE 3223 5641).
10. A.C. SURFACING IS NOT INCLUDED IN THE CONTRACT.
11. PRIME AND BITUMEN SEAL SURFACING IS NOT INCLUDED IN THE CONTRACT.
12. ALL NEW WORK IS TO BE JOINED NEATLY TO EXISTING.
13. PIPE CROSSINGS ARE TO BE REMOVED AND REPLACED AS DIRECTED BY THE SUPERINTENDENT.
14. STANDARD KERB RAMP. (REFER WS 11-3)
15. STANDARD ISLAND PEDESTRIAN RAMP .(REFER WS 11-4)
16. FIELD INLETS ARE TO BE DEPRESSED BELOW NATURAL SURFACE WITH A 450 mm WIDE CONCRETE SURROUND TRANSITIONING FROM NATURAL SURFACE TO FIELD INLET. REFER TO DETAIL ON 9905412-98
17. EXISTING CONCRETE VEHICULAR CROSSINGS ARE TO BE REINSTATED AS PER WS 12-2 AND 12-3.
18. FOR ALL STREET LIGHTING MATTERS, NOTIFY THE RELEVANT ENERGEX BRANCH DEPOT NOT LESS THAN TWO (2) MONTHS PRIOR TO THE COMMENCEMENT DATE OF CONSTRUCTION. FOR FURTHER INFORMATION CONTACT THE RELEVANT B.C.C. CITY LIGHTING OFFICER.
19. ALL EXPOSED AGGREGATE AREAS ARE TO BE BORAL CONCRETE Ex99 LAWNTON EXPOSED

NOISE BARRIER FENCE NOTES

1. ALL ACOUSTIC FENCES ARE TO BE 2.5m HIGH
2. ALL ACOUSTIC FENCES ARE TO BE SIMILAR TO WS19-2.
3. FOOTING, RHS POSTS AND BATTENS ARE TO BE SIZED AS PER WS19-2
4. BATTENS AND POSTS ARE TO BE INCREASED BY 0.5m IN HEIGHT
5. ALTERATIONS TO THE ACOUSTIC FENCE DESIGN CAN ONLY BE MADE AFTER APPROVAL FROM THE PRINCIPAL ENGINEER (R&T) CITY DESIGN
6. FOR COLOURS AND LOCATIONS OF NOISE BARRIER FENCE PAINT REFER TO SHEET 9905412-035
7. A 75mm THICK CONCRETE MOW STRIP TO BE CONSTRUCTED UNDER ALL ACOUSTIC FENCES

(60 sheets)

W11733

AMENDMENT		DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A	CONSTRUCTION ISSUE	19-9-00		MLP		

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS

FIELD BOOK 9104 | FILENAME 1395-0

REFERENCE :- B.M. DATUM : A.H.D.

ORIG. SPIKE IN BITUMEN
PT NO 9190
E1458.618 N 8194.328
RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE

DATE 20/9/00

PRINCIPAL ENGINEER - ROAD AND TRAFFIC DESIGN

ROAD AND TRAFFIC DESIGN :
PRINCIPAL ENGINEER - 3403 0543
SENIOR ENGINEER - 3403 0539
SENIOR DRAFTSMAN ROADS - 3403 0541
SENIOR DRAFTSMAN TRAFFIC - 3403 0547
FACSIMILE NUMBER - 3403 0507

CADD REFERENCE: 9905412_001

PLAN CUSTODIAN

REGISTERED

MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED	RJL	7/2000

FILE No.

SERVICES FILE No.

ACQUISITION FILE No. N/A

SUR PLAN NO. N/A

Brisbane City

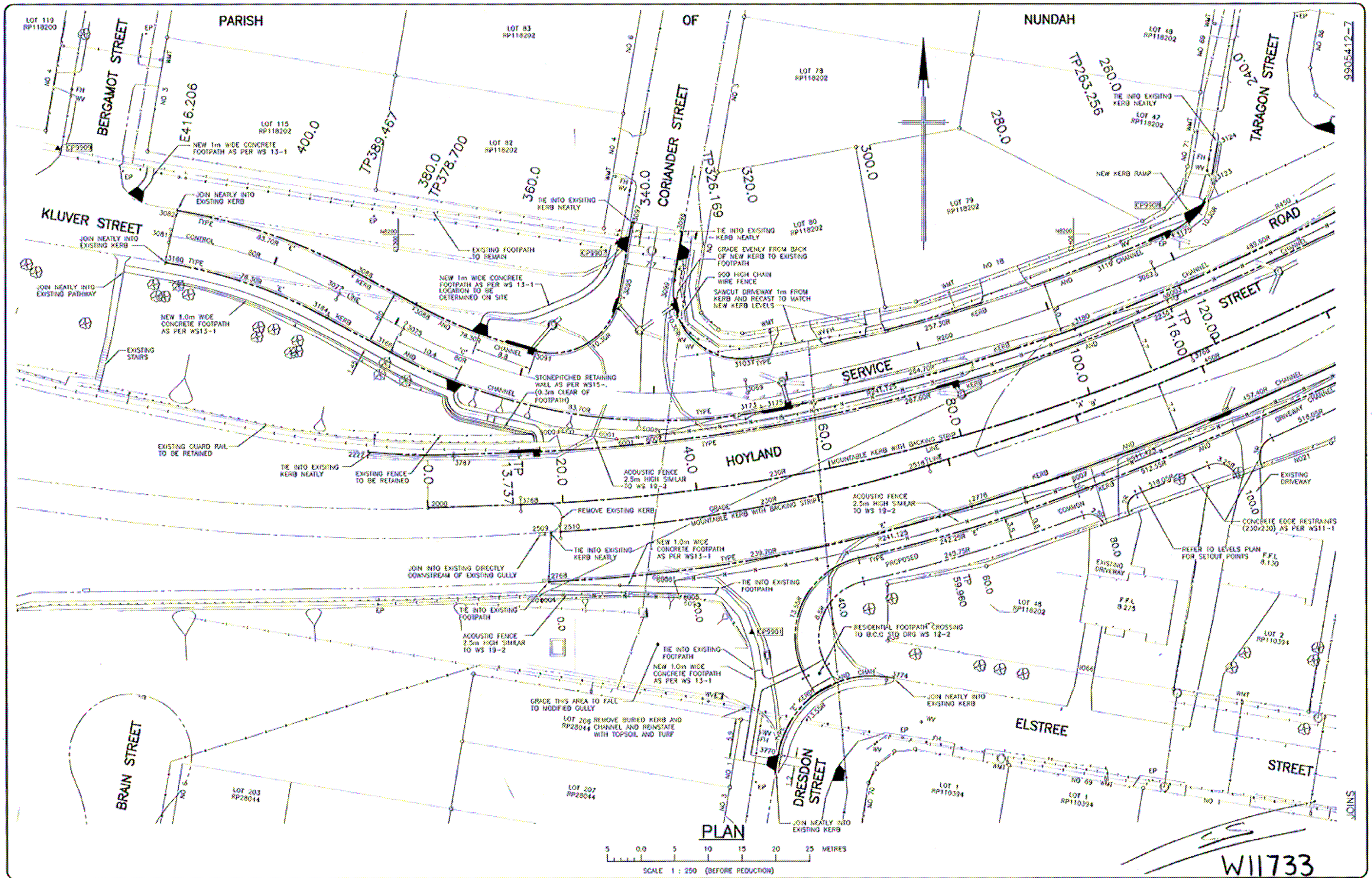
JOB: ROADWORKS AND DRAINAGE
HOYLAND STREET CONNECTION
BRACKEN RIDGE
GYMPIE ROAD TO
BRACKEN RIDGE ROAD

DRAWING TITLE: DRAWING INDEX
LOCALITY PLAN
GENERAL NOTES
AND PAVEMENT DETAILS

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN

DRAWING SHEET 1 OF 148 | ISSUE No.

DRAWING No. 9905412 | SHEET No. 1 | AMEND. A



AMENDMENT	DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A CONSTRUCTION	28-7-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS

FIELD BOOK 9104 | FILENAME 1395-0

REFERENCE :- B.M. DATUM : A.H.D.

ORIG. SPIKE IN BITUMEN PT 39 3190 E1458.618 N 8194.328 RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE

CADD REFERENCE: 9905412_006-018.dwg

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.M.	7/2000
TRACED	M.M.	7/2000
CHECKED		7/2000

FILE No. SERVICES FILE No. ACQUISITION FILE No. N/A SUR PLAN NO. N/A

Brisbane City

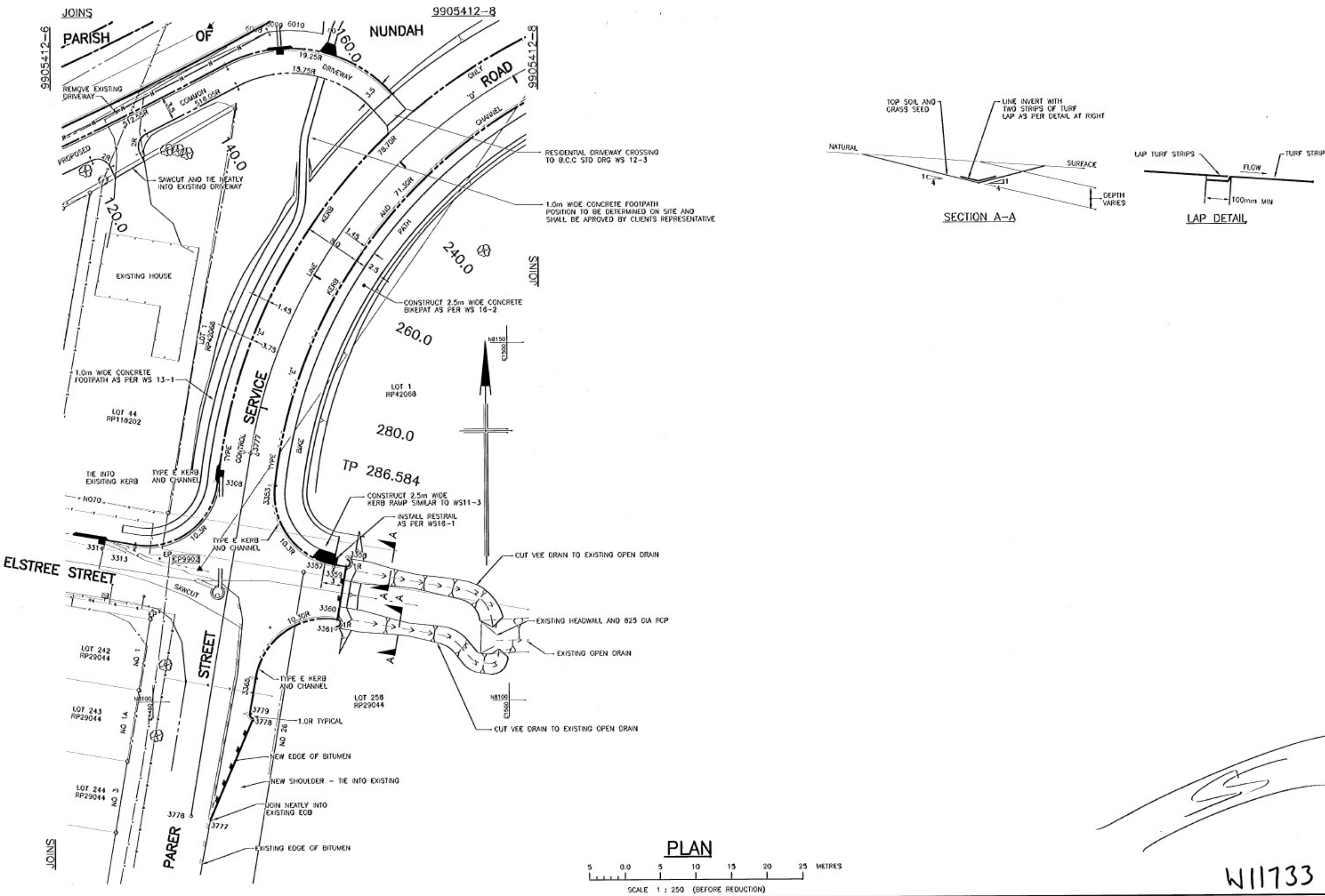
JOB: ROADWORKS AND DRAINAGE HOYLAND STREET CONNECTION BRACKEN RIDGE GYMPIE ROAD TO BRACKEN RIDGE ROAD

DRAWING TITLE: LAYOUT PLAN SHEET 1 OF 13

BRISBANE CITY COUNCIL CITY DESIGN ROAD AND TRAFFIC DESIGN

DRAWING SHEET 6 OF 148

DRAWING No. 9905412 | SHEET No. 6 | AMEND. A



W11733

AMENDMENT		DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A	CONSIDERED FOR CONSTRUCTION	26-07-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS

FIELD BOOK 9104 | FILENAME 1395-0

REFERENCE :- B.M. | DATUM : A.H.D.

ORIG. SPIKE IN BITUMEN
PT NO 9190
E1458.618 N 8194.328
RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE

PRINCIPAL ENGINEER – ROAD AND TRAFFIC DESIGN

ROAD AND TRAFFIC DESIGN :
PRINCIPAL ENGINEER – 3403 0543
SENIOR ENGINEER – 3403 0539
SENIOR DRAFTSMAN ROADS – 3403 0541
SENIOR DRAFTSMAN TRAFFIC – 3403 0547
FACSIMILE NUMBER – 3403 0507

CADD REFERENCE: 9905412_006-018.dwg

PLAN CUSTODIAN

REGISTERED

MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED	RJL	7/2000

FILE No.

SERVICES FILE No.

ACQUISITION FILE No. N/A

SUR PLAN NO. N/A

Brisbane City

JOB
ROADWORKS AND DRAINAGE
HOYLAND STREET CONNECTION
BRACKEN RIDGE
GYMPIE ROAD TO BRACKEN RIDGE ROAD

DRAWING TITLE
LAYOUT PLAN
SHEET 2 OF 13

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN

DRAWING SHEET 7 OF 148 | ISSUE No.

DRAWING No.	SHEET No.	AMEND.
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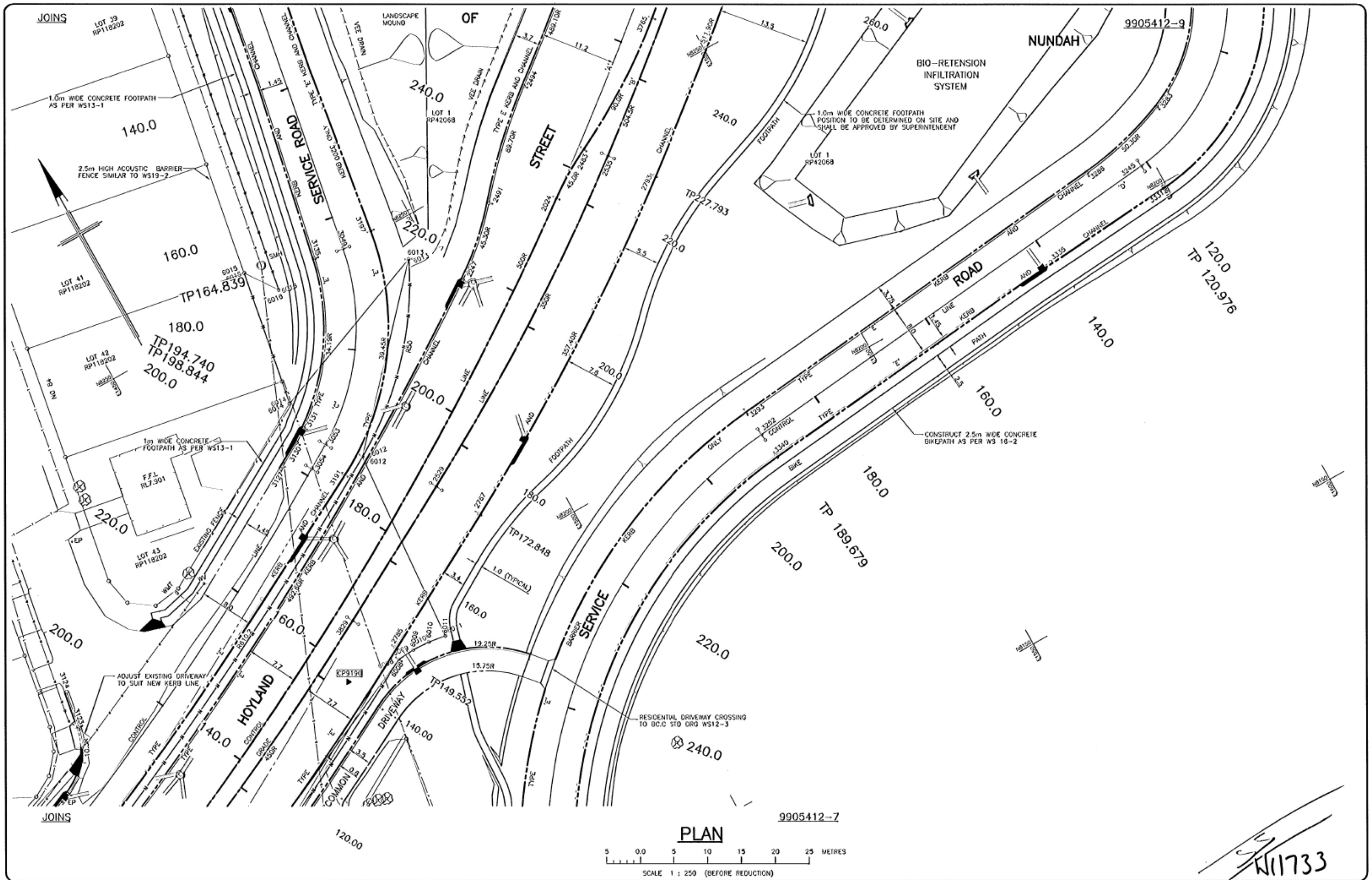


PLAN

SCALE 1 : 250 (BEFORE REDUCTION)

AMENDMENT	DATE	CHECKED	AUTHOR	AS CONST.	MICRO
A CONSTRUCTION ISSUE	06-07-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS

FIELD BOOK 9104 | FILENAME 1395-0

REFERENCE :- B.M. | DATUM : A.H.D.

ORIG. SPIKE IN BITUMEN
PT NO 9190
E1458.618 N 8194.328
RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED		7/2000

CADD REFERENCE: 9905412_006-013.dwg

PLAN CUSTODIAN

REGISTERED

MICROFILM

FILE No.

SERVICES FILE No.

ACQUISITION FILE No. N/A

SUR PLAN NO. N/A

Brisbane City

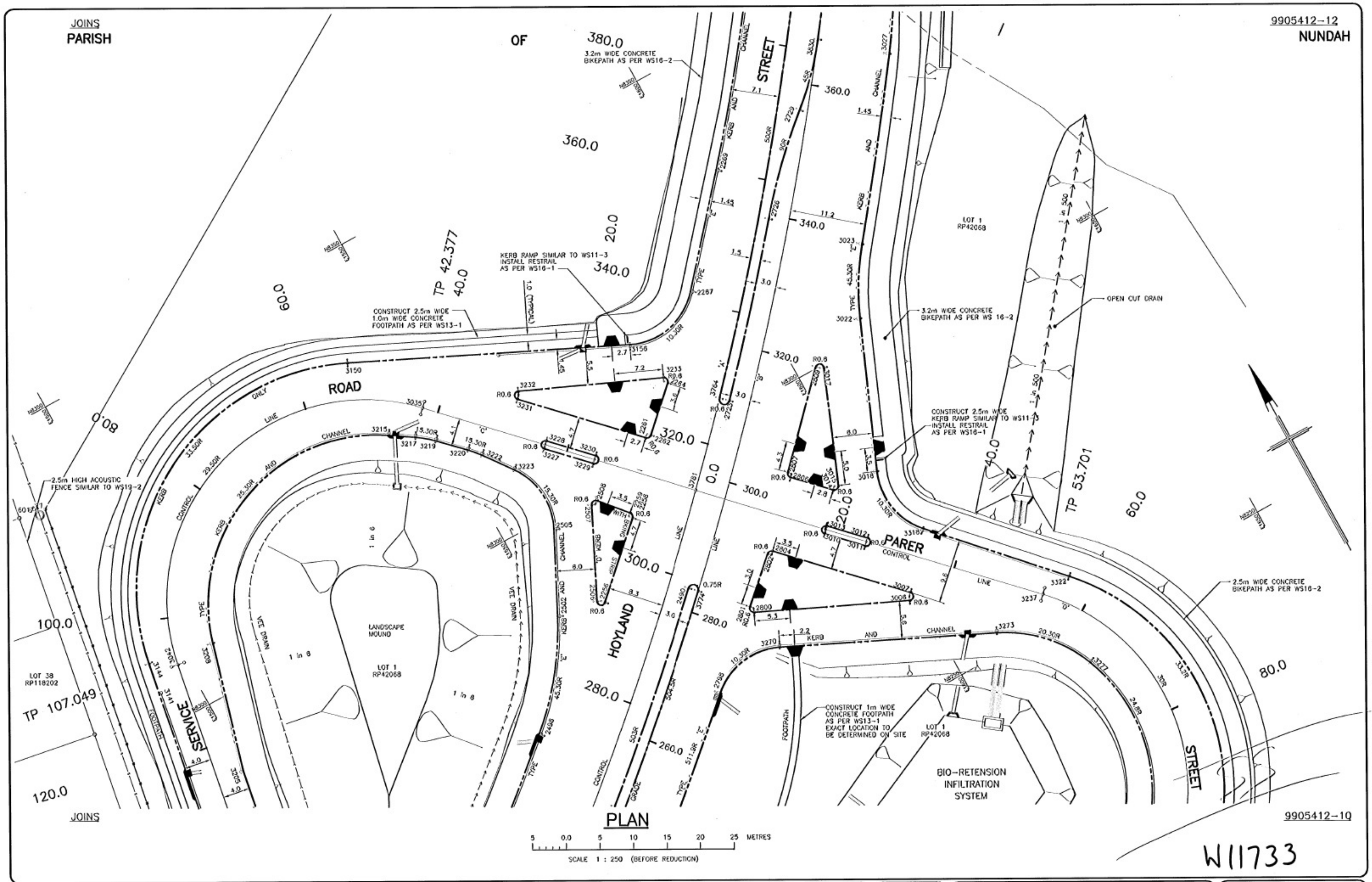
JOB: ROADWORKS AND DRAINAGE
HOYLAND STREET CONNECTION
BRACKEN RIDGE
GYMPIE ROAD TO BRACKEN RIDGE ROAD

DRAWING TITLE: LAYOUT PLAN SHEET 3 OF 13

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN

DRAWING SHEET 8 OF 148

DRAWING No. 9905412 | SHEET No. 8 | AMEND. A



AMENDMENT	DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A CONSTRUCTION ISSUE	28-7-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS
FIELD BOOK 9104 FILENAME 1395-0
REFERENCE :- B.M. DATUM : A.H.D.
ORIG. SPIKE IN BITUMEN PT NO 9190 E1458.618 N 8194.328 RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE
PRINCIPAL ENGINEER - ROAD AND TRAFFIC DESIGN
ROAD AND TRAFFIC DESIGN :
PRINCIPAL ENGINEER - 3403 0543
SENIOR ENGINEER - 3403 0539
SENIOR DRAFTSMAN ROADS - 3403 0541
SENIOR DRAFTSMAN TRAFFIC - 3403 0547
FACSIMILE NUMBER - 3403 0507

CADD REFERENCE: 9905412_006-018.dwg
PLAN CUSTODIAN
REGISTERED
MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED		7/2000

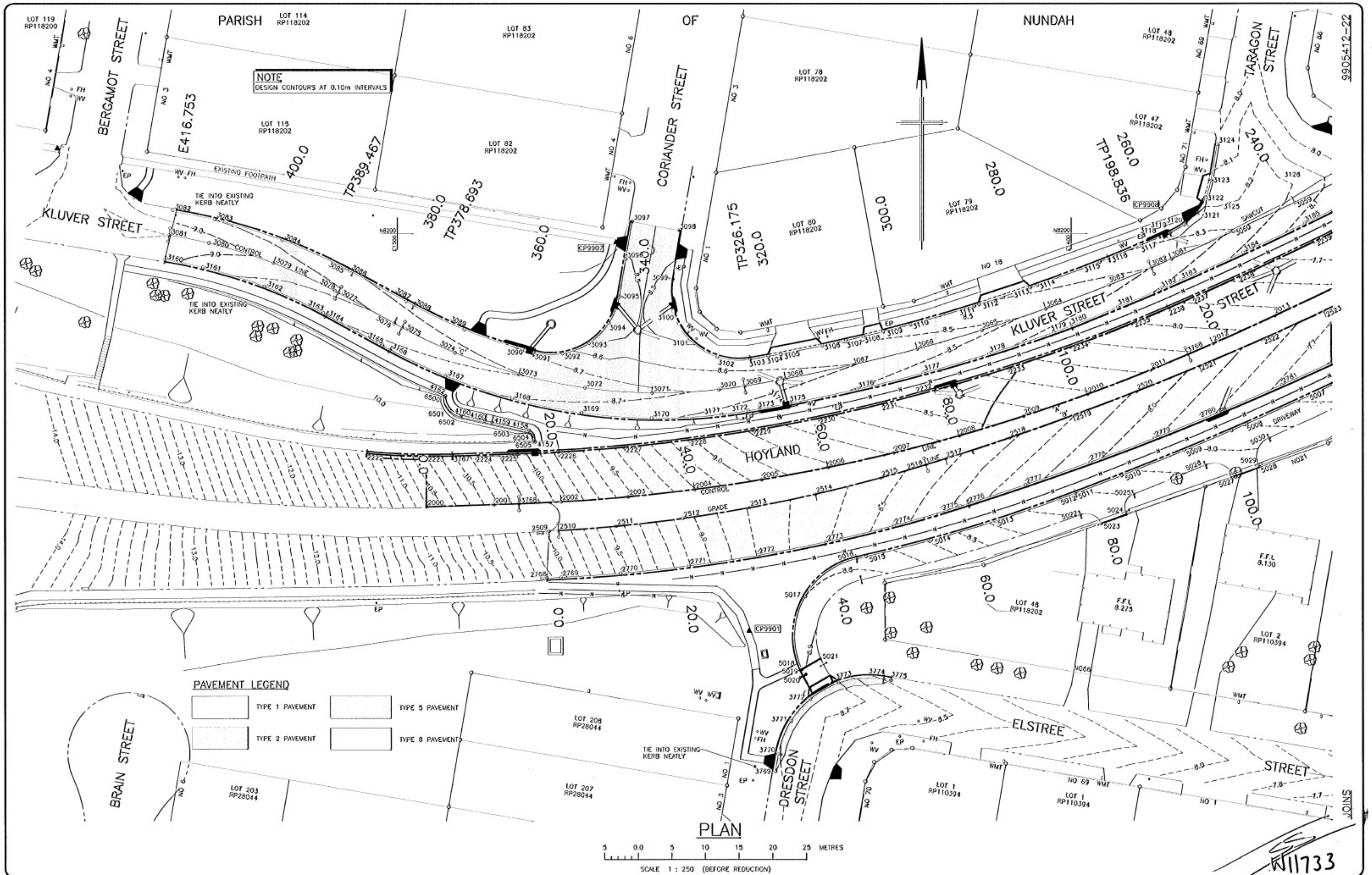
FILE No.
SERVICES FILE No.
ACQUISITION FILE No. N/A
SUR PLAN NO. N/A

Brisbane City

JOB: ROADWORKS AND DRAINAGE HOYLAND STREET CONNECTION BRACKEN RIDGE GYMPIE ROAD TO BRACKEN RIDGE ROAD

DRAWING TITLE: LAYOUT PLAN SHEET 4 OF 13

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN
DRAWING SHEET 9 OF 148
DRAWING No. 9905412 SHEET No. 9 AMEND. A



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A CONSTRUCTION ISSUE	19-9-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS

FIELD BOOK 9104 | FILENAME 1395-0

REFERENCE :- B.M. | DATUM : A.H.D.

ORIG. SPIKE IN BITUMEN
PT NO 9190
E1458.818 N 8194.328
RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE

PRINCIPAL ENGINEER – ROAD AND TRAFFIC DESIGN

CADD REFERENCE 9905412_021-033.DWG

PLAN CUSTODIAN

REGISTERED

MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED		7/2000

FILE No.
SERVICES FILE No.
ACQUISITION FILE No. N/A
SUR PLAN NO. N/A

Brisbane City

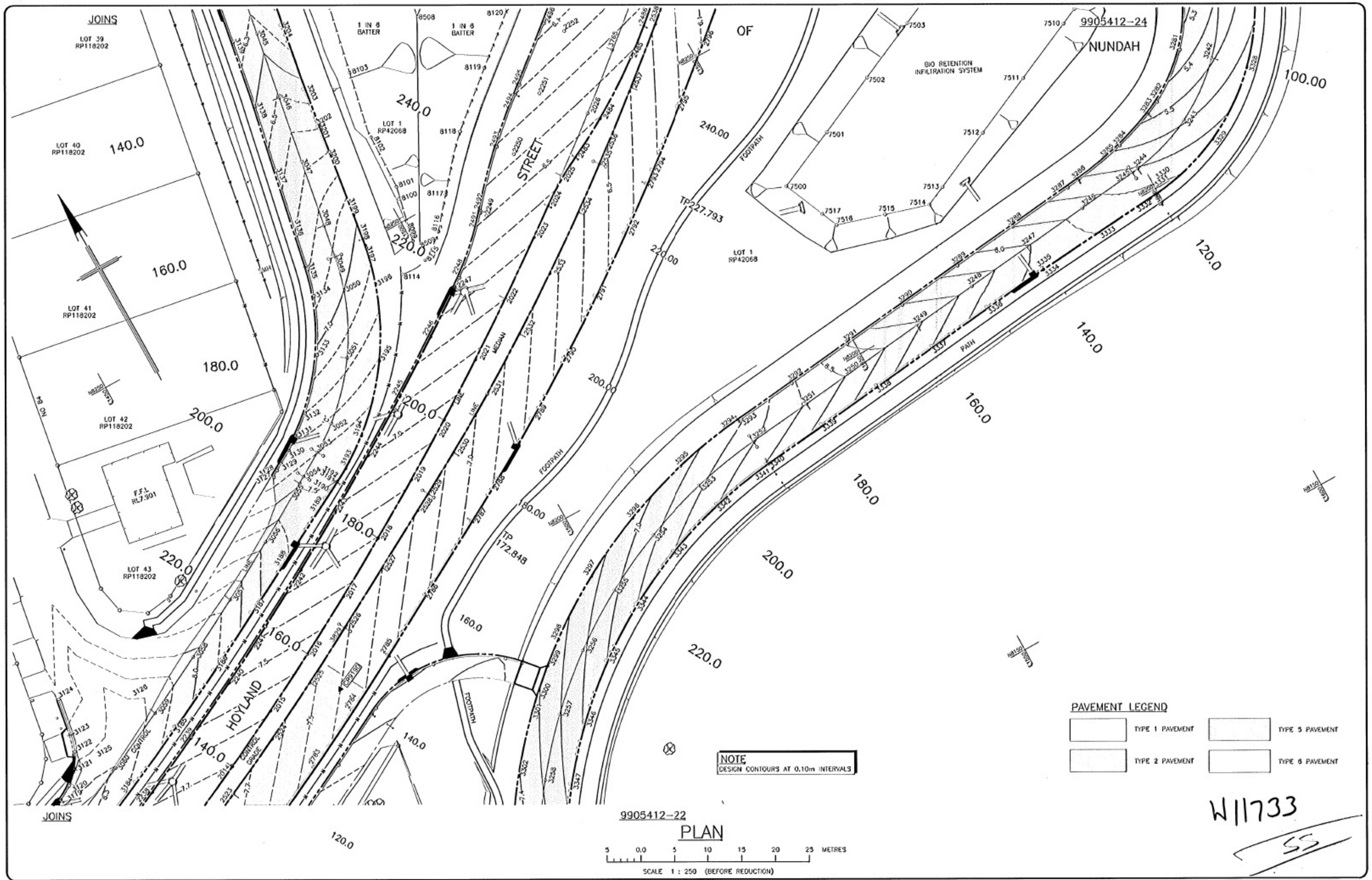
JOB
ROADWORKS AND DRAINAGE
HOYLAND STREET CONNECTION
BRACKEN RIDGE
GYMPIE ROAD TO BRACKEN RIDGE ROAD

DRAWING TITLE
LEVELS PLAN
SHEET 1 OF 13

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN

DRAWING SHEET 19 OF 148

DRAWING No. 9905412 | SHEET No. 19 | AMEND. A



AMENDMENT		DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A	CONSTRUCTION ISSUE	19-9-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS

FIELD BOOK 9104 FILENAME 1395-0

REFERENCE :- B.M. DATUM : A.H.D.

ORIG. SPIKE IN BITUMEN
PT NO 9190
E1458.618 N 8194.328
RL 7.092

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE

PRINCIPAL ENGINEER - ROAD AND TRAFFIC DESIGN DATE

ROAD AND TRAFFIC DESIGN :
PRINCIPAL ENGINEER - 3403 0543
SENIOR ENGINEER - 3403 0539
SENIOR DRAFTSMAN ROADS - 3403 0541
SENIOR DRAFTSMAN TRAFFIC - 3403 0547
FACSIMILE NUMBER - 3403 0507

CADD REFERENCE
9905412_021-033DW9
XREF 514BASE,518TT
LAYOUT TAB 3

PLAN CUSTODIAN

REGISTERED

MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED	RJL	7/2000

FILE No.
SERVICES FILE No.
ACQUISITION FILE No. N/A
SUR PLAN NO. N/A

Brisbane City

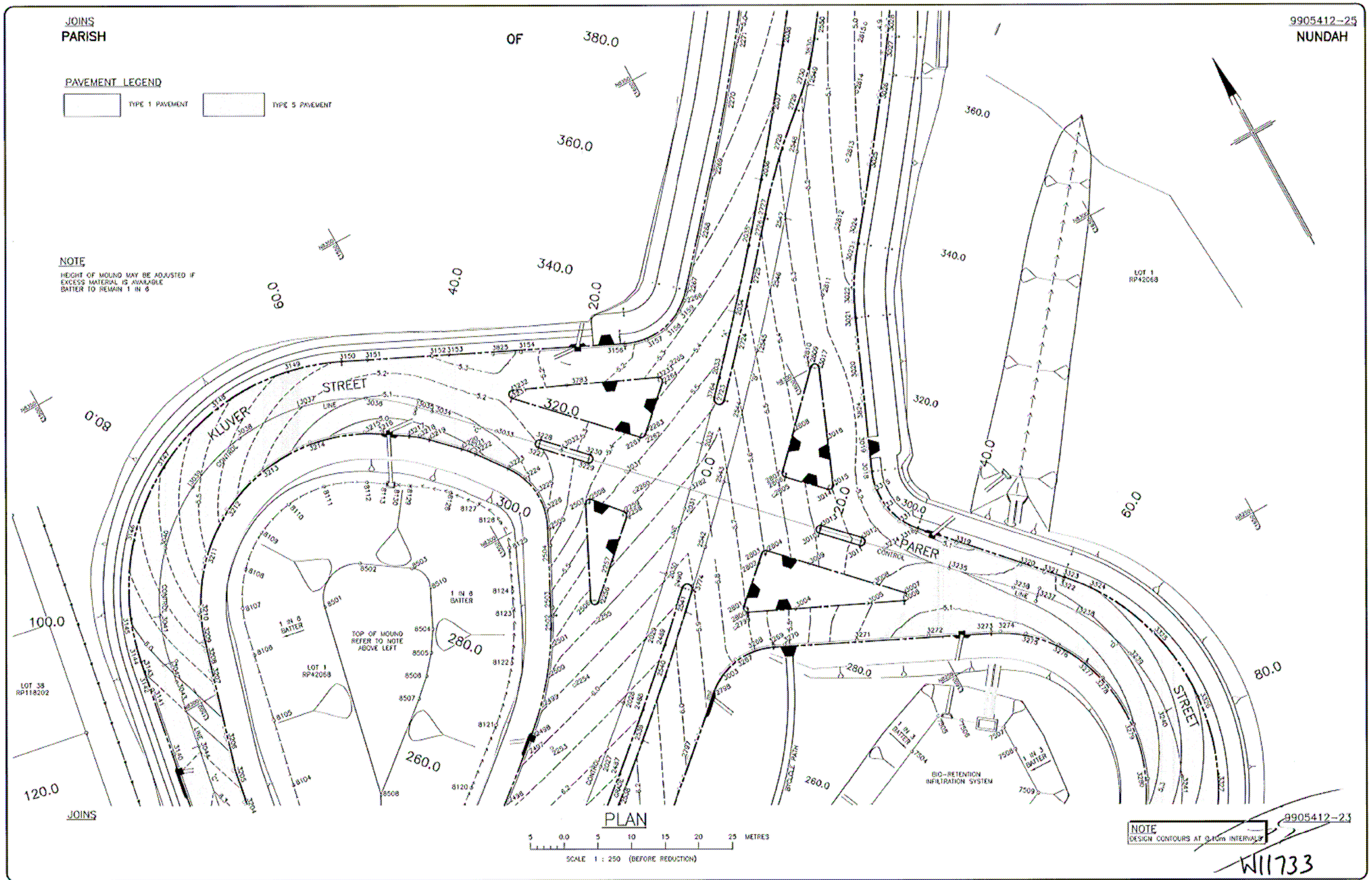
JOB
ROADWORKS AND DRAINAGE
HOYLAND STREET CONNECTION
BRACKEN RIDGE
GYMPIE ROAD TO
BRACKEN RIDGE ROAD

DRAWING TITLE
LEVELS PLAN
SHEET 3 OF 13

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN

DRAWING SHEET 21 OF 148 ISSUE No.-

DRAWING No. 9905412 SHEET No. 21 AMEND. A



AMENDMENT	DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A CONSTRUCTION ISSUE	19-9-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS

FIELD BOOK 9104 | FILENAME 1395-0

REFERENCE :- B.M. | DATUM : A.H.D.

ORIG. SPIKE IN BITUMEN
PT NO 9190
E1458.618 N 8194.328
RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE

PRINCIPAL ENGINEER – ROAD AND TRAFFIC DESIGN

ROAD AND TRAFFIC DESIGN :
PRINCIPAL ENGINEER – 3403 0543
SENIOR ENGINEER – 3403 0539
SENIOR DRAFTSMAN ROADS – 3403 0541
SENIOR DRAFTSMAN TRAFFIC – 3403 0547
FACSIMILE NUMBER – 3403 0507

CADD REFERENCE
9905412_021-033.DGN
XREF: 514BASE.518IT
VIEW: RESTORE PLOT4

PLAN CUSTODIAN

REGISTERED

MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED		7/2000

FILE No.

SERVICES FILE No.

ACQUISITION FILE No. N/A

SUR PLAN NO. N/A

Brisbane City

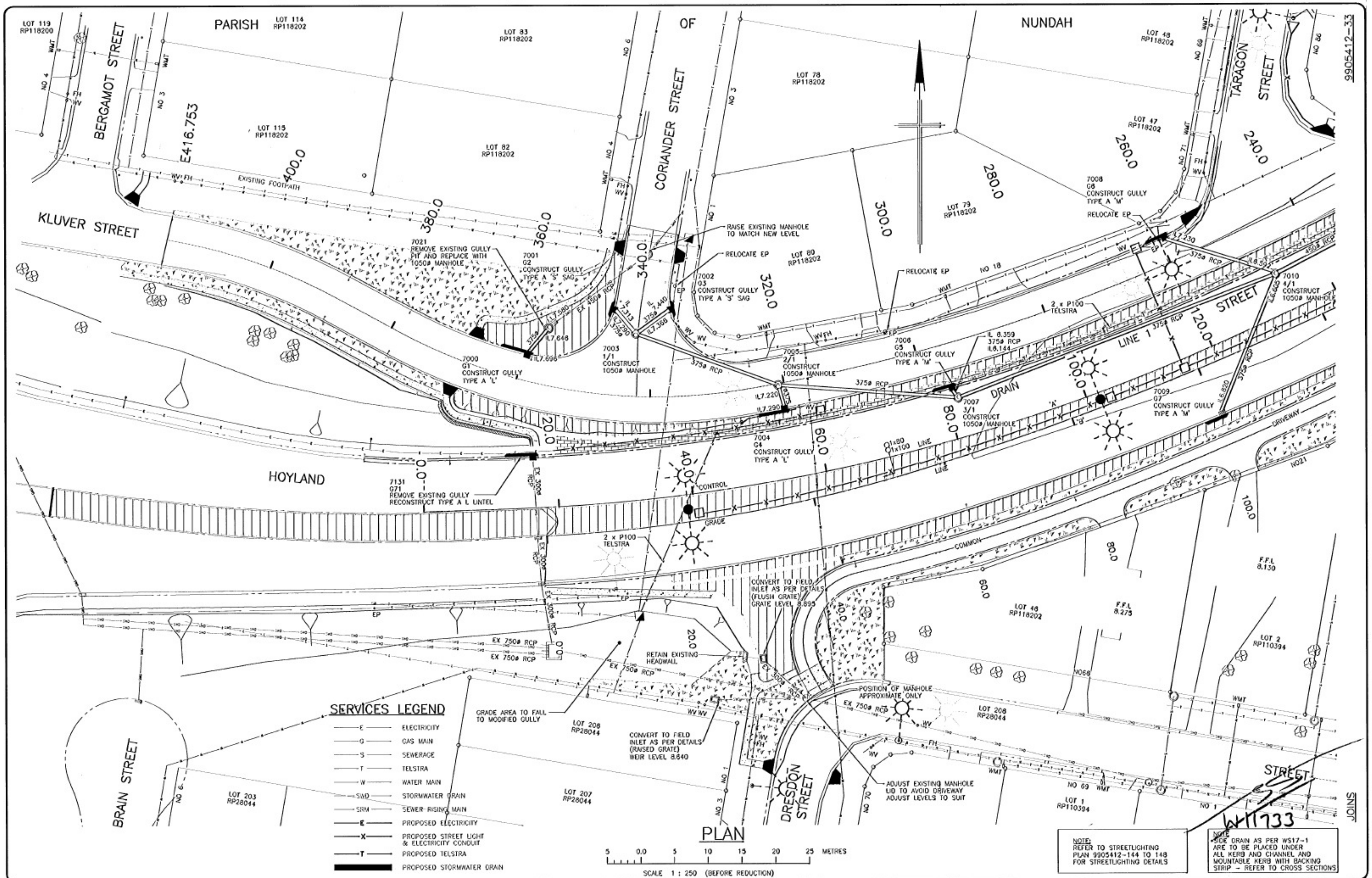
JOB
ROADWORKS AND DRAINAGE
HOYLAND STREET CONNECTION
BRACKEN RIDGE
GYMPIE ROAD TO BRACKEN RIDGE ROAD

DRAWING TITLE
LEVELS PLAN
SHEET 4 OF 13

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN

DRAWING SHEET 22 OF 148

DRAWING No. 9905412 | SHEET No. 22 | AMEND. A



AMENDMENT	DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A CONSTRUCTION ISSUE	19-9-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS

FIELD BOOK 9104 | FILENAME 1395-0

REFERENCE :- B.M. | DATUM : A.H.D.

ORIG. SPIKE IN BITUMEN
PT NO 9190
E1458.618 N 8194.328
RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE — PRINCIPAL ENGINEER - ROAD AND TRAFFIC DESIGN

CADD REFERENCE: 9905412_032-044.dwg

PLAN CUSTODIAN

REGISTERED

MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED		7/2000

FILE No.

SERVICES FILE No.

ACQUISITION FILE No. N/A

SUR PLAN NO. N/A

Brisbane City

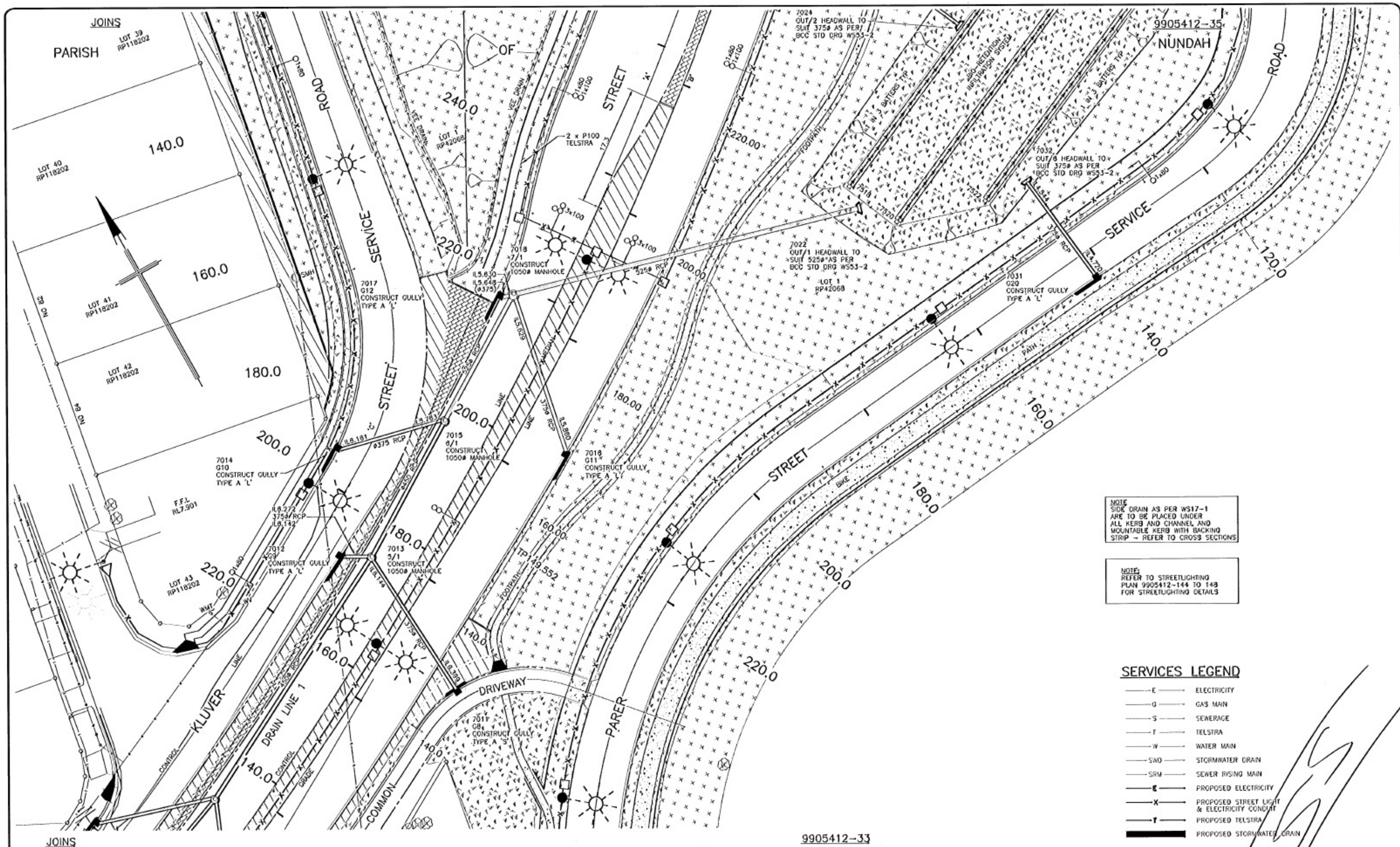
JOB: ROADWORKS AND DRAINAGE
HOYLAND STREET CONNECTION
BRACKEN RIDGE
GYMPIE ROAD TO BRACKEN RIDGE ROAD

DRAWING TITLE: DRAINAGE SERVICES AND SURFACE TREATMENT PLAN
SHEET 1 OF 13

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN

DRAWING SHEET 32 OF 148

DRAWING No. 9905412 | SHEET No. 32 | AMEND. A



PLAN

SCALE 1 : 250 (BEFORE REDUCTION) 0 5 10 15 20 25 METRES

AMENDMENT	DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A CONSTRUCTION ISSUE	19-9-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS
FIELD BOOK 9104 FILENAME 1395-0
REFERENCE :- B.M. DATUM : A.H.D.
ORIG. SPIKE IN BITUMEN PT NO 3190 E1458.618 N 8194.328 RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE — PRINCIPAL ENGINEER - ROAD AND TRAFFIC DESIGN

CADD REFERENCE: 9905412_032-044.dwg
PLAN CUSTODIAN
REGISTERED
MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED		7/2000

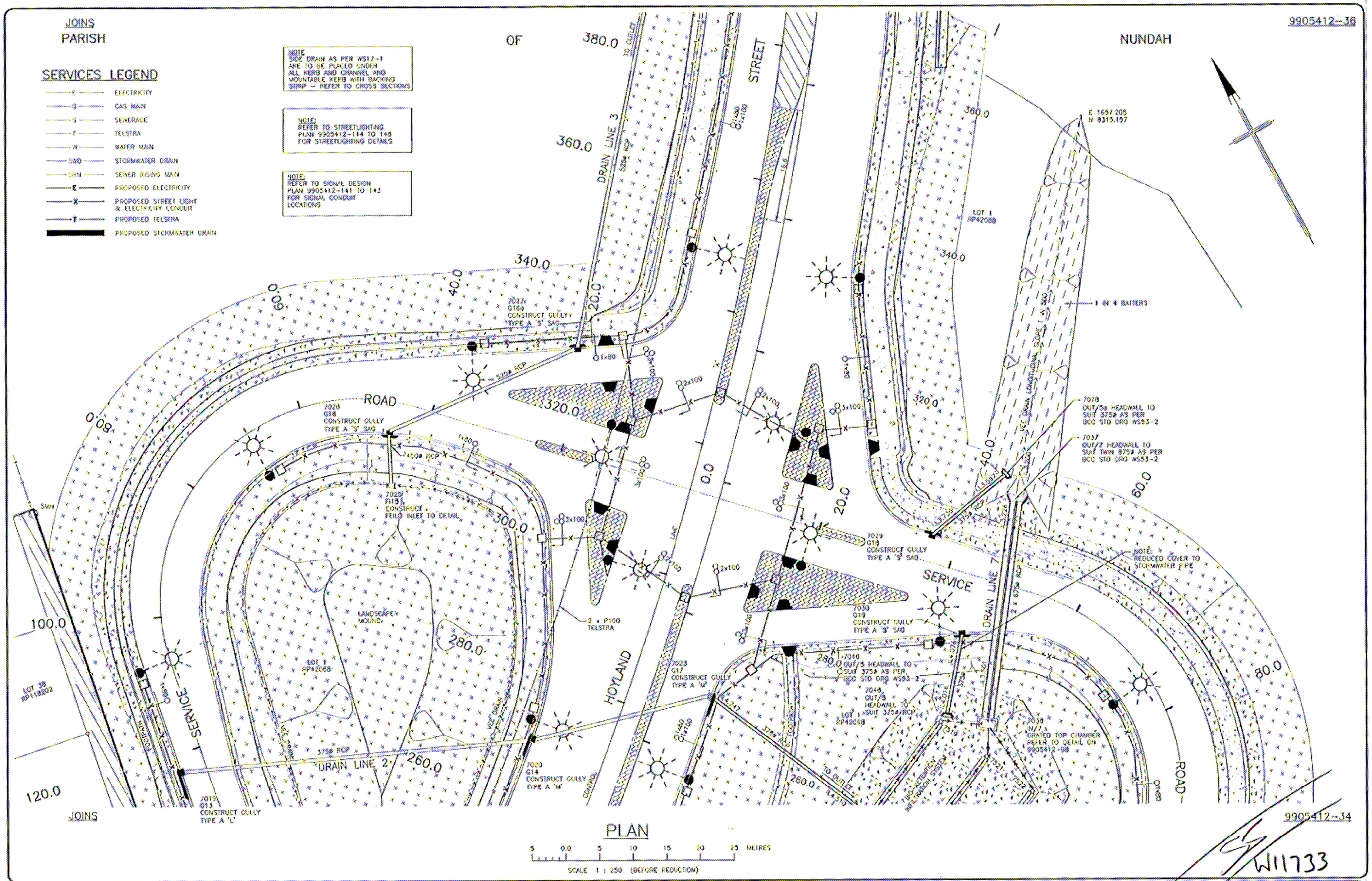
FILE No.
SERVICES FILE No.
ACQUISITION FILE No. N/A
SUR PLAN NO. N/A

Brisbane City

JOB: ROADWORKS AND DRAINAGE HOYLAND STREET CONNECTION BRACKEN RIDGE GYMPIE ROAD TO BRACKEN RIDGE ROAD

DRAWING TITLE: DRAINAGE SERVICES AND SURFACE TREATMENT PLAN SHEET 3 OF 13

BRISBANE CITY COUNCIL CITY DESIGN ROAD AND TRAFFIC DESIGN
DRAWING SHEET 34 OF 148
DRAWING No. 9905412 SHEET No. 34 AMEND. A



AMENDMENT		DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A	CONSTRUCTION ISSUE	19-9-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS

FIELD BOOK 9104 — FILENAME 1395-0

REFERENCE :- B.M. — DATUM : A.H.D.

ORIG. SPIKE IN BITUMEN PT NO 3190 E1458.618 N 8104.328 RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE

CADD REFERENCE: 9905412_032-044.dwg

PLAN CUSTODIAN

REGISTERED

MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED		7/2000

FILE No. — SERVICES FILE No. — ACQUISITION FILE No. N/A — SUR PLAN NO. N/A

Brisbane City

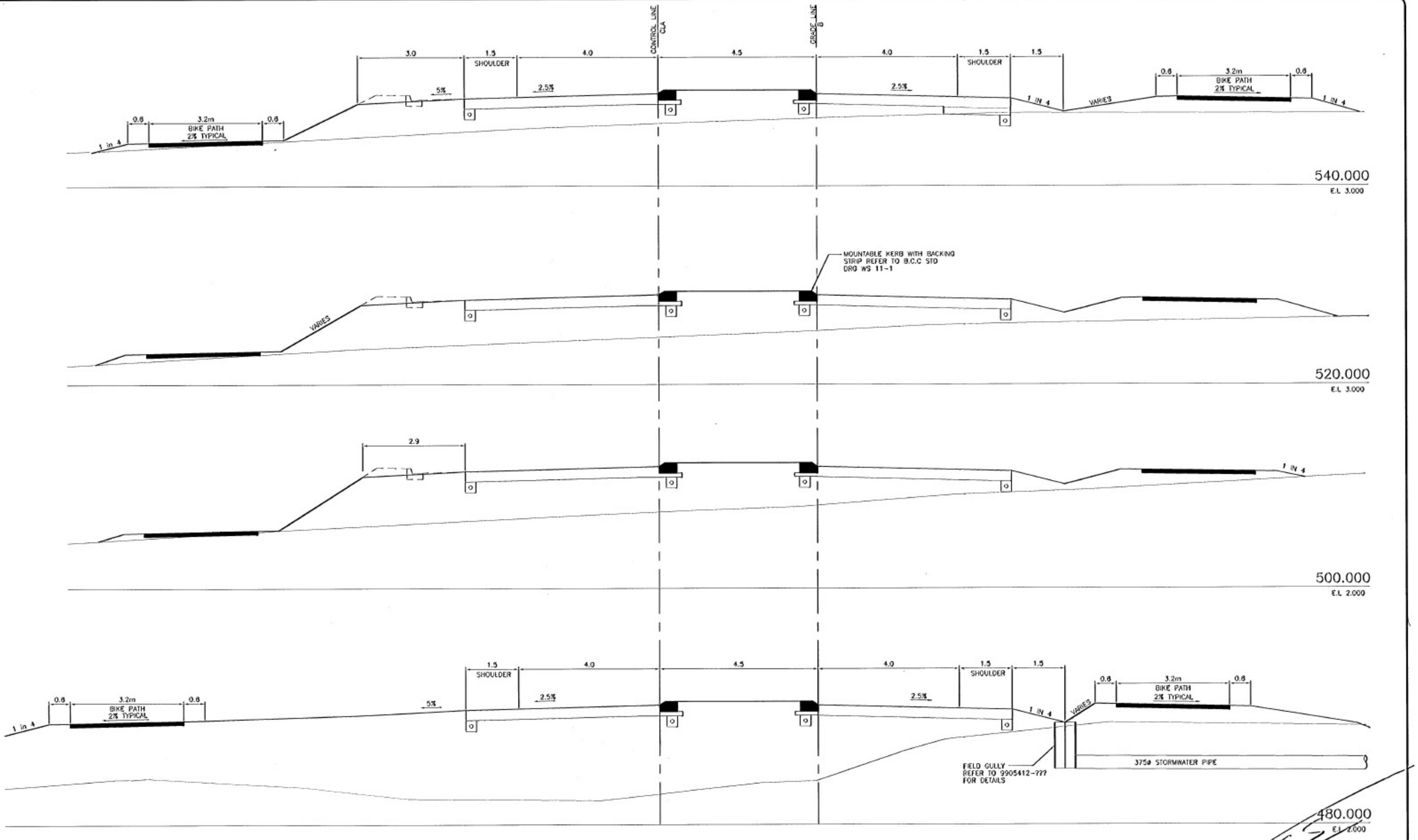
JOB: ROADWORKS AND DRAINAGE HOYLAND STREET CONNECTION BRACKEN RIDGE GYMPIE ROAD TO BRACKEN RIDGE ROAD

DRAWING TITLE: DRAINAGE SERVICES AND SURFACE TREATMENT PLAN SHEET 4 OF 13

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN

DRAWING SHEET 35 OF 148

DRAWING No. 9905412 — SHEET No. 35 — AMEND. A



ROAD CROSS SECTIONS
HOYLAND STREET

SCALE 1 : 50 (BEFORE REDUCTION) — 1 0 1 2 3 4 5 METRES

W11733

AMENDMENT		DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A	CONSTRUCTION ISSUE	19-9-00	HLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS
FIELD BOOK 9104 FILENAME 1395-0
REFERENCE :- B.M. DATUM : A.H.D.
ORIG. SPIKE IN BITUMEN
PT NO 9190
E1458.618 N 8194.328
RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE
DATE 20/9/00
PRINCIPAL ENGINEER – ROAD AND TRAFFIC DESIGN
ROAD AND TRAFFIC DESIGN :
PRINCIPAL ENGINEER – 3403 0543
SENIOR ENGINEER – 3403 0539
SENIOR DRAFTSMAN ROADS – 3403 0541
SENIOR DRAFTSMAN TRAFFIC – 3403 0547
FACSIMILE NUMBER – 3403 0507

CADD REFERENCE: 9905412_056-078.dwg
PLAN CUSTODIAN
REGISTERED
MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED	RJL	7/2000

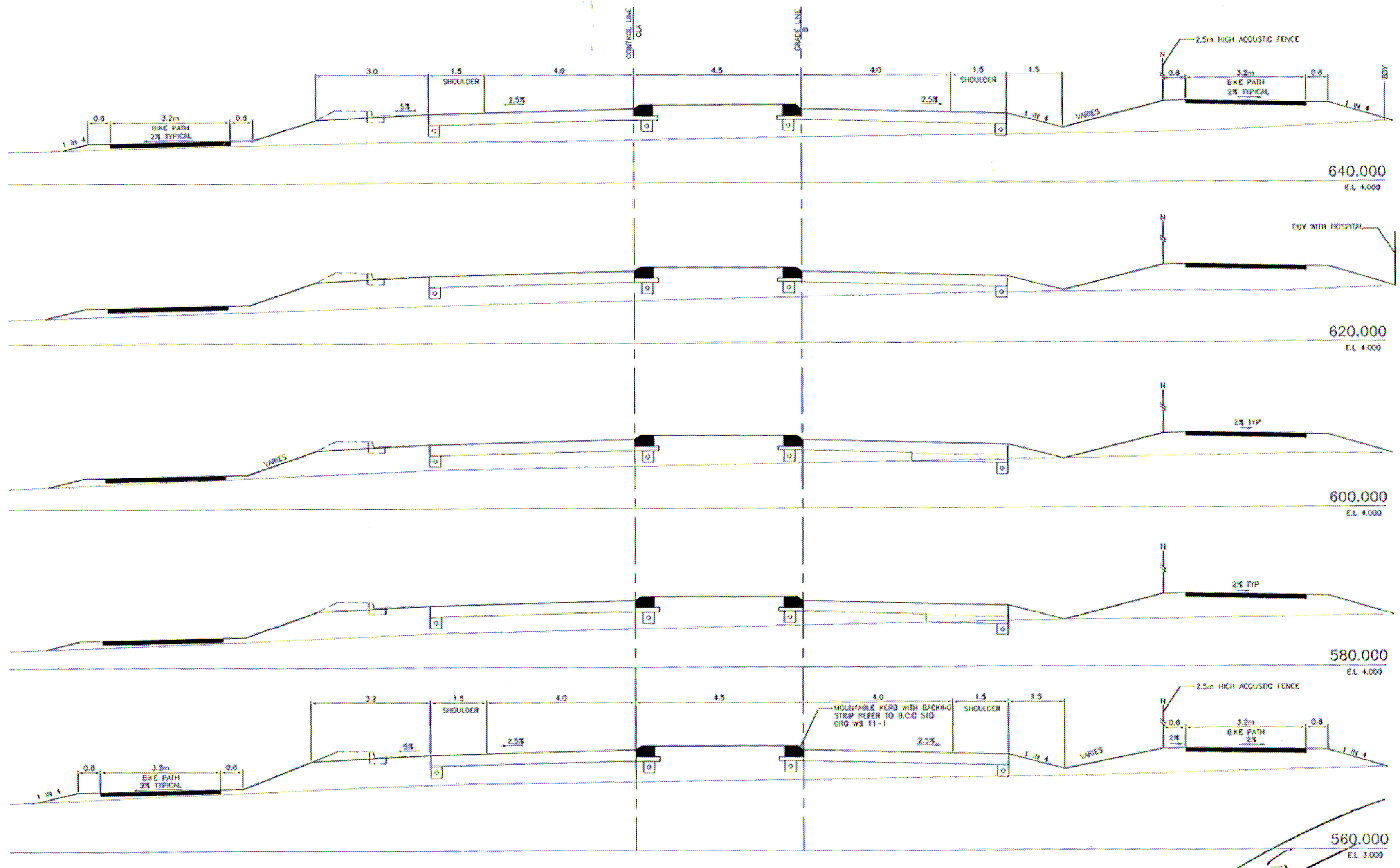
FILE No.
SERVICES FILE No.
ACQUISITION FILE No. N/A
SUR PLAN NO. N/A

Brisbane City

JOB
ROADWORKS AND DRAINAGE
HOYLAND STREET CONNECTION
BRACKEN RIDGE
GYMPIE ROAD TO
BRACKEN RIDGE ROAD

DRAWING TITLE
CROSS SECTIONS
HOYLAND STREET
CH480 – CH540.0
SHEET 6 OF 23

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN
DRAWING SHEET 59 OF 148 ISSUE No.
DRAWING No. 9905412 SHEET No. 59 AMEND. A



ROAD CROSS SECTIONS
HOYLAND STREET

SCALE 1 : 50 (BEFORE REDUCTION) — 1 0 1 2 3 4 5 METRES

W11733

AMENDMENT		DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A	CONSTRUCTION ISSUE	19-9-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS
FIELD BOOK 9104 | FILENAME 1395-0
REFERENCE :- B.M. | DATUM : A.H.D.
ORIG. SPIKE IN BITUMEN
PT NO 9190
E158,618 N 8194.328
RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE
DATE
PRINCIPAL ENGINEER – ROAD AND TRAFFIC DESIGN

CADD REFERENCE
PLAN CUSTODIAN
REGISTERED
MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	B.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED		7/2000

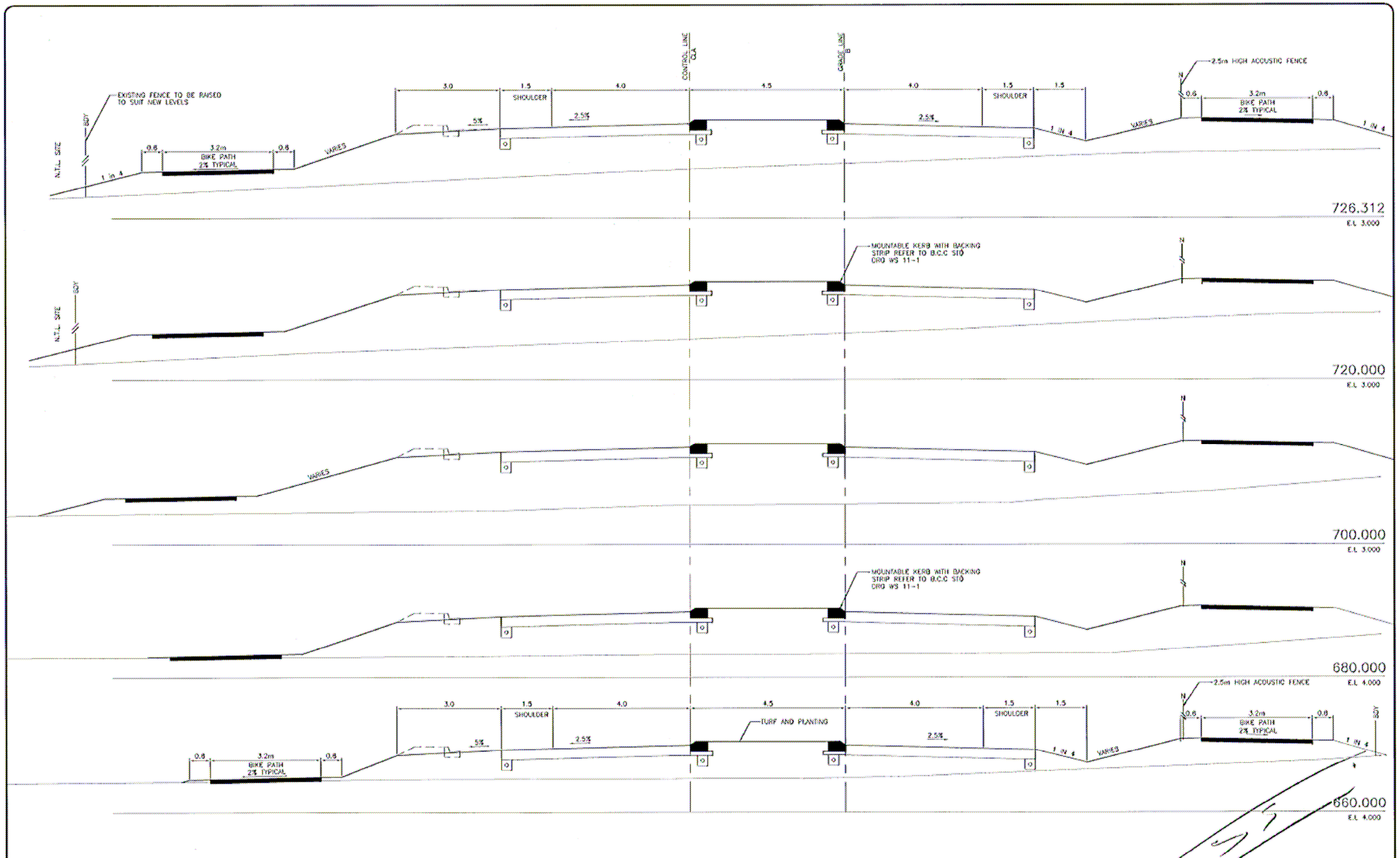
FILE No.
SERVICES FILE No.
ACQUISITION FILE No. N/A
SUR PLAN NO. N/A

Brisbane City

JOB
ROADWORKS AND DRAINAGE
HOYLAND STREET CONNECTION
BRACKEN RIDGE
GYMPIE ROAD TO
BRACKEN RIDGE ROAD

DRAWING TITLE
CROSS SECTIONS
HOYLAND STREET
CH560.0 – CH640.0
SHEET 7 OF 23

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN
DRAWING SHEET 60 OF 148
DRAWING No. 9905412 | SHEET No. 60 | AMEND. A



ROAD CROSS SECTIONS
HOYLAND STREET

AMENDMENT	DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A CONSTRUCTION ISSUE	19-9-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS
FIELD BOOK 9104 FILENAME 1395-0
REFERENCE :- B.M. DATUM : A.H.D.
ORIG. SPIKE IN BITUMEN PT NO 9190 E1458.618 N 8194.328 RL 7.092

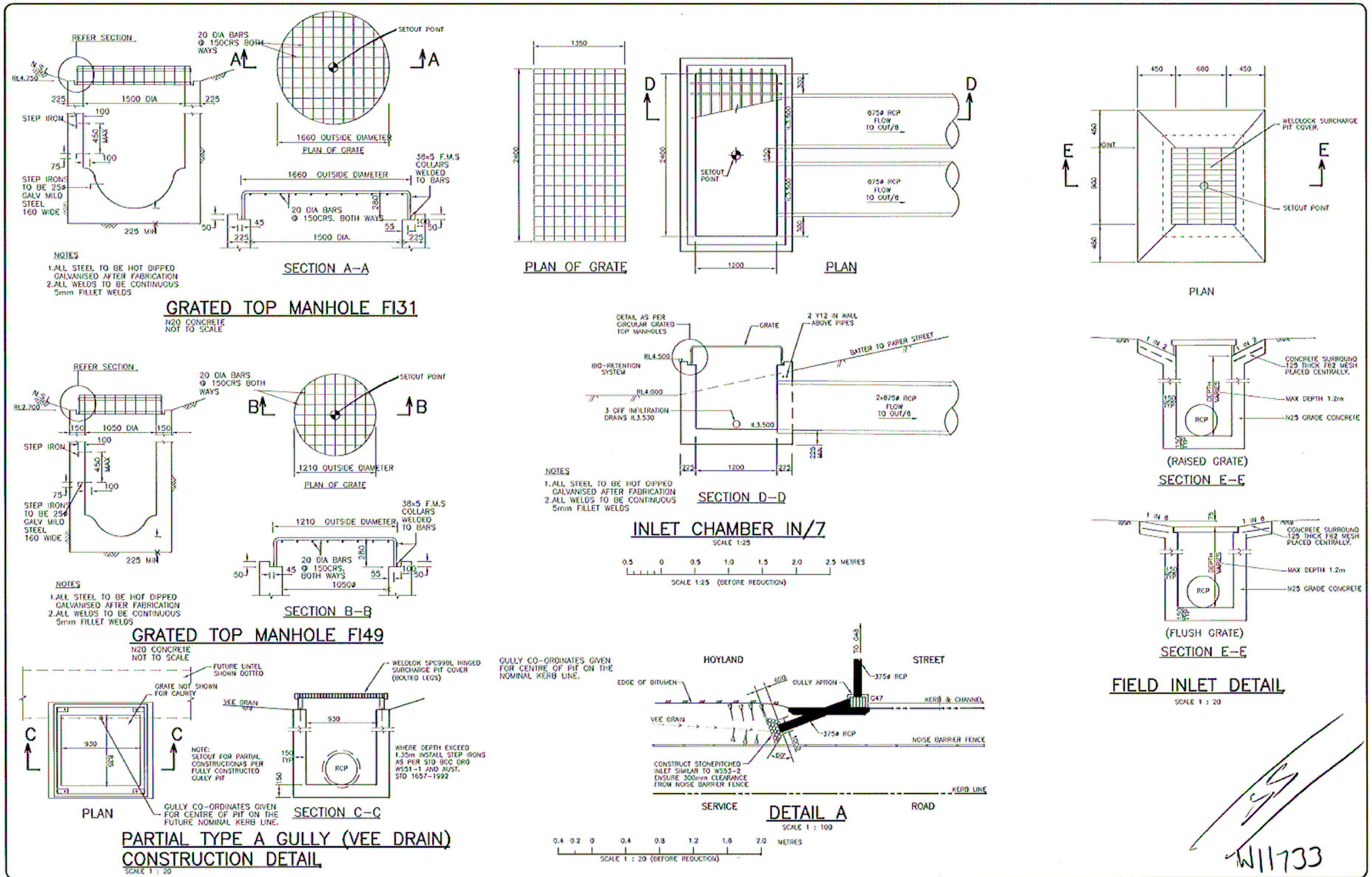
DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED		7/2000

ACQUISITION FILE No. N/A
SUR PLAN NO. N/A

JOB: ROADWORKS AND DRAINAGE HOYLAND STREET CONNECTION BRACKEN RIDGE GYMPIE ROAD TO BRACKEN RIDGE ROAD

DRAWING TITLE: CROSS SECTIONS HOYLAND STREET CH660.0 - CH726.312 SHEET 8 OF 23

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN
DRAWING SHEET 61 OF 148
DRAWING No. 9905412 SHEET No. 61 AMEND. A



AMENDMENT	DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A CONSTRUCTION ISSUE	19-9-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS

FIELD BOOK 9104 FILENAME 1395–0

REFERENCE :- B.M. DATUM : A.H.D.

ORIG. SPIKE IN BITUMEN PT NO 9190 E1458.618 N 8194.328 RL 7.692

CADD REFERENCE: 9905412_102-108.dwg

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.M.	7/2000
TRACED	M.M.	7/2000
CHECKED		7/2000

ACQUISITION FILE No. N/A
SUR PLAN NO. N/A

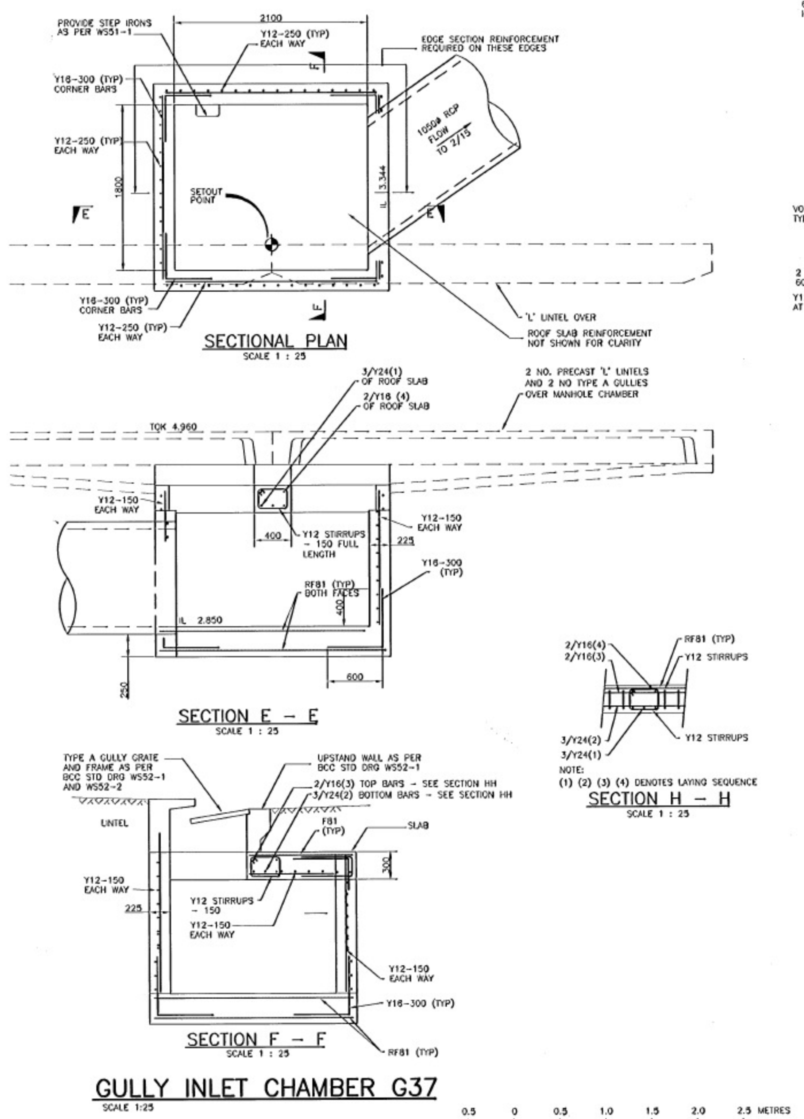
JOB: ROADWORKS AND DRAINAGE
HOYLAND STREET CONNECTION
BRACKEN RIDGE
GYMPIE ROAD TO BRACKEN RIDGE ROAD

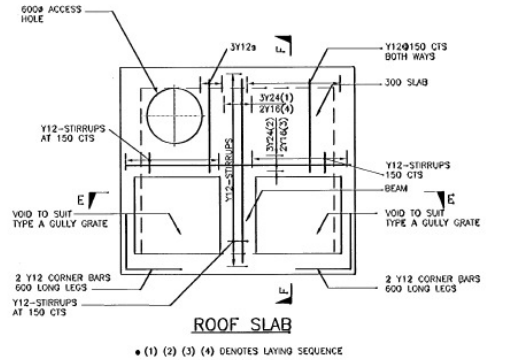
DRAWING TITLE: DETAILS SHEET 1 OF 7

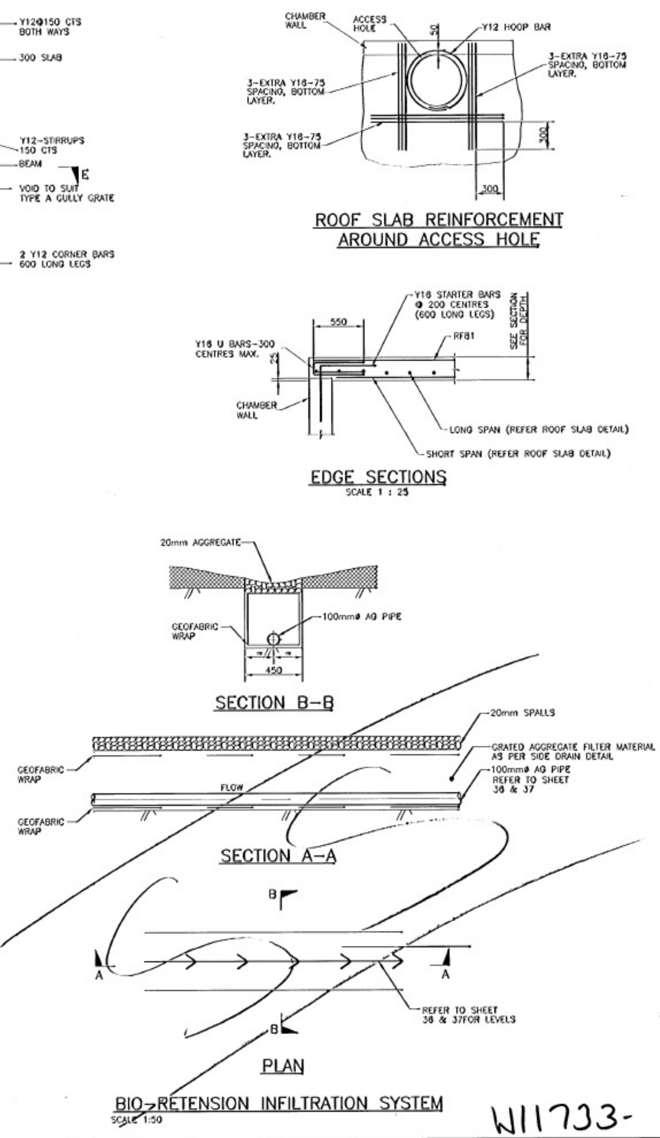
BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN

DRAWING SHEET 98 OF 148

DRAWING No. 9905412 SHEET No. 98 AMEND. A







MANHOLE CHAMBER NOTES:

1 CONCRETE CONSTRUCTION TO BE IN ACCORDANCE WITH AS 3600

2 FORMWORK SHALL BE DESIGNED AND CONSTRUCTED IN ACCORDANCE WITH AS 3610

3 ALL CONCRETE TO BE GRADE N32. 80mm SLUMP NOMINAL AGGREGATE SIZE OF 20mm

4 ALL LAPS IN REINFORCEMENT SHALL BE: Y12 - 300, Y16 - 500

5 MINIMUM CLEAR COVER TO REINFORCEMENT SHALL BE 45mm

6 COVER TO REINFORCEMENT SHALL BE MAINTAINED DURING POURING BY THE USE OF APPROVED PLASTIC CHAIRS

7 DESIGNED TO "AUSTROADS - BRIDGE DESIGN CODE 1992"

8 MANHOLE CHAMBER ROOF SLABS HAVE BEEN DESIGNED TO BE CAST INSITU WITH REINFORCEMENT SPANNING TWO WAYS. IF ROOF SLABS ARE TO BE PRECAST IN SECTIONS THEY WILL NEED TO BE REDESIGNED.

9 EXPOSED CONCRETE ON CHAMBERS 1/1, 2/1, 3/1, 10/1, and 11/1 TO BE PAINTED HERITAGE GREEN

W11733-

AMENDMENT	DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A CONSTRUCTION ISSUE	19-9-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS
FIELD BOOK 9104 FILENAME 1395-0
REFERENCE :- B.M. DATUM : A.H.D.
ORIG. SPIKE IN BITUMEN PT NO 9190 E1458.618 N 8194.328 RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE
PRINCIPAL ENGINEER - ROAD AND TRAFFIC DESIGN DATE
ROAD AND TRAFFIC DESIGN :
PRINCIPAL ENGINEER - 3403 0543
SENIOR ENGINEER - 3403 0539
SENIOR DRAFTSMAN ROADS - 3403 0541
SENIOR DRAFTSMAN TRAFFIC - 3403 0547
FACSIMILE NUMBER - 3403 0307

CADD REFERENCE 9905412_102-108.dwg
PLAN CUSTODIAN
REGISTERED
MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED	RJL	7/2000

FILE No.
SERVICES FILE No.
ACQUISITION FILE No. N/A
SUR PLAN NO. N/A

Brisbane City

JOB
ROADWORKS AND DRAINAGE
HOYLAND STREET CONNECTION
BRACKEN RIDGE
GYMPIE ROAD TO BRACKEN RIDGE ROAD

DRAWING TITLE
DETAILS
SHEET 4 OF 7

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN
DRAWING SHEET 101 OF 148 ISSUE No.-
DRAWING No. 9905412 SHEET No. 101 AMEND. A

SETOUT CO-ORDINATES

POINT Nº	EASTING	NORTHING	ELEVATION
3800	2795.020	8908.742	8.517
3801	2804.888	8905.123	8.732
3802	2814.757	8903.503	8.904
3803	2824.625	8901.884	9.049
3804	2834.493	8900.264	9.194
3805	2844.361	8898.645	9.292
3806	2854.230	8897.025	9.305
3807	2864.128	8895.573	9.275
3808	2874.023	8894.121	9.211
3809	2883.802	8892.687	9.137
3810	2893.803	8891.219	9.016
3811	2952.412	8877.849	7.784
3812	2962.266	8876.146	7.649
3813	2972.127	8874.484	7.515
3814	2981.987	8872.814	7.418
3815	2991.847	8871.145	7.320
3816	3001.703	8869.454	7.224
3817	3011.558	8867.759	7.115
3818	3021.414	8866.064	7.094
3819	3031.269	8864.369	7.033
3820	3041.124	8862.674	6.972
3821	3046.433	8861.761	6.940
3822	2438.347	8948.787	4.099
3823	2437.242	8949.028	4.080
3824	1607.377	8292.497	5.171
3825	1562.489	8324.438	5.349
3826	1649.706	8364.098	4.955
3827	2762.912	8888.225	7.804
3828	3059.526	8859.510	D.O.S
3829	1463.552	8201.877	7.420
3830	1628.613	8342.464	5.150
3831	2270.285	8991.176	3.832

LEVEL SETOUT CO-ORDINATES PATHWAYS

POINT Nº	EASTING	NORTHING	ELEVATION
4000	1626.775	8365.083	5.051
4001	1628.770	8367.562	5.057
4002	1630.915	8370.264	5.060
4003	1632.577	8372.793	5.080
4004	1637.875	8381.087	5.081
4005	1643.006	8389.485	5.113
4006	1649.114	8400.005	5.103
4007	1654.177	8412.870	5.098
4008	1659.133	8425.543	4.529
4009	1664.361	8434.906	4.181
4010	1669.087	8443.334	4.073
4011	1673.942	8452.065	4.135
4012	1678.817	8460.798	4.223
4013	1683.693	8469.527	4.311
4014	1688.568	8478.259	4.399
4015	1693.443	8486.990	4.487
4016	1698.319	8495.721	4.575
4017	1703.194	8504.452	4.663
4018	1708.069	8513.183	4.725
4019	1712.944	8521.914	4.781
4020	1717.820	8530.646	4.838
4021	1722.695	8539.377	4.894
4022	1727.570	8548.108	4.950
4023	1732.446	8556.839	5.007
4024	1737.321	8565.570	5.063
4025	1742.198	8574.302	5.118
4026	1747.071	8583.033	5.121
4027	1751.947	8591.764	5.031
4028	1756.464	8600.693	4.864
4029	1760.833	8609.815	4.688
4030	1764.802	8618.936	4.526
4031	1769.173	8627.946	4.402
4032	1774.292	8636.543	4.356
4033	1779.552	8645.062	4.386
4034	1784.860	8653.659	4.405
4035	1787.095	8657.279	4.387
4036	1790.804	8662.860	4.326
4037	1798.363	8670.644	4.173
4038	1802.310	8678.973	3.989
4039	1808.247	8687.286	4.030
4040	1814.178	8695.592	4.238
4041	1820.108	8703.897	4.505
4042	1828.044	8712.208	4.647
4043	1831.989	8720.534	4.674
4044	1838.201	8728.432	4.683
4045	1844.593	8736.676	4.700
4046	1845.797	8737.939	4.703
4047	1851.714	8744.039	4.677
4048	1858.838	8751.384	4.642
4049	1863.442	8756.132	4.653
4050	1866.082	8758.662	4.659
4051	1873.697	8765.443	4.677
4052	1881.329	8772.239	4.696
4053	1888.957	8779.032	4.714
4054	1894.457	8783.930	4.727
4055	1897.393	8786.350	4.733
4056	1904.760	8791.968	4.750
4057	1912.877	8798.157	4.768
4058	1921.622	8804.824	4.787
4059	1929.328	8810.234	4.804
4060	1937.681	8816.099	4.823
4061	1946.040	8821.968	4.840
4062	1954.414	8827.846	4.859
4063	1956.715	8829.462	4.864
4064	1962.281	8832.840	4.875
4065	1972.150	8838.015	4.892
4066	1981.204	8842.754	4.859
4067	1990.257	8847.491	4.825

LEVEL SETOUT CO-ORDINATES PATHWAYS

POINT Nº	EASTING	NORTHING	ELEVATION
4068	1999.316	8852.232	4.791
4069	2007.356	8856.440	7.735
4070	2018.826	8861.553	4.545
4071	2027.332	8864.720	4.474
4072	2036.916	8868.290	4.481
4073	2046.323	8871.793	4.488
4074	2055.694	8875.283	4.495
4075	2065.066	8878.772	4.502
4076	2074.437	8882.262	4.508
4077	2083.808	8885.752	4.529
4078	2093.179	8889.242	4.579
4079	2102.551	8892.732	4.630
4080	2111.922	8898.222	4.480
4081	2121.293	8899.712	4.731
4082	2130.665	8903.201	4.720
4083	2140.036	8906.691	4.679
4084	2140.362	8910.227	4.610
4085	2141.924	8913.136	4.590
4086	2144.141	8914.643	4.570
4087	2147.448	8912.866	4.580
4088	2149.407	8910.181	4.640
4089	2158.778	8913.671	4.601
4090	2168.150	8917.161	4.562
4091	2177.521	8920.651	4.522
4092	2188.892	8924.141	4.440
4093	2198.264	8927.630	4.190
4094	2205.835	8931.120	4.013
4095	2215.008	8934.610	4.015
4096	2225.203	8938.408	4.024
4097	2237.389	8945.620	4.037
4098	2250.419	8956.873	4.052
4099	2251.849	8956.787	4.049
4100	2252.829	8955.652	3.858
4101	1647.621	8356.435	5.030
4102	1652.399	8368.068	5.071
4103	1660.550	8379.271	5.118
4104	1665.829	8387.260	5.150
4105	1672.514	8397.734	5.192
4106	1676.505	8404.938	5.219
4107	1681.351	8413.685	5.253
4108	1685.997	8422.069	5.288
4109	1691.044	8431.179	5.326
4110	1695.890	8439.927	5.365
4111	1700.736	8448.674	5.403
4112	1704.582	8455.615	5.433
4113	1705.600	8457.411	5.442
4114	1709.982	8464.314	5.468
4115	1715.214	8472.743	5.499
4116	1716.150	8474.432	5.511
4117	1720.996	8483.179	5.603
4118	1725.842	8491.926	5.703
4119	1730.688	8500.673	5.742
4120	1735.535	8509.421	5.781
4121	1740.381	8518.168	5.820
4122	1745.227	8526.915	5.858
4123	1750.073	8535.662	5.879
4124	1754.919	8544.410	5.937
4125	1759.766	8553.157	5.976
4126	1764.612	8561.904	6.013
4127	1769.458	8570.651	6.029
4128	1774.304	8579.399	5.989
4129	1779.150	8588.146	5.948
4130	1783.996	8596.893	5.909
4131	1788.843	8605.640	5.869
4132	1793.689	8614.388	5.825
4133	1798.535	8623.135	5.788
4134	1801.722	8628.885	5.762
4135	1803.327	8631.912	5.747

LEVEL SETOUT CO-ORDINATES PATHWAYS

POINT Nº	EASTING	NORTHING	ELEVATION
4136	1808.085	8640.577	5.707
4137	1812.929	8648.987	5.669
4138	1817.949	8657.253	5.630
4139	1823.143	8665.431	5.591
4140	1828.509	8673.497	5.552
4141	1834.044	8681.448	5.512
4142	1839.746	8689.281	5.474
4143	1845.612	8698.991	5.434
4144	1851.640	8704.575	5.393
4145	1854.428	8707.975	5.355
4146	1857.120	8710.801	5.290
4147	1861.000	8714.348	5.141
4148	2441.277	8933.747	4.158
4149	2444.514	8942.219	4.088
4150	2452.707	8943.515	4.150
4151	2452.165	8940.057	4.175
4152	2759.513	8873.256	8.160
4153	2763.670	8880.095	8.130
4154	2763.544	8886.456	7.915
4155	2770.377	8884.894	7.950
4156	2774.693	8888.920	7.889
4157	1320.406	8169.301	9.949
4158	1319.539	8170.942	9.705
4159	1314.003	8172.188	9.310
4160	1313.027	8172.407	9.287
4161	1309.450	8173.212	9.029
4162	1307.110	8176.030	8.943

LEVEL SETOUT CO-ORDINATES COMMON DRIVEWAY

POINT Nº	EASTING	NORTHING	ELEVATION
5000	1483.939	8184.575	7.503
5001	1482.161	8186.337	7.478
5002	1472.448	8190.780	7.408
5003	1461.874	8189.265	7.430
5004	1460.860	8188.765	4.442
5005	1452.935	8184.649	7.545
5006	1444.002	8180.216	7.660
5007	1434.985	8175.958	7.776
5008	1425.887	8171.877	7.891
5009	1416.712	8167.973	8.007
5010	1407.462	8164.248	8.123
5011	1400.603	8161.620	8.204
5012	1398.146	8160.713	8.239
5013	1388.735	8157.516	8.380
5014	1379.200	8154.707	8.580
5015	1369.558	8152.291	8.747
5016	1368.095	8151.960	8.759
5017	1360.503	8148.389	8.801
5018	1359.987	8135.692	8.884
5019	1359.841	8135.298	8.864
5020	1360.161	8134.685	8.875
5021	1362.745	8137.234	8.958
5022	1401.288	8158.459	8.294
5023	1404.426	8157.174	8.308
5024	1408.048	8158.899	8.286
5025	1409.182	8161.485	8.291
5026	1419.795	8165.802	8.064
5027	1424.029	8164.109	8.142
5028	1427.807	8165.447	8.079
5029	1427.612	8165.905	8.081
5030	1429.161	8169.820	8.023
5031	1441.910	8175.664	7.868
5032	1444.574	8174.716	7.805
5033	1445.275	8173.243	7.818
5034	1449.298	8175.543	7.757
5035	1448.713	8176.725	7.757
5036	1449.618	8179.404	7.780
5037	1481.506	8182.496	7.371

LEVEL SETOUT CO-ORDINATES ACOUSTIC FENCE SETOUT

POINT Nº	EASTING	NORTHING
6000	1323.545	8170.817
6001	1332.231	8169.721
6002	1338.581	8170.430
6003	1413.784	8190.257
6004	1320.914	8146.880
6005	1341.506	8146.424
6006	1340.787	8148.936
6007	1400.103	8162.954
6008	1466.760	8193.569
6009	1469.328	8193.771
6010	1471.903	8193.667
6011	1474.447	8193.260
6012	1476.550	8222.187
6013	1498.701	8244.323
6014	1470.931	8234.248
6015	1474.389	8254.270
6016	1477.650	8249.647
6017	1492.709	8336.848
6018	1711.906	8469.028
6019	1805.359	8638.001
6020	2047.003	8846.156
6021	2287.013	8928.106
6022	2266.060	8925.283
6023	2270.558	8926.959
6024	2269.751	8929.125
6025	2315.294	8946.090

SETOUT CO-ORDINATES RETAINING WALLS

POINT Nº	EASTING	NORTHING
6501	1307.751	8173.818
6502	1309.373	8172.916
6503	1319.678	8170.604
6504	1320.069	8170.136
6505	1320.101	8169.288
6506	1791.292	8662.512
6507	1826.518	8711.840
6508	2198.865	8936.398
6509	2199.919	8936.352
6510	2213.375	8941.012
6511	2215.884	8943.030

NOTE: SETOUT TO TOE OF WALL

LEVEL SETOUT CO-ORDINATES BIO-RETENSION INFILTRATION SYSTEM

POINT Nº	EASTING	NORTHING	ELEVATION
7500	1552.472	8226.870	4.900
7501	1561.589	8230.980	4.707
7502	1570.705	8235.090	4.513
7503	1579.822	8239.200	4.320
7504	1588.938	8243.310	4.126
7505	1594.881	8245.989	4.000
7506	1597.616	8243.835	4.017
7507	1602.598	8239.915	4.047
7508	1602.548	8236.253	4.065
7509	1602.452	8228.976	4.100
7510	1599.970	8227.858	4.176
7511	1590.852	8223.751	4.453
7512	1581.734	8219.644	4.731
7513	1572.617	8215.537	5.008
7514	1569.606	8214.182	5.100
7515	1563.199	8216.136	5.052
7516	1556.172	8218.278	5.000
7517	1555.123	8220.716	4.972
7518	1553.256	8226.405	4.890
7519	1594.754	8245.064	4.021
7520	1556.742	8218.652	4.995
7521	1598.240	8237.312	4.098
7522	1569.348	8215.001	5.058
7523	1601.726	8229.559	4.118

LEVEL SETOUT CO-ORDINATES LANDSCAPE MOUND

POINT Nº	EASTING	NORTHING	ELEVATION
8500	1516.820	8275.356	8.217
8501	1522.755	8303.578	8.217
8502	1530.419	8306.711	8.217
8503	1536.843	8302.432	7.488
8504	1535.279	8293.090	7.714
8505	1533.387	8290.148	7.820
8506	1531.143	8287.466	7.926
8507	1528.543	8285.051	8.032
8508	1516.818	8275.356	8.217
8509	1500.627	8245.436	6.737
8510	1537.895	8298.660	7.552

W11733

TABLES

AMENDMENT		DATE	CHECKED	AUTHOR.	AS CONST.	MICRO
A	CONSTRUCTION ISSUE	19-9-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS
FIELD BOOK 9104 FILENAME 1395-0
REFERENCE :- B.M. DATUM : A.H.D.
ORIG. SPIKE IN BITUMEN
PT NO 9190
E1458.618 N 8194.328
RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE
PRINCIPAL ENGINEER – ROAD AND TRAFFIC DESIGN DATE
ROAD AND TRAFFIC DESIGN :
PRINCIPAL ENGINEER – 3403 0543
SENIOR ENGINEER – 3403 0539
SENIOR DRAFTSMAN ROADS – 3403 0541
SENIOR DRAFTSMAN TRAFFIC – 3403 0547
FACSIMILE NUMBER – 3403 0507

CADD REFERENCE 9905412_105-112 XREF 5181IT
PLAN CUSTODIAN
REGISTERED
MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.I.M.	7/2000
TRACED	M.I.M.	7/2000
CHECKED	ADL	7/2000

FILE No.
SERVICES FILE No.
ACQUISITION FILE No. N/A
SUB PLAN NO. N/A

Brisbane City

JOB
ROADWORKS AND DRAINAGE
HOYLAND STREET CONNECTION
BRACKEN RIDGE
GYMPIE ROAD TO BRACKEN RIDGE ROAD

DRAWING TITLE
TABLES
SHEET 5 OF 8

BRISBANE CITY COUNCIL
CITY DESIGN
ROAD AND TRAFFIC DESIGN
DRAWING SHEET 109 OF 148 ISSUE No.-
DRAWING No. 9905412 SHEET No. 109 AMEND. A

GULLY SETOUT TABLE

POINT Nº	GULLY NUMBER	EASTING	NORTHING	DESCRIPTION	LIP LEVEL	LENGTH	CONNECTION SIZE (mm)	FUTURE LIP LEVEL WHERE APPLICABLE
7000	G1	1319.668	8182.914	L LINTEL	8.731	5.00	375	
7001	G2	1332.583	8189.250	S LINTEL (SAG)	8.397	5.70	375	
7002	G3	1340.651	8189.380	S LINTEL (SAG)	8.428	6.50	375	
7004	G4	1357.771	8174.554	L LINTEL	8.370	3.50	375	
7006	G5	1382.449	8177.926	M LINTEL	8.363	2.00	375	
7008	G6	1413.849	8200.091	M LINTEL	8.276	17.50	375	
7009	G7	1422.544	8173.598	M LINTEL	7.785	22.00	375	
7011	G8	1468.373	8191.226	S LINTEL (SAG)	7.391	22.50	375	
7012	G9	1463.187	8215.966	L LINTEL	7.583	4.50	375	
7014	G10	1470.293	8229.922	L LINTEL	7.285	16.00	375	
7016	G11	1498.758	8212.719	L LINTEL	6.829	29.00	375	
7017	G12	1501.469	8237.531	L LINTEL	6.646	1.60	375	
7019	G13	1492.178	8292.643	L LINTEL	6.200	52.50	375	
7020	G14	1540.282	8272.112	M LINTEL	5.951	27.00	375	
7025	F115	1539.986	8314.743	FIELD INLET	5.000	7.50	450	
7026	G16	1543.324	8321.266	S LINTEL (SAG)	4.934	30.50	525	
7027	G16a	1574.034	8319.383	S LINTEL (SAG)	5.098	81.00	525	
7028	G17	1566.795	8264.396	M LINTEL	5.881	30.00	375	
7029	G18	1607.041	8270.002	S LINTEL (SAG)	5.083	14.00	375	
7030	G19	1603.662	8254.738	S LINTEL (SAG)	5.034	11.50	375	
7031	G20	1578.010	8197.318	L LINTEL	5.985	16.50	375	
7033	G21	1443.098	8122.757	L LINTEL	7.627	17.00	375	
7034	G22	1459.447	8131.892	S LINTEL	7.411	16.50	375	
7036	IN/7	1600.615	8241.486	GRATED TOP MANHOLE REFER DETAIL	4.500	33.00	TWIN 675	
7038	G23	1639.793	8343.075	S LINTEL	4.877	8.50	375	
7039	G24	1630.536	8368.077	S LINTEL	4.951	14.00	375	
7040	G25	1684.292	8423.529	P/C FUTURE L	4.823	11.00	375	5.206
7042	G26	DELETED						
7044	G27	1744.111	8531.649	P/C FUTURE S	5.470	42.00	375	5.684
7045	G28	1723.701	8494.746	P/C FUTURE M	5.413	18.00	375	5.521
7046	G29	1707.538	8503.746	P/C FUTURE L	5.496	12.40	375	5.528
7048	IN/13a	1792.291	8599.680	FIELD INLET	5.200	11.50	375	
7049	G30	1787.469	8610.054	P/C FUTURE M	5.543	35.00	375	5.670
7050	F131	1808.637	8627.205	GRATED TOP MANHLE 1500 DIA	4.745	39.50	900	
7053	G31	1807.072	8645.396	P/C FUTURE S	5.290	14.70	375	5.508
7054	G32	1791.087	8634.683	P/C FUTURE L	5.479	10.00	375	5.309

GULLY SETOUT TABLE –CONTINUED

POINT Nº	GULLY NUMBER	EASTING	NORTHING	DESCRIPTION	LIP LEVEL	LENGTH	CONNECTION SIZE (mm)	FUTURE LIP LEVEL WHERE APPLICABLE
7056	G33	1829.341	8680.423	P/C FUTURE S	5.297	40.30	375	5.539
7057	G34	1853.932	8712.454	P/C FUTURE S	5.033	7.00	375	5.176
7058	G35	1839.763	8724.367	P/C FUTURE L	5.147	14.00	375	5.174
7060	G36	1878.258	8732.550	GULLY CHAMBER	4.870	14.50	1050	
7062	G37	1890.340	8733.356	GULLY CHAMBER	4.921	26.00	1050	
7064	G38	1897.435	8748.461	S LINTEL	4.843	7.00	375	
7065	G39	1907.644	8735.383	M LINTEL	4.955	OVER EXIST		
7066	G40	1916.432	8744.725	L LINTEL	4.885	OVER EXIST		
7067	G41	1909.920	8768.545	P/C FUTURE S	4.464	5.00	375	4.926
7069	G42	1899.922	8784.304	P/C FUTURE S	4.900	6.50	375	4.926
7072	G43	1996.747	8826.319	P/C FUTURE L	5.036	18.00	375	5.271
7073	G44	1988.291	8842.773	P/C FUTURE M	5.250	29.50	375	5.269
7075	G45	2131.415	8887.333	P/C FUTURE L	5.012	17.75	375	5.136
7076	G46	2144.959	8904.652	L LINTEL	5.129	39.00	375	
7079	G47	2229.131	8916.263	S LINTEL	4.565	17.75	375	
7080	G48	2222.708	8933.612	S LINTEL	4.567	13.00	375	
7084	F149	2274.428	8984.343	GRATED TOP MANHOLE 1050 DIA	2.650	42.00	525	
7085	G50	2237.050	9008.376	S LINTEL (SAG)	2.782	9.00	375	
7086	G51	2234.856	8999.056	S LINTEL (SAG)	2.769	9.00	375	
7089	G52	2346.754	8957.388	M LINTEL (SAG)	3.836	2.00	375	
7091	G53	2339.758	8974.743	M LINTEL (SAG)	3.839	33.00	375	
7096	G54	2445.125	8943.819	S LINTEL (SAG)	3.961	6.00	375	
7098	G55	2465.999	8937.694	S LINTEL	4.011	5.00	375	
7097	G56	2461.138	8949.497	S LINTEL (SAG)	3.979	10.00	375	
7095	G57	2438.893	8925.600	L LINTEL	4.209	OVER EXIST		
7100	G58	2466.065	8948.898	L LINTEL	3.947	9.00	375	
7101	G59	2514.401	8943.022	S LINTEL (SAG)	3.697	2.00	375	
7104	G60	2565.677	8936.575	S LINTEL (SAG)	3.745	13.00	375	
7103	G61	2569.617	8953.731	S LINTEL (SAG)	3.728	10.00	375	
7107	G62	2559.867	8955.388	S LINTEL	4.598	8.00	375	
7108	G63	2612.231	8921.738	L LINTEL	4.273	14.00	375	
7120	G64	2605.400	8927.167	S LINTEL (SAG)	7.666	2.00	375	
7121	G65	2780.074	8896.044	L LINTEL	7.928	7.50	450	
7124	G66	2779.373	8897.379	L LINTEL	7.886	3.00	300	
7123	G67	2748.648	8876.088	L LINTEL	8.062	1.50	375	
7126	G68	2759.264	8872.081	L LINTEL	6.672	13.00	375	
7129	F169	2727.071	8926.963	FIELD INLET	7.365	9.00	375	
7116	G70	2967.187	8869.317	L LINTEL	5.609	12.00	375	
7131	G71	1320.381	8167.889	L LINTEL	9.940	OVER EXIST		

1: ALL GULLIES TO BE TO BCC STD DRG WS52–1 AND WS52–2 UNLESS NOTED OTHERWISE

2: REFER TO DETAIL SHEETS FOR FIELD INLETS, GRATED TOP MANHOLES AND PARTIAL CONSTRUCTION DETAILS

3: P/C – PATRIAL CONSTRUCTION – REFER BELOW

GULLIES TO SOUTHERN SIDE OF HOYLAND STREET TO BE TO DETAIL ON 9905412–98

GULLIES TO NORTHERN SIDE OF HOYLAND STREET TO BE SEALED WITH 100mm PRECAST SLAB AND MORTARED ONTO GULLY WALLS

4: FUTURE – FINAL LEVEL AFTER FULL CONSTRUCTION

MANHOLE SETOUT TABLE

POINT Nº	MANHOLE NUMBER	EASTING	NORTHING	FINISHED LEVEL	MANHOLE DIAMETRE(mm)/ CONFIGURATION
7003	1/1	1335.701	8165.795	8.550	1050
7005	2/1	1358.803	8178.173	8.875	1050
7007	3/1	1383.397	8178.283	8.397	1050
7010	4/1	1430.262	8194.438	7.250	1050
7013	5/1	1468.944	8213.698	7.218	1050
7015	6/1	1485.745	8225.558	6.923	1050
7018	7/1	1503.171	8238.487	6.872	1200
7035	1/8	1459.177	8115.238	7.570	1500
7029	1/3	1628.097	8381.449	3.870	1050
7059	1/15	1853.374	8719.905	5.280	1050
7061	2/15	1878.582	8747.033	5.129	1500ex600
7063	3/15	1894.301	8761.835	5.083	MANHOLE CHAMBER
7068	4/15	1902.738	8769.392	5.052	MANHOLE CHAMBER
7070	5/15	1908.882	8762.300	5.087	1500ex600
7082	1/22	2280.510	8948.464	4.859	1050
7090	1/21	2345.852	8958.020	3.980	1350
7092	2/21	2311.131	8958.072	4.234	1500
7093	3/21	2267.552	8959.920	4.160	1500ex600
7087	1/19	2232.960	8990.381	2.275	1050
7099	1/23	2469.193	8942.244	4.162	1500ex600
7109	1/24	2592.201	8921.371	4.378	1350
7122	1/28	2774.441	8903.323	7.914	1050
7125	2/28	2717.997	8912.899	6.568	1500
7127	3/28	2712.468	8920.990	6.587	1200
7117	4/28	2664.860	8929.115	5.785	1200
7118	5/28	2581.649	8942.833	4.150	MANHOLE CHAMBER
7130	–	2757.464	8872.431	8.120	1050
7021	–	1322.779	8188.819	8.875	1050
7132	ECOSOL	2587.758	8942.399	4.250	ECOSOL
7133	ECOSOL	2591.897	8941.688	4.290	ECOSOL

1: ALL MANHOLES TO BCC STD DRG WS51–1,WS51–2,WS51–3.

2: ALL CHAMBERS TO BCC STD DRAWING WS51–4.

3: 1500ex600 – 1500 DIA EXTENDED 600mm

4: REFER TO DETAILS FOR MANHOLE CHAMBERS

HEADWALL SETOUT TABLE

POINT Nº	SETOUT NUMBER	EASTING	NORTHING
7022	OUT/1	1552.748	8223.062
7024	OUT/2	1578.324	8239.021
7000	OUT/5	1598.139	8245.584
7032	OUT/8	1575.958	8214.344
7037	OUT/7	1620.188	8268.138
7000	OUT/5a	1620.562	8272.391
7000	–	1647.372	8338.559
7028	–	1630.339	8383.008
7041	OUT/10	1693.678	8418.364
7043	OUT/11	DELETED	
7047	OUT/12	1697.093	8509.859
7051	OUT/13a	1771.110	8641.347
7051A	OUT/13	1772.228	8642.768
7055	OUT/14	1782.917	8659.824
7071	OUT/15	1915.353	8812.223
7074	OUT/16	1975.453	8868.923
7077	OUT/17	2119.171	8933.290
7081	OUT/18	2215.662	8944.753
7094	OUT/21	2223.139	8960.964
7088	OUT/19	2228.307	8990.164
7104	–	2578.532	8957.081
7110	HWALL	2578.753	8964.427
7111	HWALL	2575.587	8957.474
7112	HWALL	2583.157	8983.352
7113	HWALL	2581.991	8958.400

1: ALL HEADWALLS TO BE TO BCC STD DRG WS53–2 HOWEVER PRECAST CONCRETE UNITS MAY BE USED IN LIEU

BOX CULVERT SPECIALS SETOUT

POINT Nº	SETOUT NUMBER	EASTING	NORTHING
7114	R.C.B.C	2575.907	8953.179
7115	R.C.B.C	2577.924	8952.740
7116	R.C.B.C	2580.192	8952.802

1. CULVERT SPECIAL SETOUT TO BE CONFIRMED ON SITE.

SUPPLEMENTARY SETOUT TO MANHOLE CHAMBER 5/26

POINT Nº	EASTING	NORTHING
7200	2579.894	8943.608
7201	2579.023	8942.258
7202	2579.023	8942.258
7203	2584.230	8972.322

TABLES

W11733

	AMENDMENT	DATE	CHECKED	AUTHOR	AS CONST.	MICRO
A	CONSTRUCTION ISSUE	19-9-00	MLP			

CONTACT SURVEYOR-IN-CHARGE CONCERNING ENDANGERED PERMANENT SURVEY MARKS

FIELD BOOK 9104 FILENAME 1395–0

REFERENCE :- B.M. DATUM : A.H.D.

ORIG. SPIKE IN BITUMEN PT NO 9190 E1458.618 N 8194.328 RL 7.692

DESIGN ACCEPTED AND AUTHORISED FOR ISSUE

DATE

PRINCIPAL ENGINEER – ROAD AND TRAFFIC DESIGN

ROAD AND TRAFFIC DESIGN :
PRINCIPAL ENGINEER – 3403 0545
SENIOR ENGINEER – 3403 0539
SENIOR DRAFTSMAN ROADS – 3403 0541
SENIOR DRAFTSMAN TRAFFIC – 3403 0547
FACSIMILE NUMBER – 3403 0507

CADD REFERENCE 9905412_105–112 XREF S18ST

PLAN CUSTODIAN

REGISTERED

MICROFILM

DESIGN	M.L.P.	7/2000
DESIGN CHECKED	R.J.L.	7/2000
DRAWN	M.A.M.	7/2000
TRACED	M.A.M.	7/2000
CHECKED	RJL	7/2000

FILE No.

SERVICES FILE No.

ACQUISITION FILE No. N/A

SUB PLAN NO. N/A

Brisbane City

JOB ROADWORKS AND DRAINAGE HOYLAND STREET CONNECTION BRACKEN RIDGE GYMPIE ROAD TO BRACKEN RIDGE ROAD

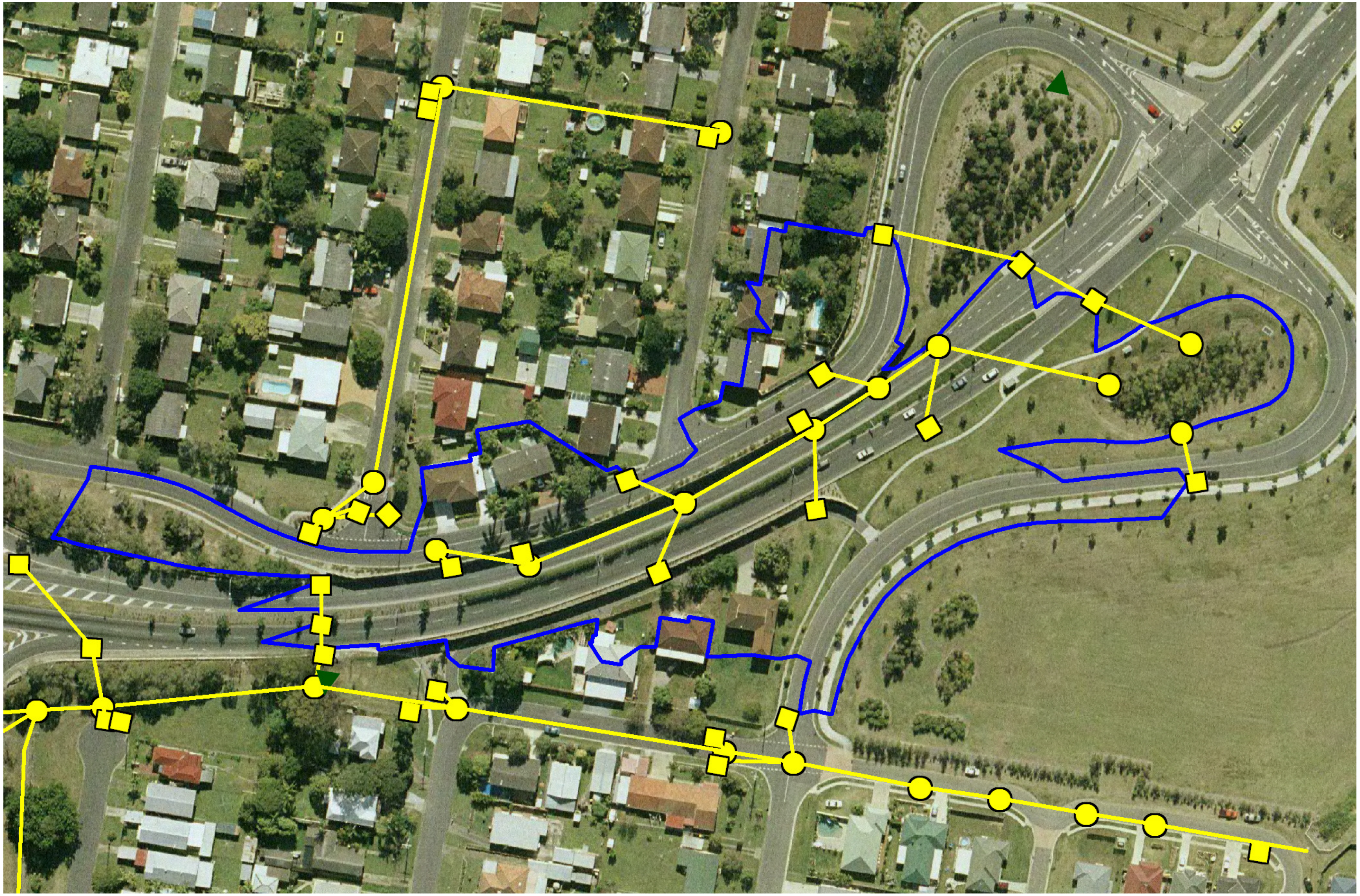
DRAWING TITLE TABLES SHEET 8 OF 8

BRISBANE CITY COUNCIL CITY DESIGN ROAD AND TRAFFIC DESIGN

DRAWING SHEET 112 OF 148 ISSUE No.

DRAWING No. 9905412 SHEET No. 112 AMEND. A

APPENDIX D: Amended Drainage Infrastructure



APPENDIX E: Hoyland Street Catchments

APPENDIX F: DRAINS Pipe and Catchment Output

PIT / NODE DETAILS Version 9

Name	Type	Family	Size	Ponding Volume (cu.m)	Pressure Change Coeff. Ku	Surface Elev (m)	Max Pond Depth (m)	Base Inflow (cu.m/s)	Blocking Factor	x	y	Bolt-down lid	id	Part Full Shock Loss
G4	OnGrade	Brisbane C	L Lintel		5	8.462		0	0	102	-393	No	130	1 x Ku
M 2/1	OnGrade	Brisbane C	L Lintel		1	8.558		0	0	110	-348	Yes	324	1 x Ku
M 3/1	OnGrade	Brisbane C	L Lintel		1.5	8.451		0	0	187	-373	Yes	317	1 x Ku
M 4/1	OnGrade	Brisbane C	L Lintel		0.2	7.77		0	0	312	-339	Yes	313	1 x Ku
M 5/1	OnGrade	Brisbane C	L Lintel		1.5	7.224		0	0	449	-298	Yes	310	1 x Ku
M 6/1	OnGrade	Brisbane C	L Lintel		1.5	6.94		0	0	546	-270	Yes	300	1 x Ku
M 7/1	OnGrade	Brisbane C	L Lintel		2	6.687		0	0	626	-246	Yes	291	1 x Ku
N117	Node					2.5		0		976	-326		413	
G5	OnGrade	Brisbane C	M Lintel		5	8.345		0	0	187	-318	No	136	1 x Ku
G6	OnGrade	Brisbane C	M Lintel		5	8.217		0	0	272	-309	No	150	1 x Ku
G9	OnGrade	Brisbane C	L Lintel		5	7.519		0	0	429	-278	No	152	1 x Ku
G8	Sag	Brisbane C	S Lintel	10	5	7.309	0.5	0	0	454	-408	No	153	1 x Ku
G10	OnGrade	Brisbane C	L Lintel		5	7.212		0	0	473	-235	No	154	1 x Ku
G11	OnGrade	Brisbane C	L Lintel		5	6.757		0	0	616	-332	No	155	1 x Ku
G20	OnGrade	Brisbane C	L Lintel		2	5.933		0	0	916	-411	No	156	1 x Ku
G13	OnGrade	Brisbane C	L Lintel		5	6.423		0	0	582	-105	No	170	1 x Ku
G14	OnGrade	Brisbane C	M Lintel		0.5	6.069		0	0	735	-173	No	177	1 x Ku
G17	OnGrade	Brisbane C	M Lintel		0.5	6.065		0	0	895	-196	No	171	1 x Ku
G7	OnGrade	Brisbane C	M Lintel		5	7.75		0	0	305	-419	No	184	1 x Ku
G12	OnGrade	Brisbane C	L Lintel		5	6.607		0	0	583	-202	No	337	1 x Ku

DETENTION BASIN DETAILS

Name	Elev	Surf. Area	Init Vol. (cu	Outlet Type	K	Dia(mm)	Centre RL	Pit Family	Pit Type	x	y	HED	Crest RL	Crest Leng	id
Basin3	3.227	1400	0	Orifice		675	3.5645			890	-334	No			398
	3.3	1400													
	3.5	1400													
	3.6	1400													
	3.65	1400													
	3.66	1400													
	3.67	1400													

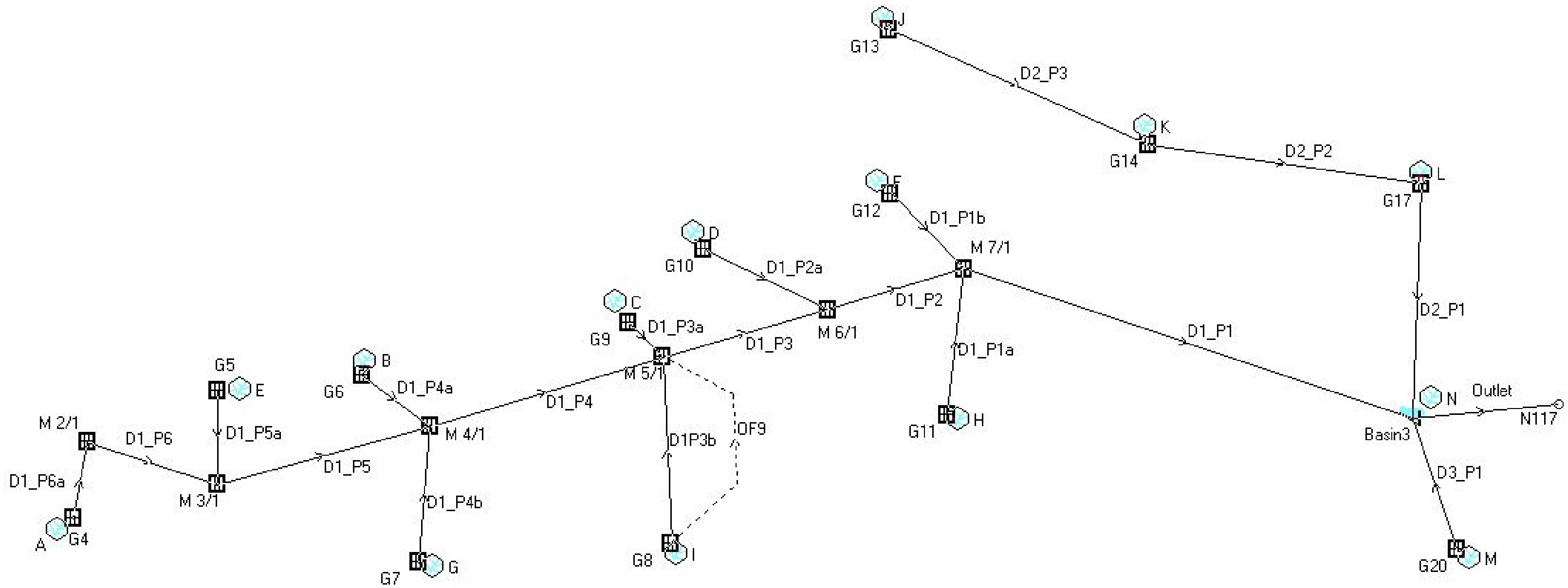
SUB-CATCHMENT DETAILS

Name	Pit or Node	Total Area (ha)	Paved Area %	Grass Area %	Supp Area %	Paved Time (min)	Grass Time (min)	Supp Time (min)	Paved Length (m)	Grass Length (m)	Supp Length (m)	Paved Slope(%) %	Grass Slope %	Supp Slope %	Paved Rough	Grass Rough	Supp Rough
A	G4	0.1667	25.8	67.1	7.1	0	25	25	110	20	20	0.5	3	3	0.015	0.13	0.015
N	Basin3	0.2579	0	96.4	3.6	0	0	0	-1	50	50	-1	2	2	-1	0.13	0.015
E	G5	0.0619	100	0	0	0	0	0	82	-1	-1	3.3	-1	-1	0.015	-1	-1
B	G6	0.0967	50	42	8	0	10	10	72	43	30	1	1	1	0.015	0.13	0.015
C	G9	0.0651	68.9	31.1	0	0	10	0	110	1.5	-1	1.5	0.5	-1	0.015	0.13	-1
I	G8	0.1991	42.6	56.3	1.1	0	60	2	120	35	30	1.5	0.5	0.5	0.015	0.13	0.015
D	G10	0.0596	33.6	53.2	13.2	0	60	20	42	12	2	1.5	2	2	0.015	0.13	0.015
H	G11	0.1249	50.6	49.4	0	0	60	0	91	27	-1	1	1	-1	0.015	0.13	-1
M	G20	0.2969	34.3	50.4	15.2	0	10	0	150	29	2	1	1.7	0.5	0.015	0.13	0.015
J	G13	0.0775	66.7	25.1	8.1	0	20	20	65	65	70	1.5	0.5	0.5	0.015	0.13	0.015
K	G14	0.0413	100	0	0	0	0	0	45	-1	-1	1	-1	-1	0.015	-1	-1
L	G17	0.1099	49.7	50.3	0	0	25	0	70	6	-1	1	0.5	-1	0.015	0.13	-1
G	G7	0.1343	61.4	38.6	0	0	15	0	120	9	-1	2.6	1	-1	0.015	0.13	-1
F	G12	0.1251	92.1	7.9	0	0	0	0	140	1.94	-1	1.2	0.5	-1	0.015	0.13	-1

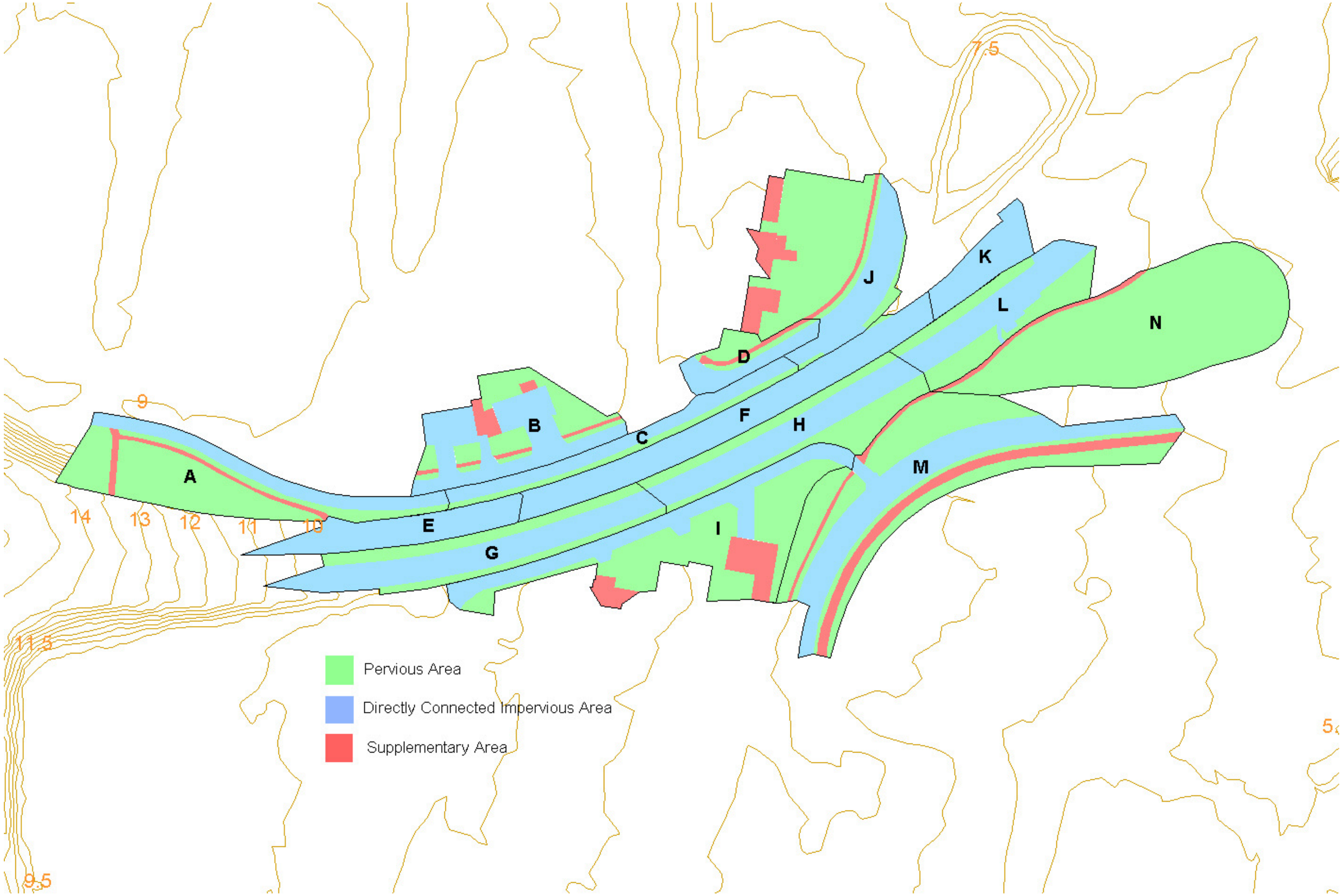
PIPE DETAILS

Name	From	To	Length (m)	U/S IL (m)	D/S IL (m)	Slope (%)	Type	Dia (mm)	I.D. (mm)	Rough	Pipe Is	No. Pipes	Chg From	At Chg	Chg (m)	Rl (m)	Chg (m)
D1_P6a	G4	M 2/1	4.30323	7.436	6.858	13.43	Concrete, u	375	375	0.3	Existing	1	G4	0			
D1_P6	M 2/1	M 3/1	23.025	6.828	6.691	0.6	Concrete, u	375	375	0.3	New	1	M 2/1	0			
D1_P5	M 3/1	M 4/1	46.591	6.621	6.22	0.86	Concrete, u	375	375	0.3	Existing	1	M 3/1	0			
D1_P4	M 4/1	M 5/1	41.4138	6.18	5.789	0.94	Concrete, u	450	450	0.3	Existing	1	M 4/1	0			
D1_P3	M 5/1	M 6/1	22.1032	5.719	5.41	1.4	Concrete, u	450	450	0.3	New	1	M 5/1	0			
D1_P2	M 6/1	M 7/1	20.9356	5.365	5.237	0.61	Concrete, u	525	525	0.3	Existing	1	M 6/1	0			
D1_P1	M 7/1	Basin3	51.3529	5.212	4.964	0.48	Concrete, u	525	525	0.3	NewFixed	1	M 7/1	0			
Outlet	Basin3	N117	60	3.227	2.5	1.21	Concrete, u	675	675	0.3	Existing	2	Basin3	0			
D1_P5a	G5	M 3/1	2.52386	7.438	7.301	5.43	Concrete, u	375	375	0.3	Existing	1	G5	0			
D1_P4a	G6	M 4/1	19.1604	7.313	6.23	5.65	Concrete, u	375	375	0.3	Existing	1	G6	0			
D1_P3a	G9	M 5/1	4.819	5.919	5.819	2.08	Concrete, u	375	375	0.3	Existing	1	G9	0			
D1P3b	G8	M 5/1	22.0933	5.889	5.779	0.5	Concrete, u	375	375	0.3	New	1	G8	0			
D1_P2a	G10	M 6/1	15.7087	5.823	5.43	2.5	Concrete, u	375	375	0.3	Existing	1	G10	0			
D1_P1a	G11	M 7/1	23.7636	5.586	5.312	1.15	Concrete, u	375	375	0.3	Existing	1	G11	0			
D3_P1	G20	Basin3	18.6402	4.968	4.756	1.14	Concrete, u	375	375	0.3	Existing	1	G20	0			
D2_P3	G13	G14	41.205	4.877	4.683	0.47	Concrete, u	375	375	0.3	New	1	G13	0			
D2_P2	G14	G17	24.4263	4.686	4.568	0.48	Concrete, u	375	375	0.3	Existing	1	G14	0			
D2_P1	G17	Basin3	24.4452	4.508	4.347	0.66	Concrete, u	375	375	0.3	Existing	1	G17	0			

APPENDIX G: DRAINS Model



APPENDIX H: DRAINS Surfaces

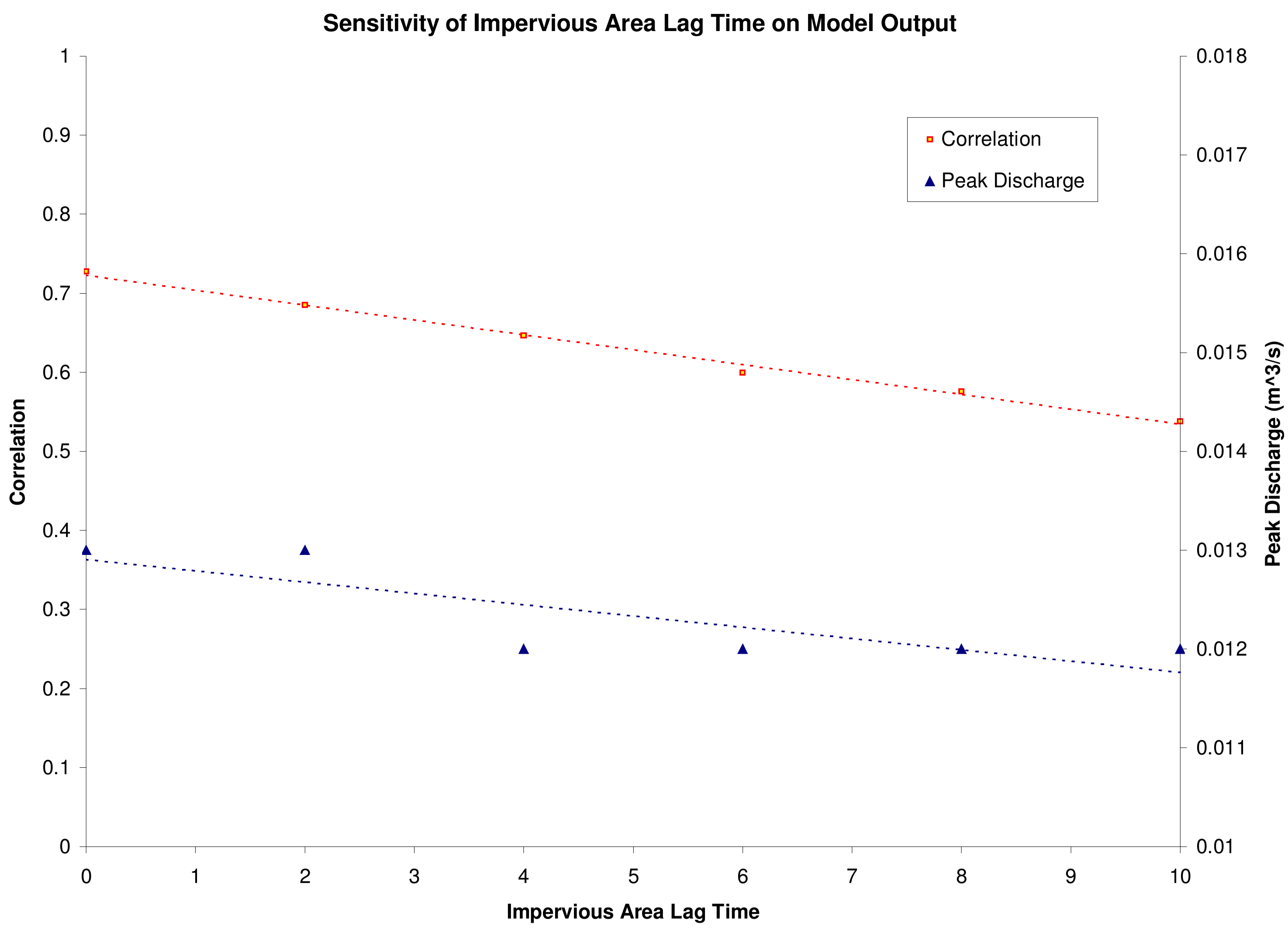


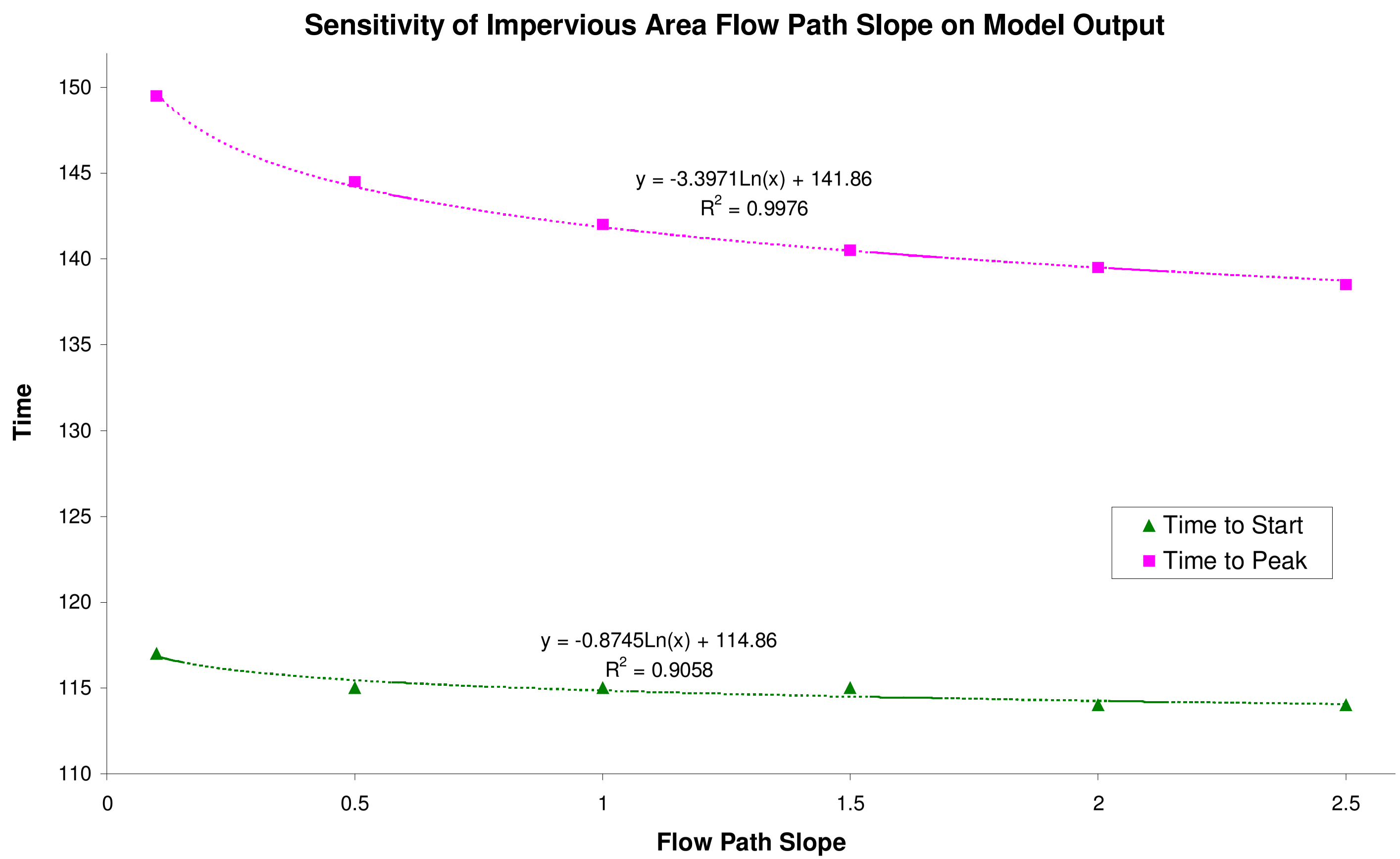
APPENDIX I: Sensitivity Analysis Summary

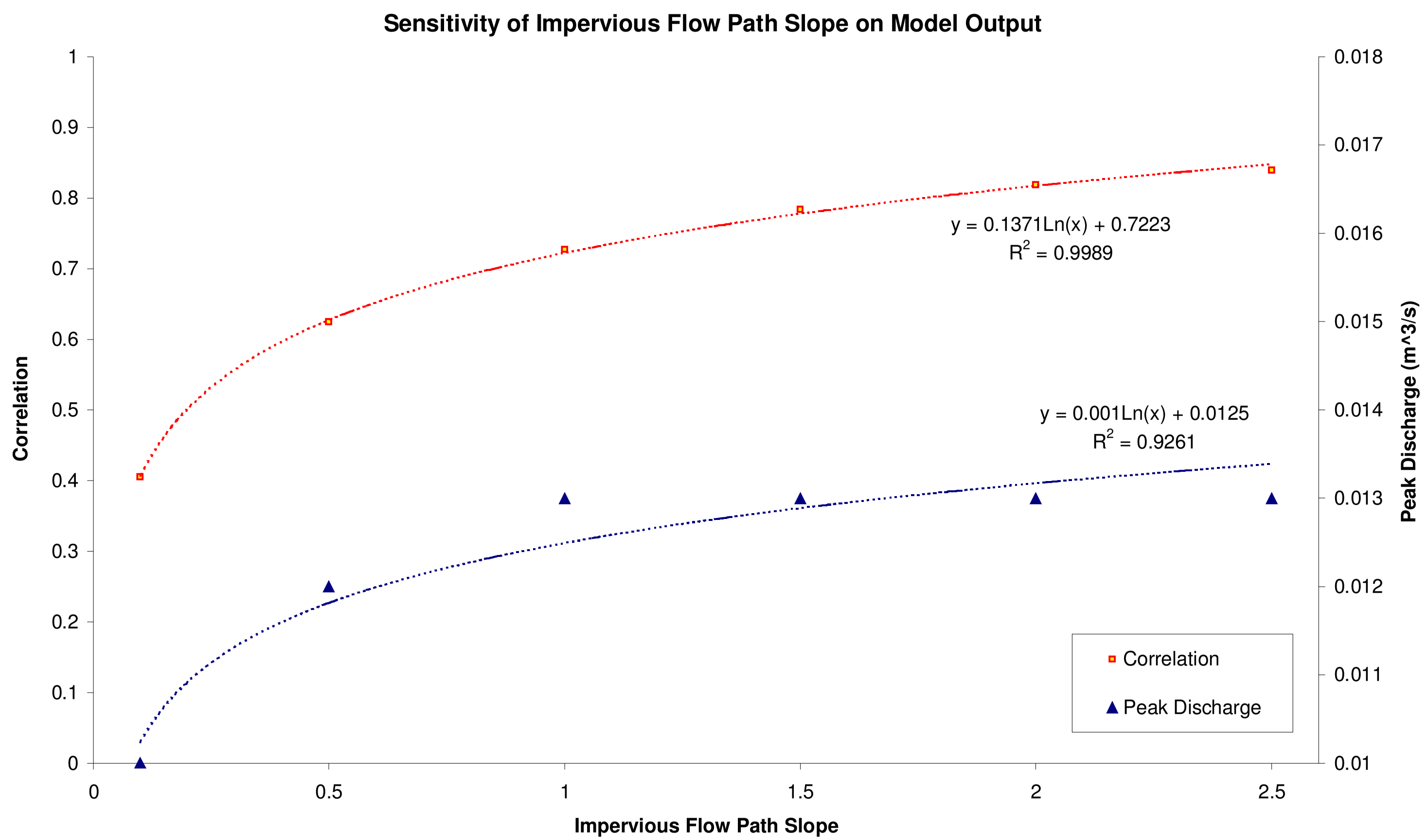
Paved				Supplementary					Grassed				Pipes	Soil	Results									
Additional Time	Flow Path Slope	Flow Path Roughness	Area Depression Storage	Additional Time	Flow Path Slope	Flow Path Roughness	Area Depression Storage	Lag Time	Additional Time	Flow Path Slope	Flow Path Roughness	Area Depression Storage	Pressure Loss Coefficient	Soil Type	Total Volume	Change in Total Volume	Peak Discharge	Change in Peak Discharge	TS2	TS2 Correlation	Time to Peak	Tp Correlation	Correlation (shape)	Change in R2
min	%		mm	min	%		mm	min	min	%		mm			m^3	%	m^3/s	%					R	%
0	**1**	**0.015**	**1.5**	**5**	**1.7**	**0.015**	**1**	**10**	**15**	**1.7**	**0.13**	**3**	**4**	**4**	**22.7**	-	**0.013**	-	**115**	**7**	**142**	**-10**	**0.7275622**	
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	115	**7**	144.5	**-12.5**	0.684776	-5.88 %
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.012	-7.69 %	115	**7**	144.5	**-12.5**	0.6463182	-11.17 %
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.012	-7.69 %	115	**7**	145	**-13**	0.5993776	-17.62 %
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.012	-7.69 %	116	**6**	145.5	**-13.5**	0.5759351	-20.84 %
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.012	-7.69 %	116	**6**	145	**-13**	0.5378972	-26.07 %
-	1.5	-	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	115	**7**	140.5	**-8.5**	0.7838455	7.74 %
-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	114	**8**	139.5	**-7.5**	0.8189314	12.56 %
-	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	114	**8**	138.5	**-6.5**	0.8391271	15.33 %
-	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.012	-7.69 %	115	**7**	144.5	**-12.5**	0.6246081	-14.15 %
-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.01	-23.08 %	117	**5**	149.5	**-17.5**	0.4054244	-44.28 %
-	-	0.03	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.012	-7.69 %	116	**6**	145.5	**-13.5**	0.5243946	-27.92 %
-	-	0.045	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.01	-23.08 %	117	**5**	149	**-17**	0.4203241	-42.23 %
-	-	0.08	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.008	-38.46 %	118	**4**	150.5	**-18.5**	0.314743	-56.74 %
-	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.012	-7.69 %	115	**7**	144.5	**-12.5**	0.6429902	-11.62 %
-	-	0.01	-	-	-	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	114	**8**	139.5	**-7.5**	0.8251691	13.42 %
-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	22.2	-2.20 %	0.013	0.00 %	115	**7**	142	**-10**	0.7275622	0.00 %
-	-	-	2.5	-	-	-	-	-	-	-	-	-	-	-	21.7	-4.41 %	0.013	0.00 %	116	**6**	142	**-10**	0.719969	-1.04 %
-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	23.2	2.20 %	0.013	0.00 %	115	**7**	142	**-10**	0.7256599	-0.26 %
-	-	-	0.5	-	-	-	-	-	-	-	-	-	-	-	23.7	4.41 %	0.013	0.00 %	115	**7**	142	**-10**	0.725486	-0.29 %
-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	24.1	6.17 %	0.013	0.00 %	115	**7**	142	**-10**	0.7253151	-0.31 %
-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	22.6	-0.44 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7374537	1.36 %
-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	22.3	-1.76 %	0.012	-7.69 %	115	**7**	142.5	**-10.5**	0.7376376	1.38 %
-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	22	-3.08 %	0.012	-7.69 %	115	**7**	142	**-10**	0.7486449	2.90 %
-	-	-	-	25	-	-	-	-	-	-	-	-	-	-	21.6	-4.85 %	0.012	-7.69 %	115	**7**	141.5	**-9.5**	0.7564987	3.98 %
-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	22.9	0.88 %	0.013	0.00 %	115	**7**	142	**-10**	0.7254611	-0.29 %
-	-	-	-	-	2.5	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7255453	-0.28 %
-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7255453	-0.28 %
-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142	**-10**	0.7275622	0.00 %
-	-	-	-	-	0.5	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142	**-10**	0.7275622	0.00 %
-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142	**-10**	0.7296549	0.29 %
-	-	-	-	-	-	0.03	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142	**-10**	0.7275622	0.00 %
-	-	-	-	-	-	0.045	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142	**-10**	0.727203	-0.05 %
-	-	-	-	-	-	0.08	-	-	-	-	-	-	-	-	22.6	-0.44 %	0.013	0.00 %	115	**7**	142	**-10**	0.7296549	0.29 %
-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142	**-10**	0.7275622	0.00 %
-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7255453	-0.28 %

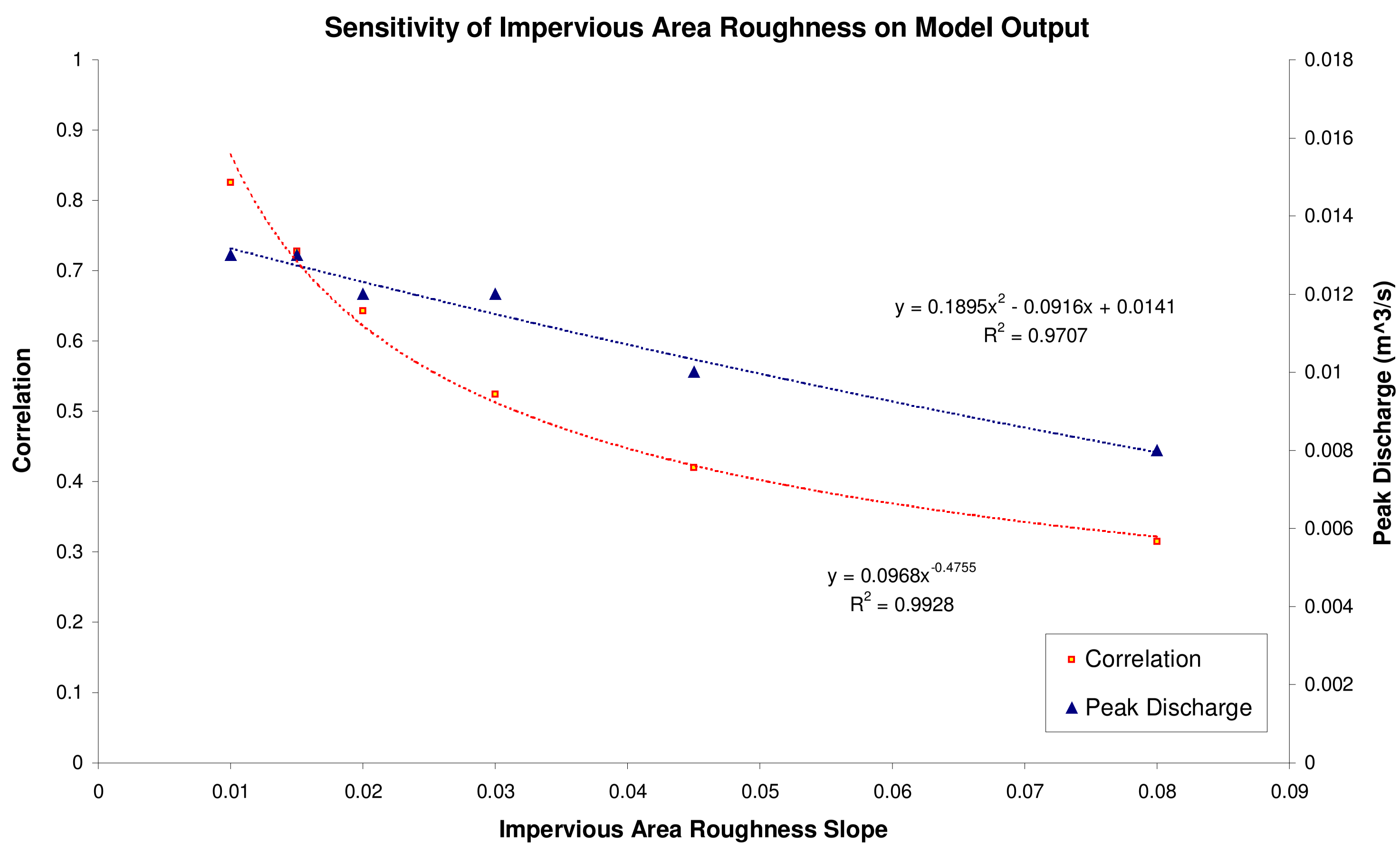
Paved				Supplementary					Grassed				Pipes	Soil	Results									
Additional Time	Flow Path Slope	Flow Path Roughness	Area Depression Storage	Additional Time	Flow Path Slope	Flow Path Roughness	Area Depression Storage	Lag Time	Additional Time	Flow Path Slope	Flow Path Roughness	Area Depression Storage	Pressure Loss Coefficient	Soil Type	Total Volume	Change in Total Volume	Peak Discharge	Change in Peak Discharge	TS2	TS2 Correlation	Time to Peak	Tp Correlation	Correlation (shape)	Change in R2
min	%		mm	min	%		mm	min	min	%		mm			m^3	%	m^3/s	%					R	%
0	**1**	**0.015**	**1.5**	**5**	**1.7**	**0.015**	**1**	**10**	**15**	**1.7**	**0.13**	**3**	**4**	**4**	**22.7**	-	**0.013**	-	**115**	**7**	**142**	**-10**	**0.7275622**	
-	-	-	-	-	-	-	1.5	-	-	-	-	-	-	-	22.6	-0.44 %	0.013	0.00 %	115	**7**	142	**-10**	0.7292119	0.23 %
-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	22.5	-0.88 %	0.013	0.00 %	115	**7**	142	**-10**	0.7326742	0.70 %
-	-	-	-	-	-	-	2.5	-	-	-	-	-	-	-	22.4	-1.32 %	0.013	0.00 %	115	**7**	142	**-10**	0.7327787	0.72 %
-	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-	22.8	0.44 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7251891	-0.33 %
-	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	22.9	0.88 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7251891	-0.33 %
-	-	-	-	-	-	-	-	15	-	-	-	-	-	-	22.7	0.00 %	0.011	-15.38 %	115	**7**	135.5	**-3.5**	0.7365714	1.24 %
-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	22.7	0.00 %	0.011	-15.38 %	115	**7**	135.5	**-3.5**	0.7691533	5.72 %
-	-	-	-	-	-	-	-	25	-	-	-	-	-	-	22.7	0.00 %	0.011	-15.38 %	115	**7**	135.5	**-3.5**	0.7897354	8.55 %
-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	22.7	0.00 %	0.014	7.69 %	115	**7**	141	**-9**	0.7582141	4.21 %
-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	22.7	0.00 %	0.014	7.69 %	115	**7**	138	**-6**	0.8184187	12.49 %
-	-	-	-	-	-	-	-	-	25	-	-	-	-	-	21.7	-4.41 %	0.012	-7.69 %	115	**7**	142	**-10**	0.7536821	3.59 %
-	-	-	-	-	-	-	-	-	35	-	-	-	-	-	20.9	-7.93 %	0.012	-7.69 %	115	**7**	141.5	**-9.5**	0.769232	5.73 %
-	-	-	-	-	-	-	-	-	45	-	-	-	-	-	20.3	-10.57 %	0.012	-7.69 %	115	**7**	142	**-10**	0.7789695	7.07 %
-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	23.2	2.20 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7104711	-2.35 %
-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	24.1	6.17 %	0.014	7.69 %	115	**7**	143.5	**-11.5**	0.6750113	-7.22 %
-	-	-	-	-	-	-	-	-	-	2.5	-	-	-	-	23	1.32 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7201928	-1.01 %
-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	23.1	1.76 %	0.013	0.00 %	115	**7**	143	**-11**	0.7127013	-2.04 %
-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	22.2	-2.20 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7391966	1.60 %
-	-	-	-	-	-	-	-	-	-	0.5	-	-	-	-	21.6	-4.85 %	0.012	-7.69 %	115	**7**	142	**-10**	0.7569072	4.03 %
-	-	-	-	-	-	-	-	-	-	0.1	-	-	-	-	20.1	-11.45 %	0.012	-7.69 %	115	**7**	141.5	**-9.5**	0.7883488	8.35 %
-	-	-	-	-	-	-	-	-	-	-	0.2	-	-	-	21.9	-3.52 %	0.012	-7.69 %	115	**7**	142.5	**-10.5**	0.7480827	2.82 %
-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	21.1	-7.05 %	0.012	-7.69 %	115	**7**	142	**-10**	0.7641996	5.04 %
-	-	-	-	-	-	-	-	-	-	-	0.4	-	-	-	20.6	-9.25 %	0.012	-7.69 %	115	**7**	141.5	**-9.5**	0.7749155	6.51 %
-	-	-	-	-	-	-	-	-	-	-	0.075	-	-	-	23.5	3.52 %	0.013	0.00 %	115	**7**	143	**-11**	0.7034288	-3.32 %
-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	24.9	9.69 %	0.016	23.08 %	115	**7**	144.5	**-12.5**	0.6301682	-13.39 %
-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	21.2	-6.61 %	0.012	-7.69 %	115	**7**	142.5	**-10.5**	0.7469658	2.67 %
-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	19.9	-12.33 %	0.012	-7.69 %	115	**7**	142	**-10**	0.7676475	5.51 %
-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	24.2	6.61 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7067909	-2.85 %
-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	25.7	13.22 %	0.014	7.69 %	115	**7**	142.5	**-10.5**	0.6903463	-5.12 %
-	-	-	-	-	-	-	-	-	-	-	-	0.1	-	-	27	18.94 %	0.015	15.38 %	115	**7**	142	**-10**	0.6750294	-7.22 %
-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7254434	-0.29 %
-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7249873	-0.35 %
-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142.5	**-10.5**	0.7253421	-0.31 %
-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	22.7	0.00 %	0.013	0.00 %	115	**7**	142	**-10**	0.7275622	0.00 %
-	-	-	-	-	-	-	-	-	-	-	-	-	0.5	-	22.7	0.00 %	0.013	0.00 %	114	**8**	142	**-10**	0.7349656	1.02 %
-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	16.9	-25.55 %	0.011	-15.38 %	115	**7**	135.5	**-3.5**	0.8509259	16.96 %
-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	16.9	-25.55 %	0.011	-15.38 %	115	**7**	135.5	**-3.5**	0.8509259	16.96 %
-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	16.9	-25.55 %	0.011	-15.38 %	115	**7**	135.5	**-3.5**	0.8509259	16.96 %

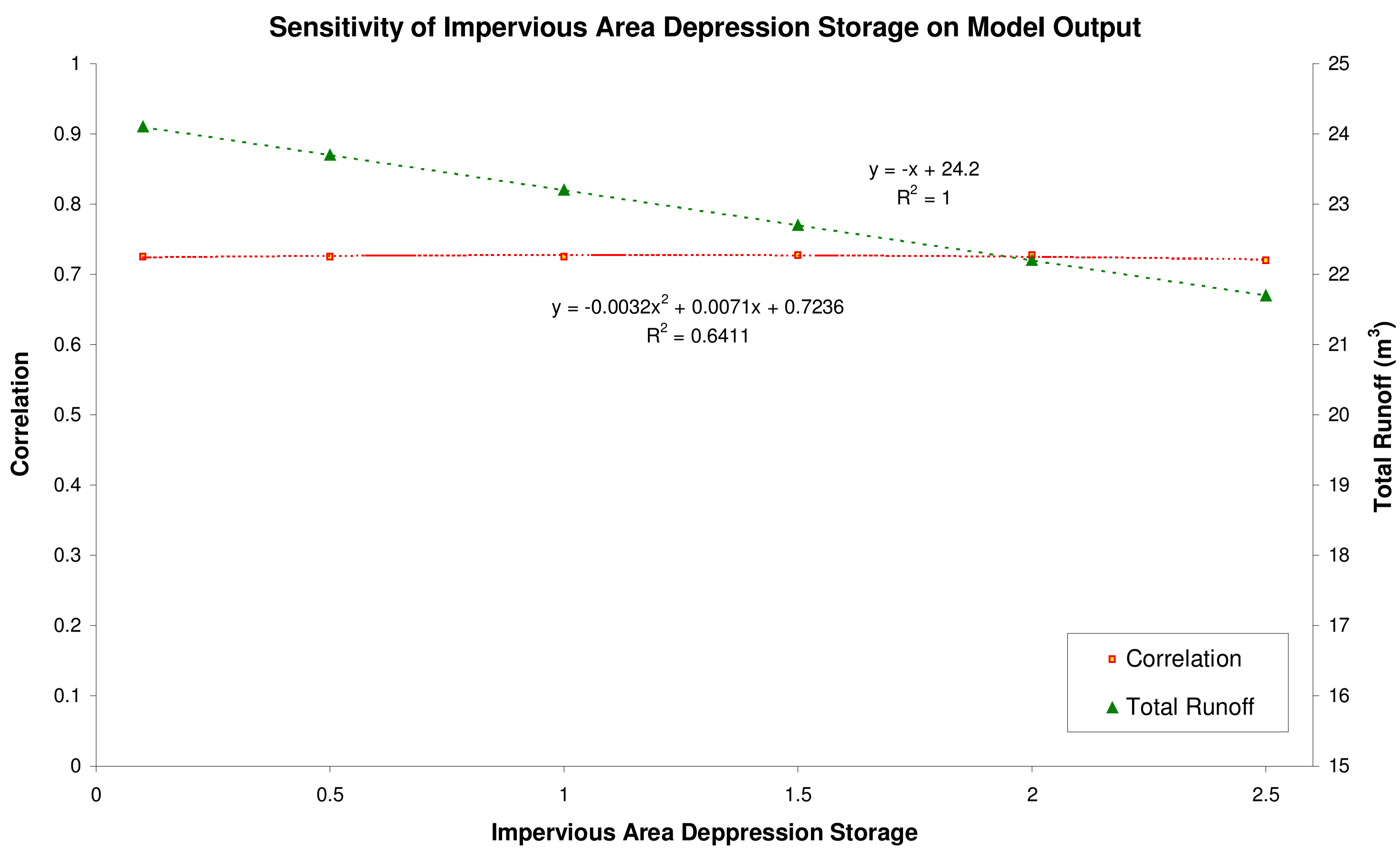
APPENDIX J: Sensitivity Analysis Plots


Sensitivity of Impervious Area Lag Time on Model Output
Correlation
Peak Discharge
Correlation
Peak Discharge (m^3/s)
Impervious Area Lag Time
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0
1
2
3
4
5
6
7
8
9
10

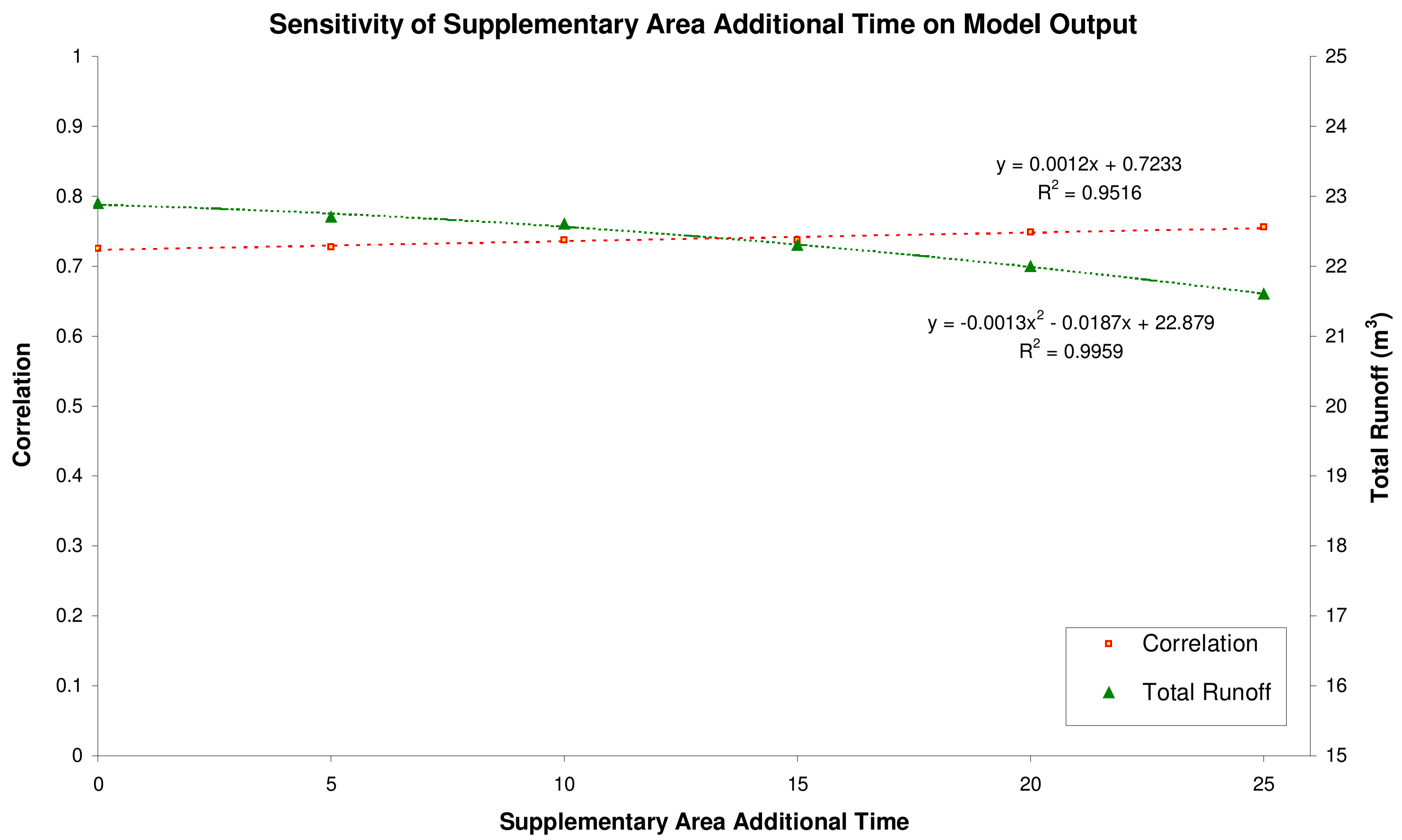

Sensitivity of Impervious Area Flow Path Slope on Model Output
Time
150
145
140
135
130
125
120
115
110
0
0.5
1
1.5
2
2.5
Flow Path Slope
y = -3.3971Ln(x) + 141.86
R2 = 0.9976
y = -0.8745Ln(x) + 114.86
R2 = 0.9058
Time to Start
Time to Peak

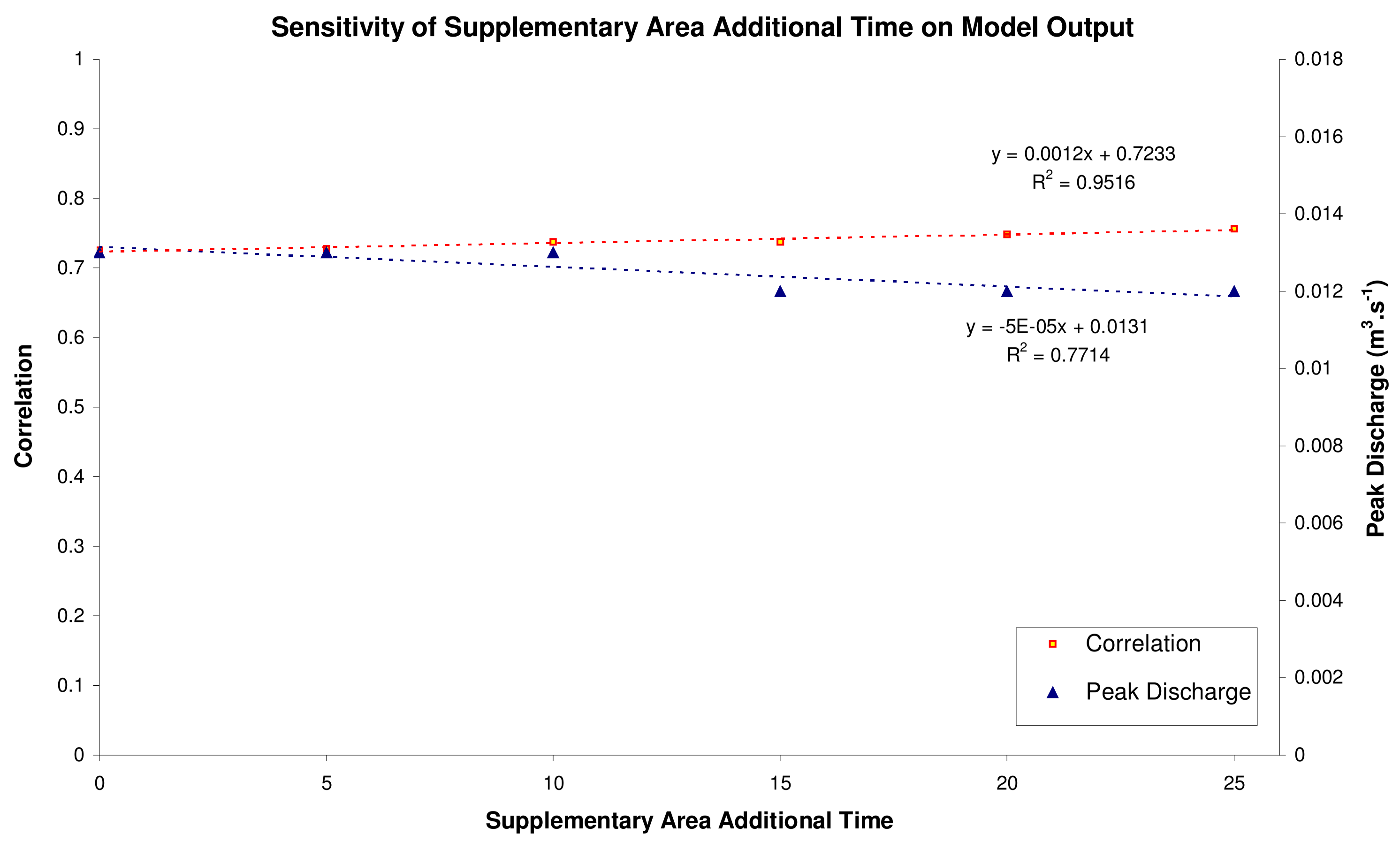

Sensitivity of Impervious Flow Path Slope on Model Output
Correlation
Peak Discharge (m^3/s)
Impervious Flow Path Slope
y = 0.1371Ln(x) + 0.7223
R2 = 0.9989
y = 0.001Ln(x) + 0.0125
R2 = 0.9261
Correlation
Peak Discharge
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.01
0.011
0.012
0.013
0.014
0.015
0.016
0.017
0.018
0.5
1.5
2
2.5

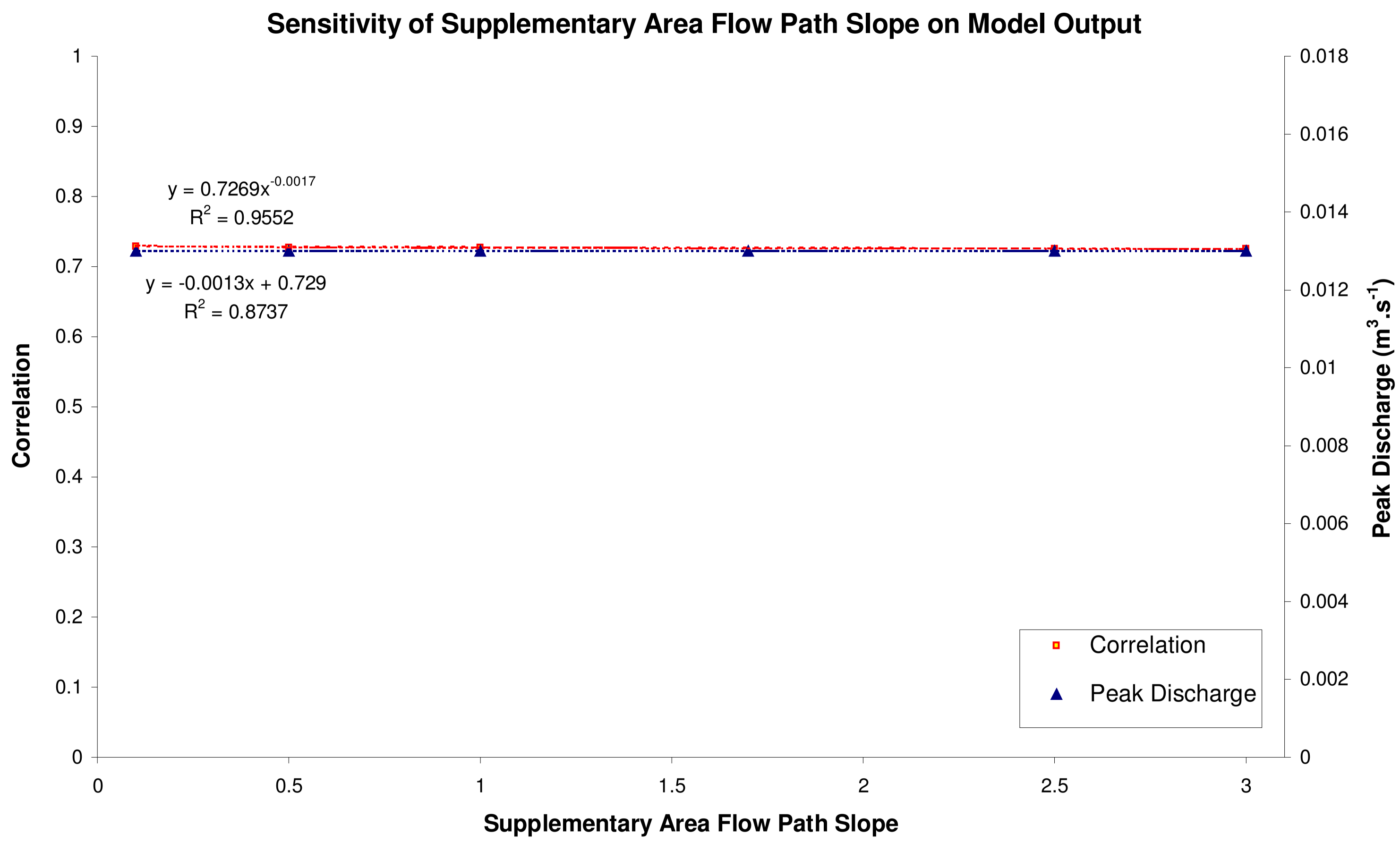

Sensitivity of Impervious Area Roughness on Model Output
Correlation
Peak Discharge (m^3/s)
Impervious Area Roughness Slope
y = 0.1895x2 - 0.0916x + 0.0141
R2 = 0.9707
y = 0.0968x-0.4755
R2 = 0.9928
Correlation
Peak Discharge
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09

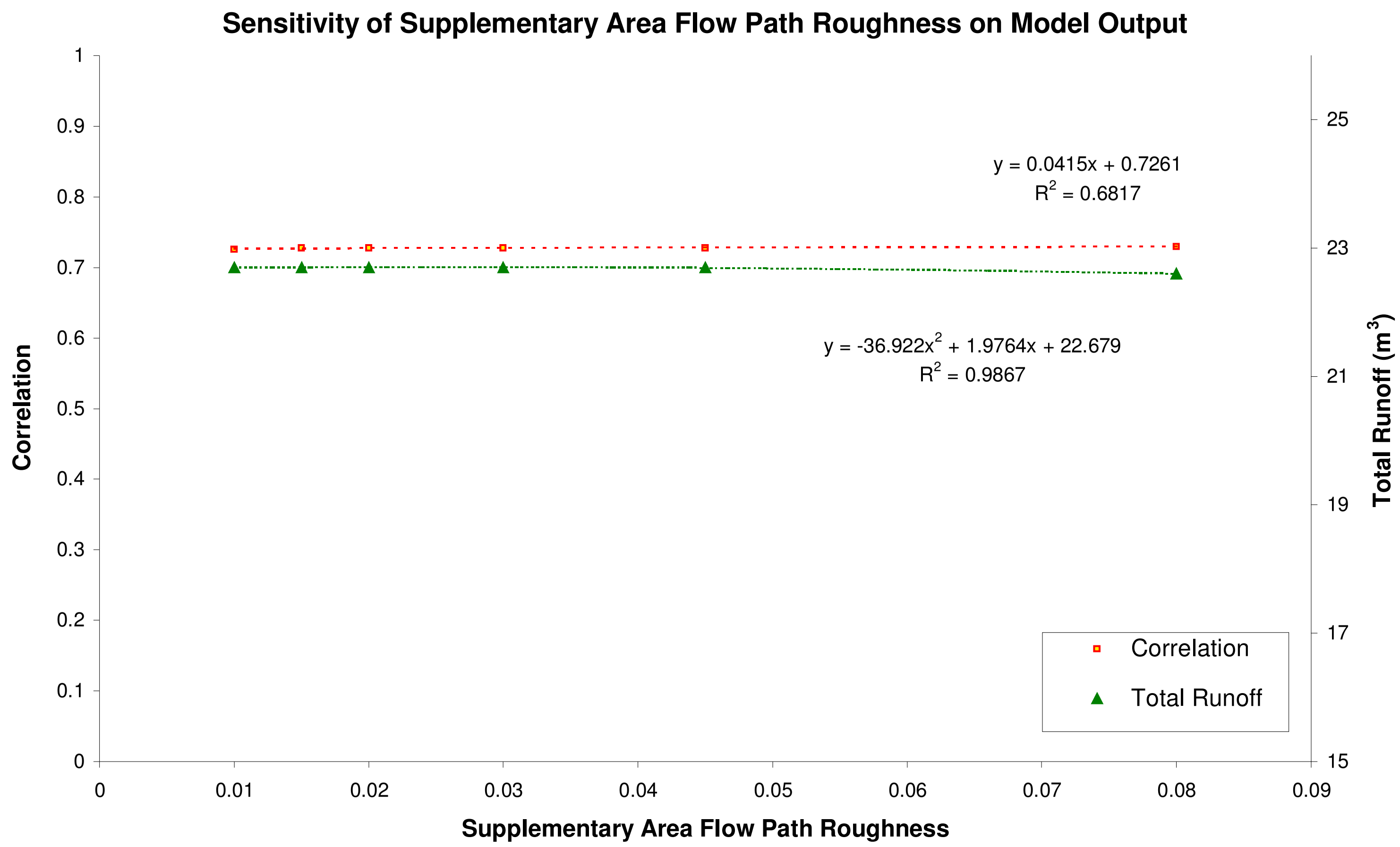


Sensitivity of Impervious Area Depression Storage on Model Output
Correlation
Total Runoff (m3)
Impervious Area Deppression Storage
y = -x + 24.2
R2 = 1
y = -0.0032x2 + 0.0071x + 0.7236
R2 = 0.6411
Correlation
Total Runoff
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.5
1.5
2
2.5
15
16
17
18
19
20
21
22
23
24
25

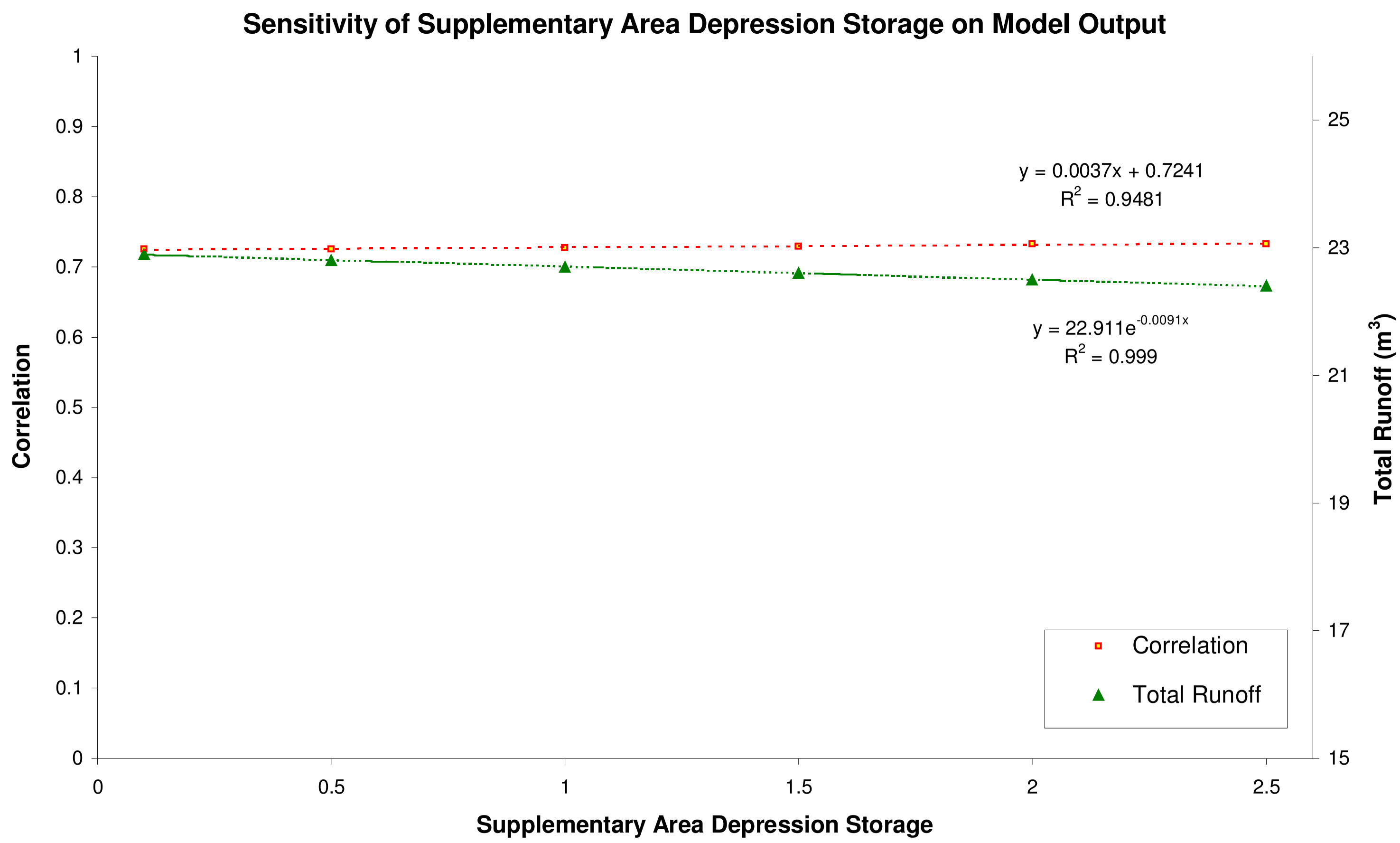

Sensitivity of Supplementary Area Additional Time on Model Output
Correlation
Total Runoff (m3)
Supplementary Area Additional Time
y = 0.0012x + 0.7233
R2 = 0.9516
y = -0.0013x2 - 0.0187x + 22.879
R2 = 0.9959
Correlation
Total Runoff
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
15
16
17
18
19
20
21
22
23
24
25
0
5
10
15
20
25


Sensitivity of Supplementary Area Additional Time on Model Output
Correlation
Peak Discharge (m3.s-1)
Supplementary Area Additional Time
y = 0.0012x + 0.7233
R2 = 0.9516
y = -5E-05x + 0.0131
R2 = 0.7714
Correlation
Peak Discharge
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0
5
10
15
20
25

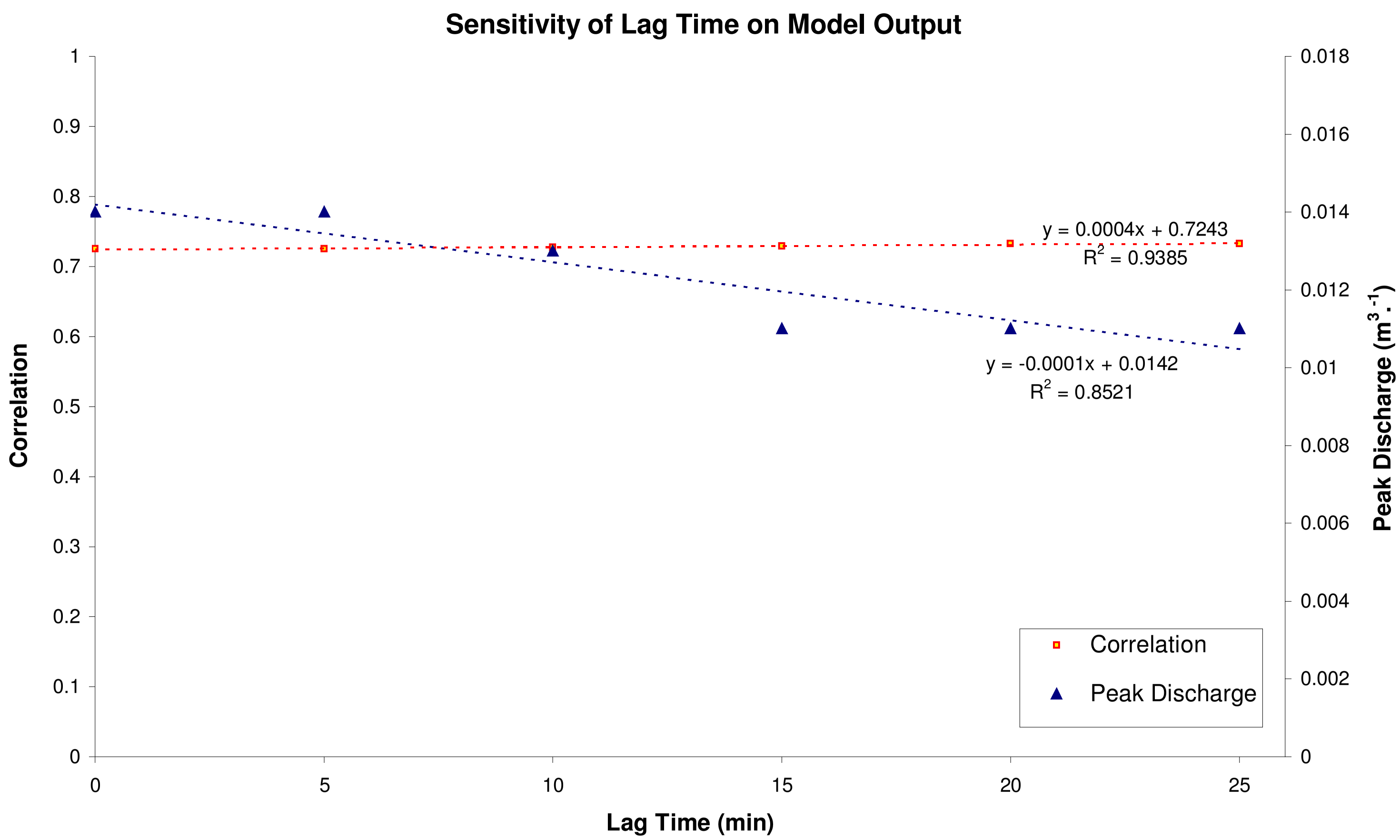

Sensitivity of Supplementary Area Flow Path Slope on Model Output
Correlation
Peak Discharge (m3.s-1)
Supplementary Area Flow Path Slope
y = 0.7269x-0.0017
R2 = 0.9552
y = -0.0013x + 0.729
R2 = 0.8737
Correlation
Peak Discharge
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0.5
1.5
2
2.5
3



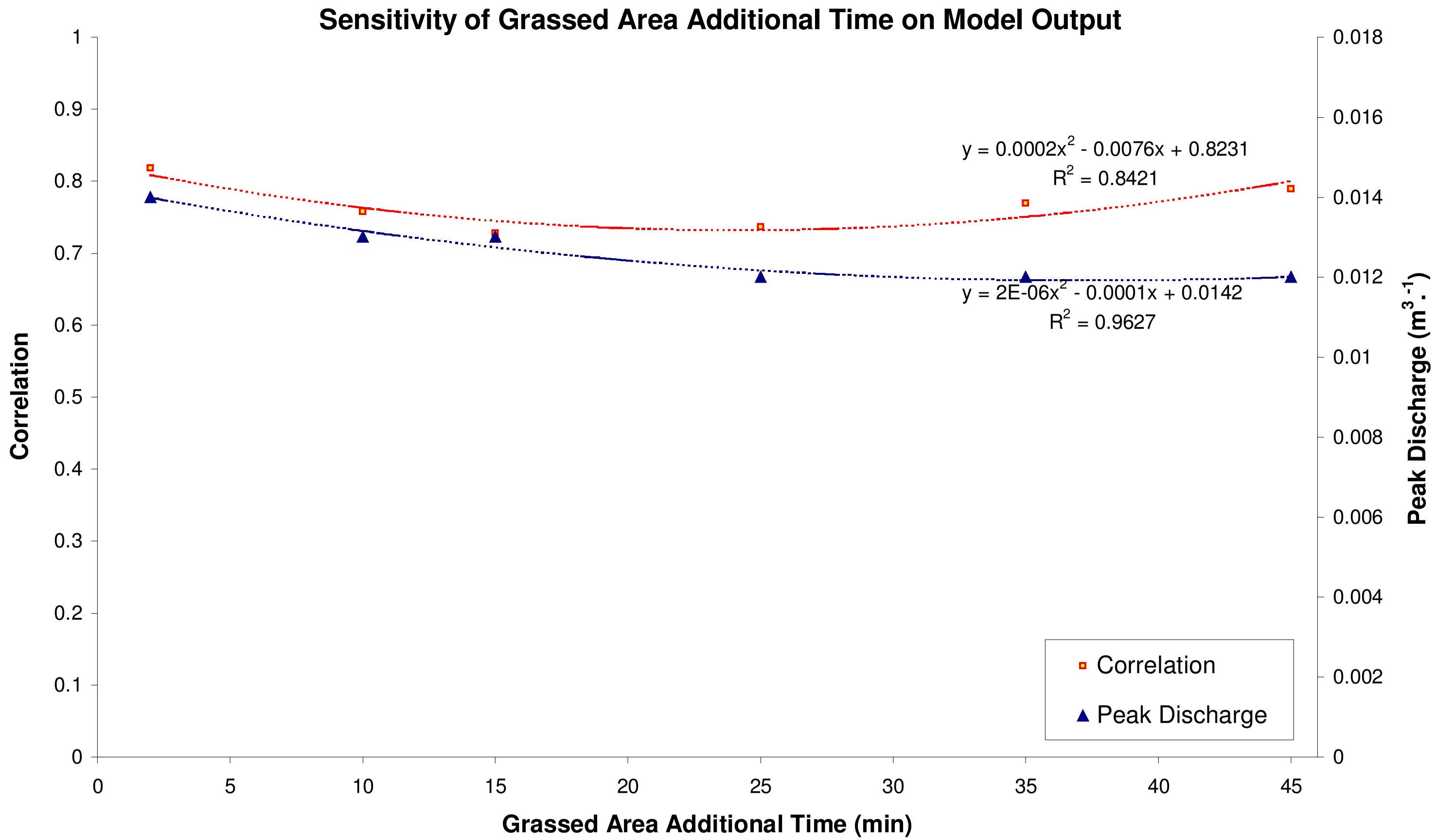
Sensitivity of Supplementary Area Flow Path Roughness on Model Output
Correlation
Total Runoff (m3)
Supplementary Area Flow Path Roughness
y = 0.0415x + 0.7261
R2 = 0.6817
y = -36.922x2 + 1.9764x + 22.679
R2 = 0.9867
Correlation
Total Runoff
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
15
17
19
21
23
25
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09

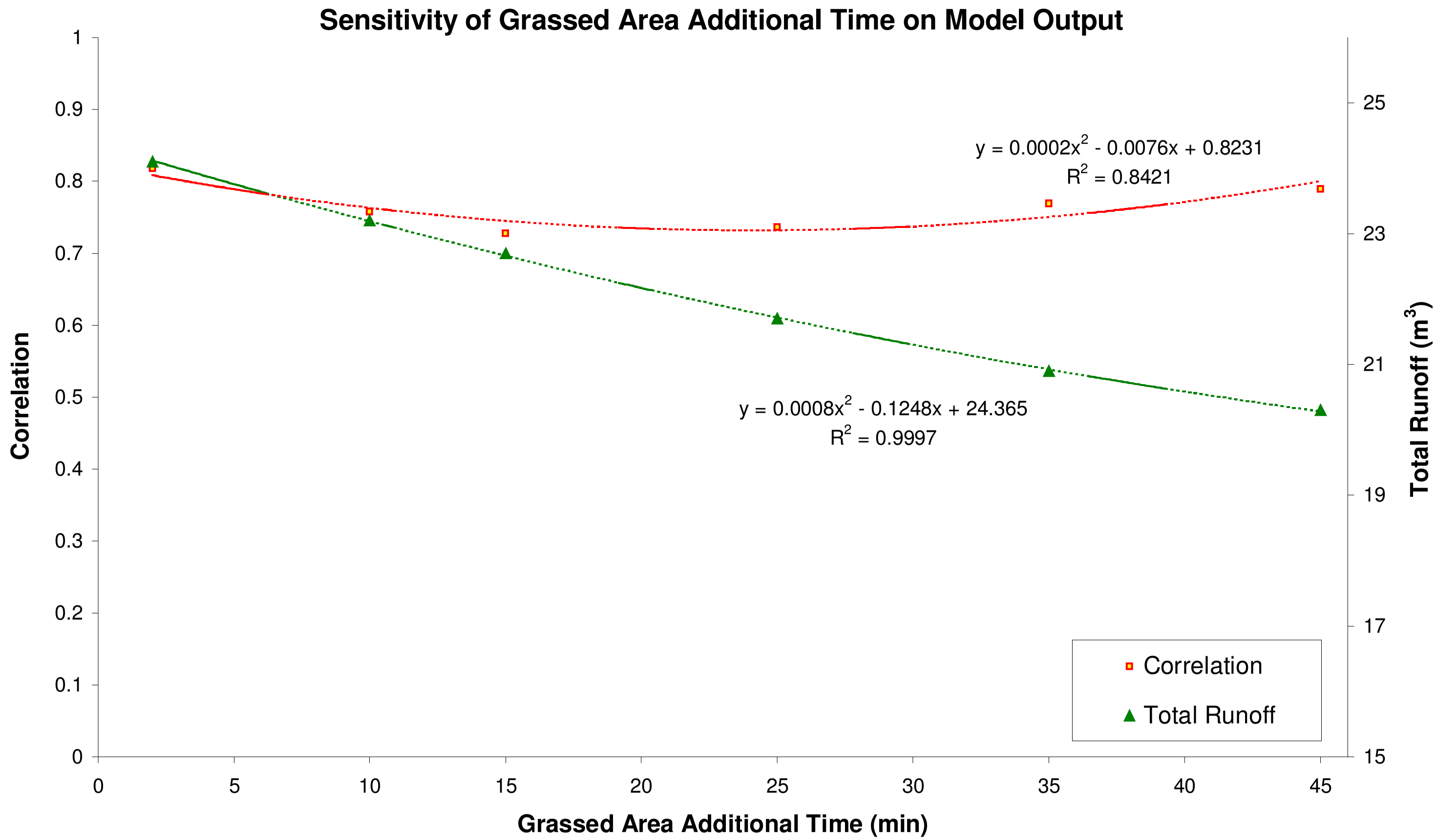


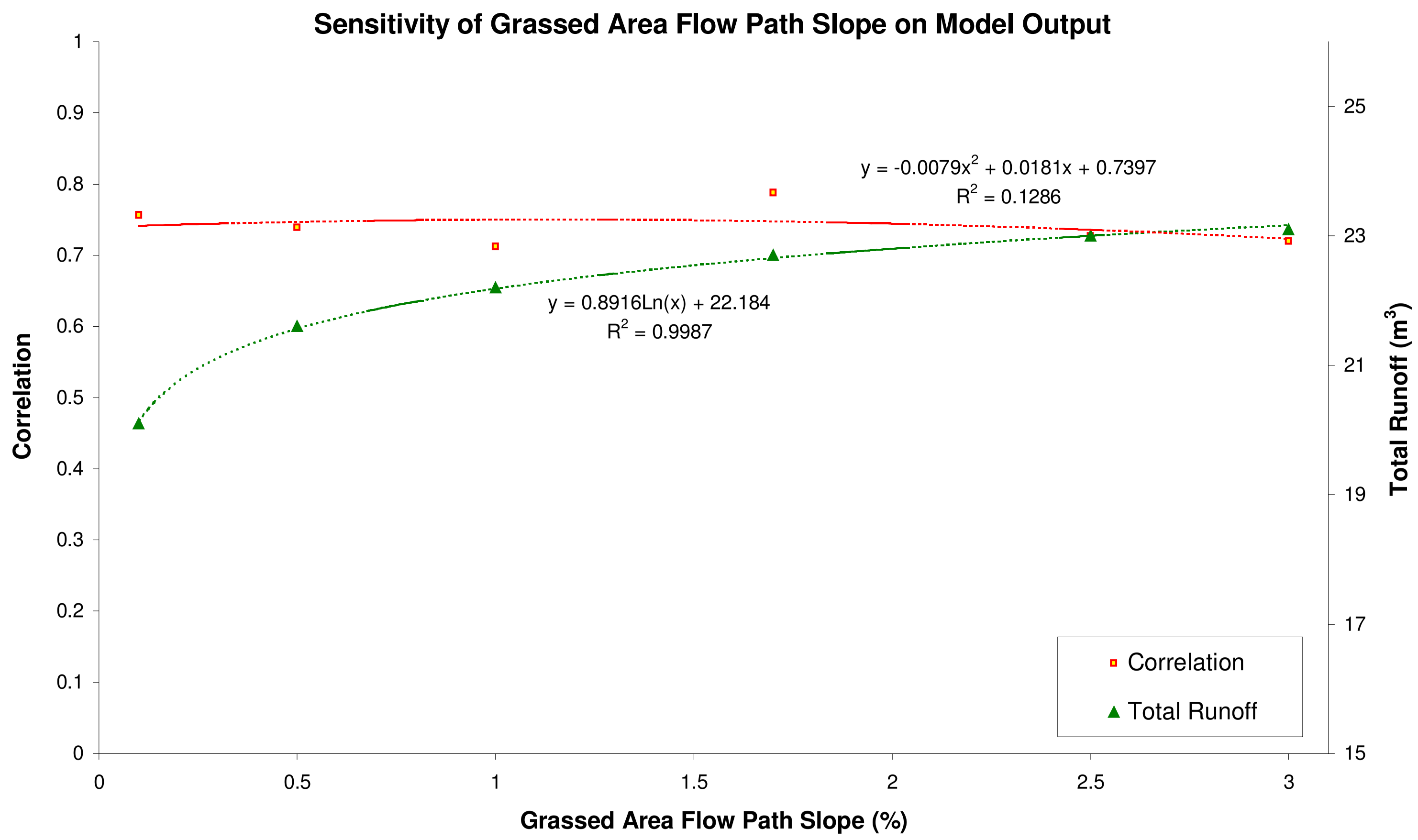
Sensitivity of Supplementary Area Depression Storage on Model Output
Correlation
Total Runoff (m³)
Supplementary Area Depression Storage
y = 0.0037x + 0.7241
R² = 0.9481
y = 22.911e^-0.0091x
R² = 0.999
Correlation
Total Runoff
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.5
1.5
2
2.5
15
17
19
21
23
25



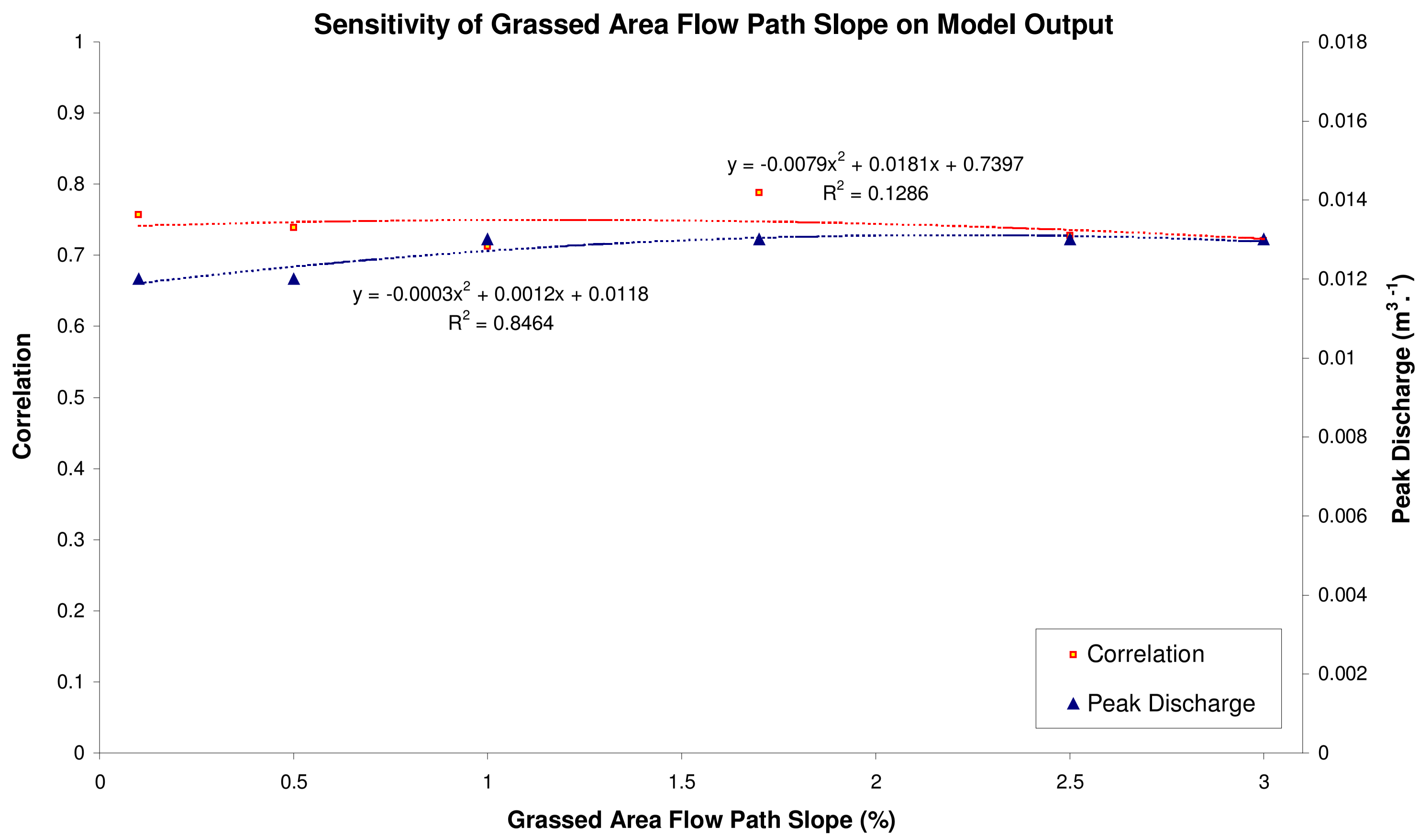
Sensitivity of Lag Time on Model Output
Correlation
Peak Discharge (m3.-1)
Lag Time (min)
y = 0.0004x + 0.7243
R2 = 0.9385
y = -0.0001x + 0.0142
R2 = 0.8521
Correlation
Peak Discharge
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0
5
10
15
20
25


Sensitivity of Grassed Area Additional Time on Model Output
y = 0.0002x2 - 0.0076x + 0.8231
R2 = 0.8421
y = 2E-06x2 - 0.0001x + 0.0142
R2 = 0.9627
Correlation
Peak Discharge
Correlation
Peak Discharge (m3.-1)
Grassed Area Additional Time (min)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0
5
10
15
20
25
30
35
40
45

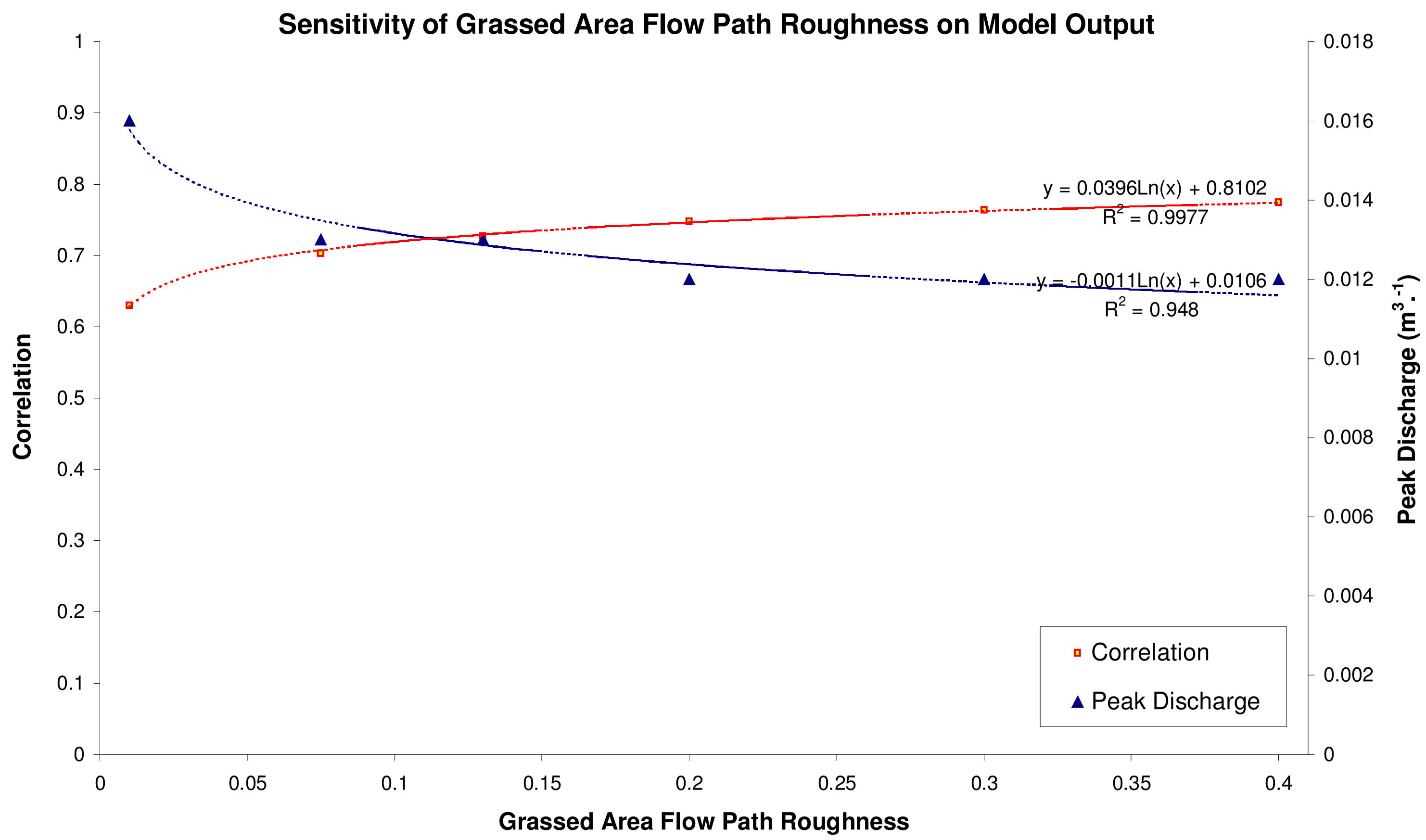

Sensitivity of Grassed Area Additional Time on Model Output
Correlation
Total Runoff (m3)
Grassed Area Additional Time (min)
y = 0.0002x2 - 0.0076x + 0.8231
R2 = 0.8421
y = 0.0008x2 - 0.1248x + 24.365
R2 = 0.9997
Correlation
Total Runoff
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
30
35
40
45
15
17
19
21
23
25

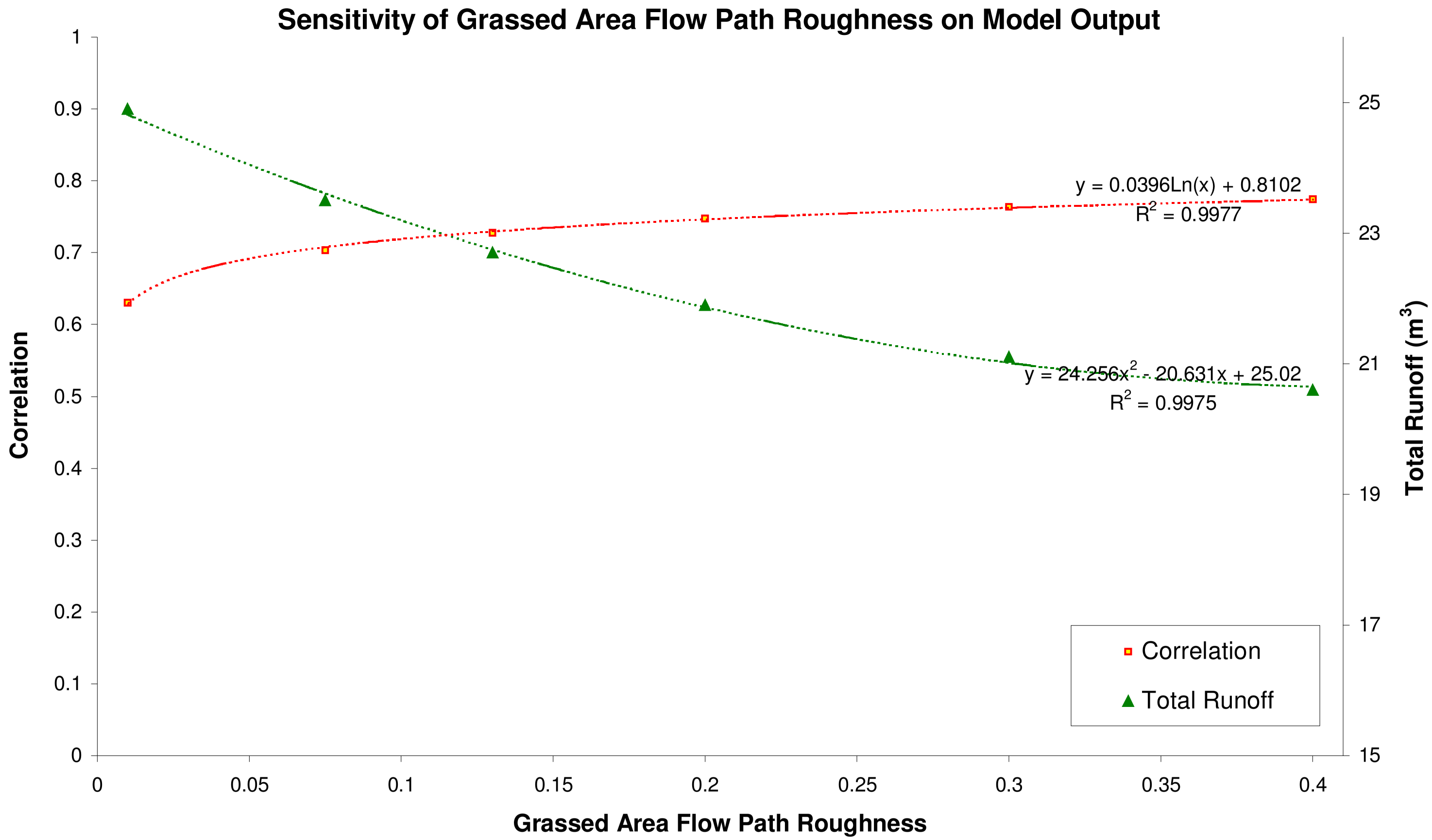


Sensitivity of Grassed Area Flow Path Slope on Model Output
Correlation
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1
1.5
2
2.5
3
Grassed Area Flow Path Slope (%)
Total Runoff (m3)
25
23
21
19
17
15
y = -0.0079x2 + 0.0181x + 0.7397
R2 = 0.1286
y = 0.8916Ln(x) + 22.184
R2 = 0.9987
Correlation
Total Runoff

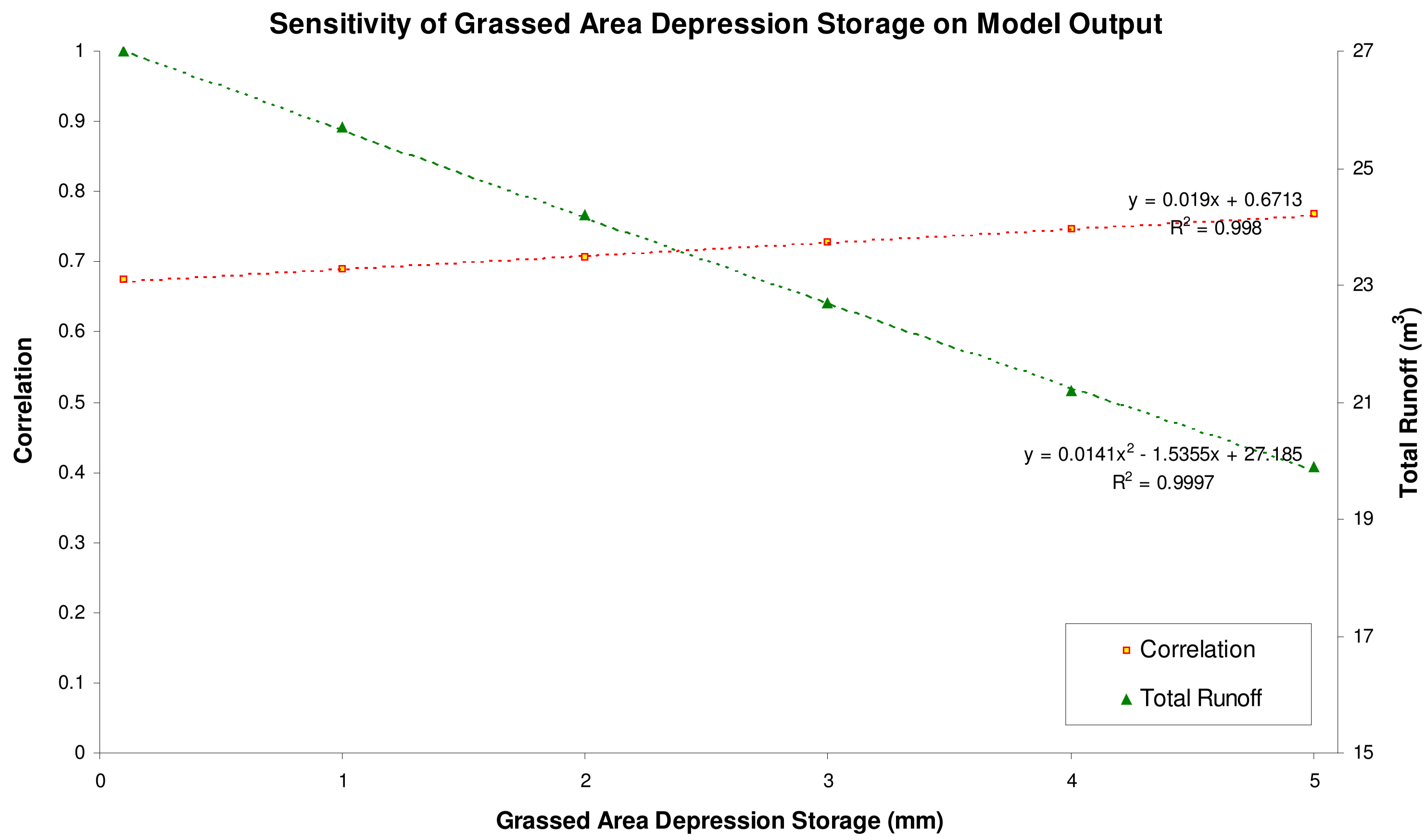


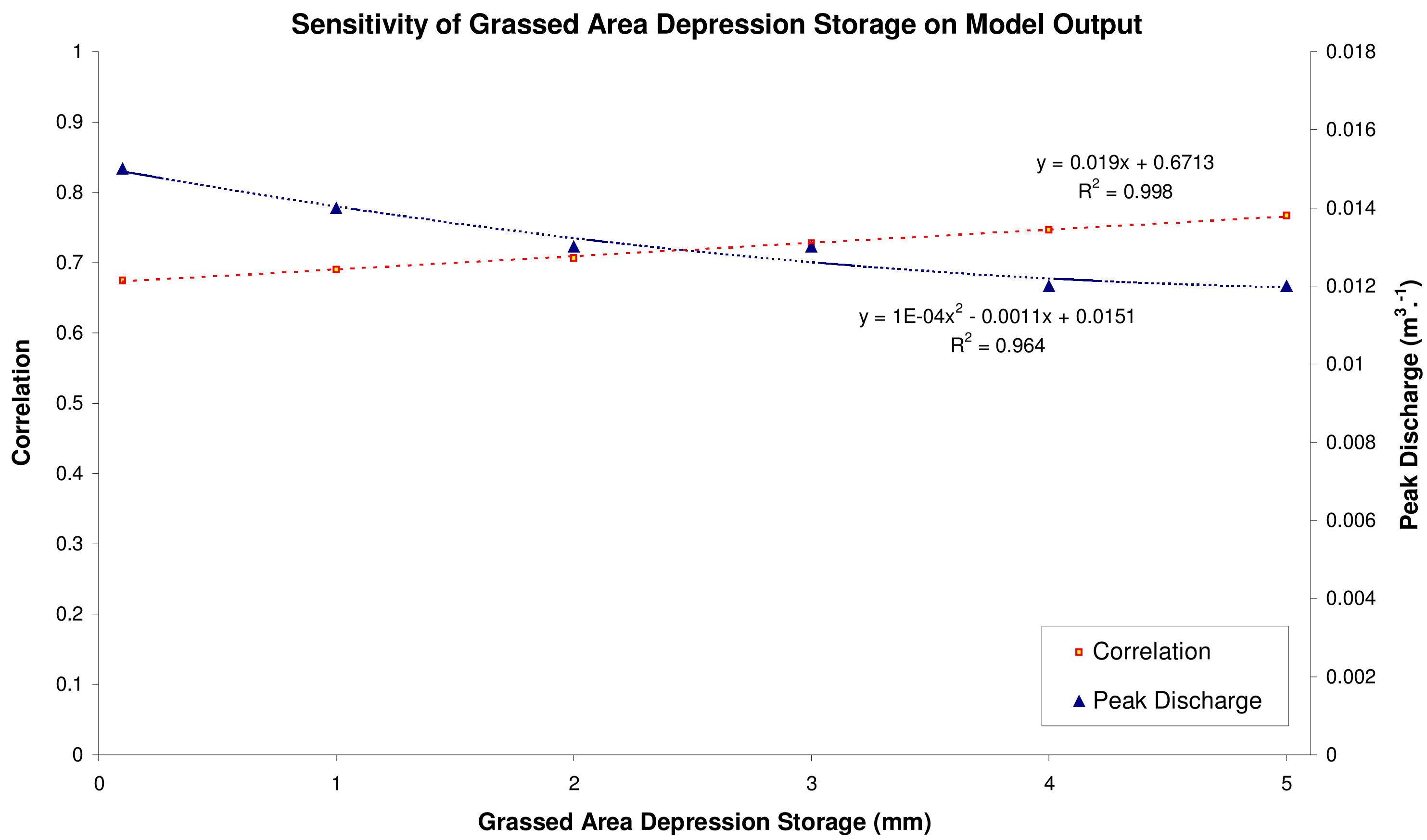
Sensitivity of Grassed Area Flow Path Slope on Model Output
Correlation
Peak Discharge (m3.-1)
Grassed Area Flow Path Slope (%)
y = -0.0079x2 + 0.0181x + 0.7397
R2 = 0.1286
y = -0.0003x2 + 0.0012x + 0.0118
R2 = 0.8464
Correlation
Peak Discharge
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.5
1.5
2
2.5
3
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018

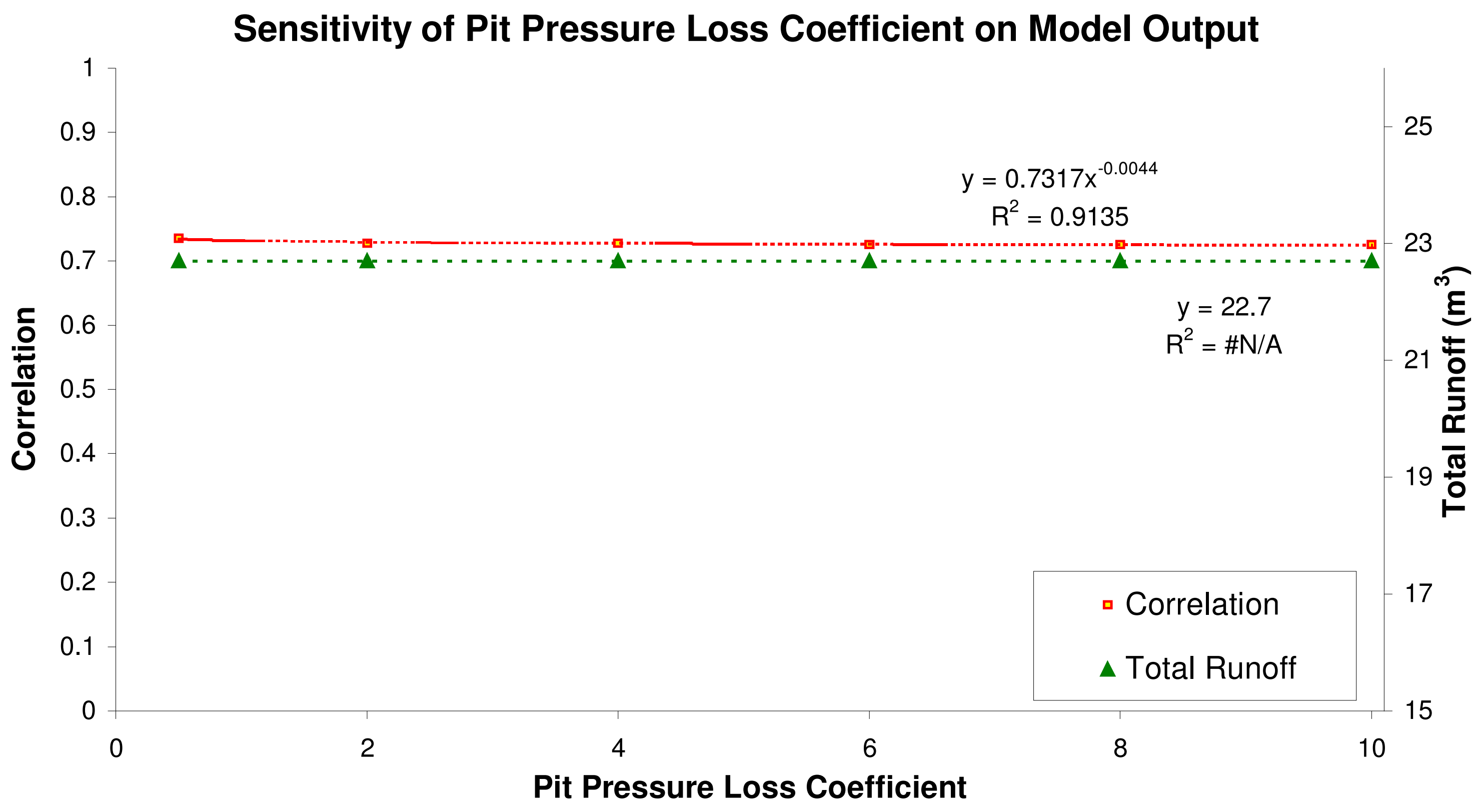

Sensitivity of Grassed Area Flow Path Roughness on Model Output
Correlation
Peak Discharge (m3.-1)
Grassed Area Flow Path Roughness
y = 0.0396Ln(x) + 0.8102
R2 = 0.9977
y = -0.0011Ln(x) + 0.0106
R2 = 0.948
Correlation
Peak Discharge
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0.05
0.15
0.25
0.35



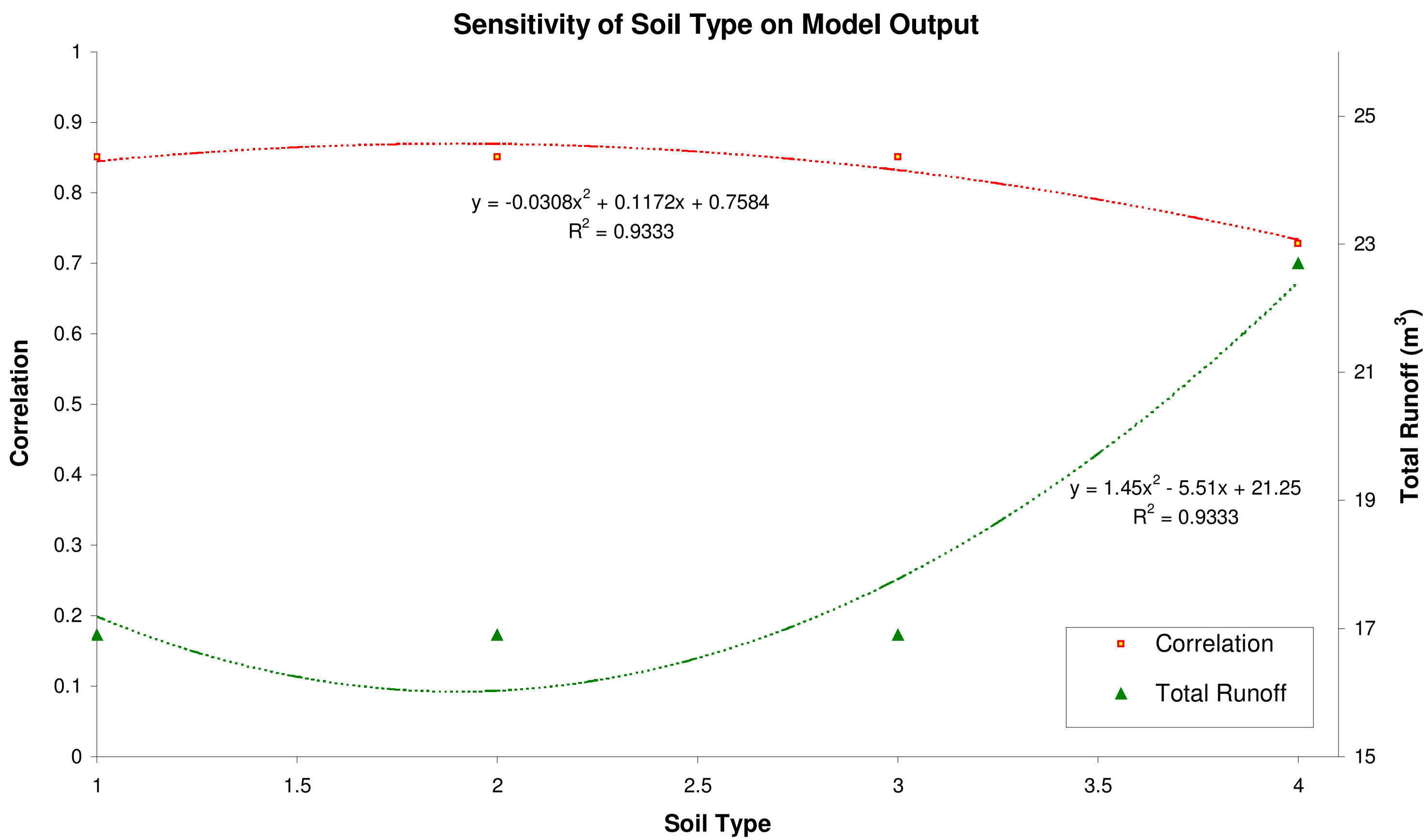
Sensitivity of Grassed Area Flow Path Roughness on Model Output
Correlation
Total Runoff (m3)
Grassed Area Flow Path Roughness
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
25
23
21
19
17
15
y = 0.0396Ln(x) + 0.8102
R2 = 0.9977
y = 24.256x2 - 20.631x + 25.02
R2 = 0.9975
Correlation
Total Runoff


Sensitivity of Grassed Area Depression Storage on Model Output
Correlation
Total Runoff (m3)
Grassed Area Depression Storage (mm)
y = 0.019x + 0.6713
R2 = 0.998
y = 0.0141x2 - 1.5355x + 27.185
R2 = 0.9997
Correlation
Total Runoff
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
15
17
19
21
23
25
27
0
1
2
3
4
5

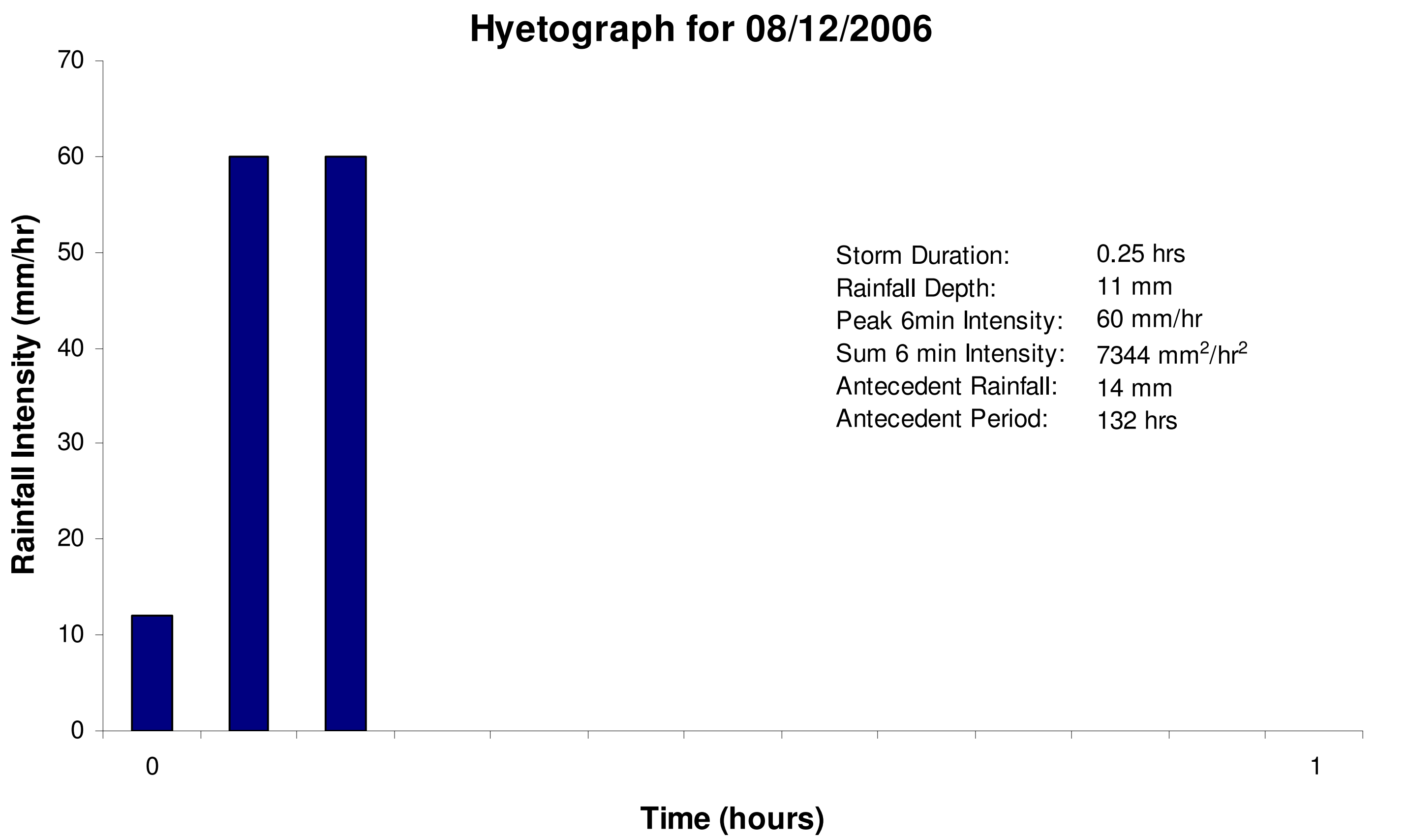

Sensitivity of Grassed Area Depression Storage on Model Output
Correlation
Peak Discharge (m3.-1)
Grassed Area Depression Storage (mm)
y = 0.019x + 0.6713
R2 = 0.998
y = 1E-04x2 - 0.0011x + 0.0151
R2 = 0.964
Correlation
Peak Discharge
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
0
1
2
3
4
5



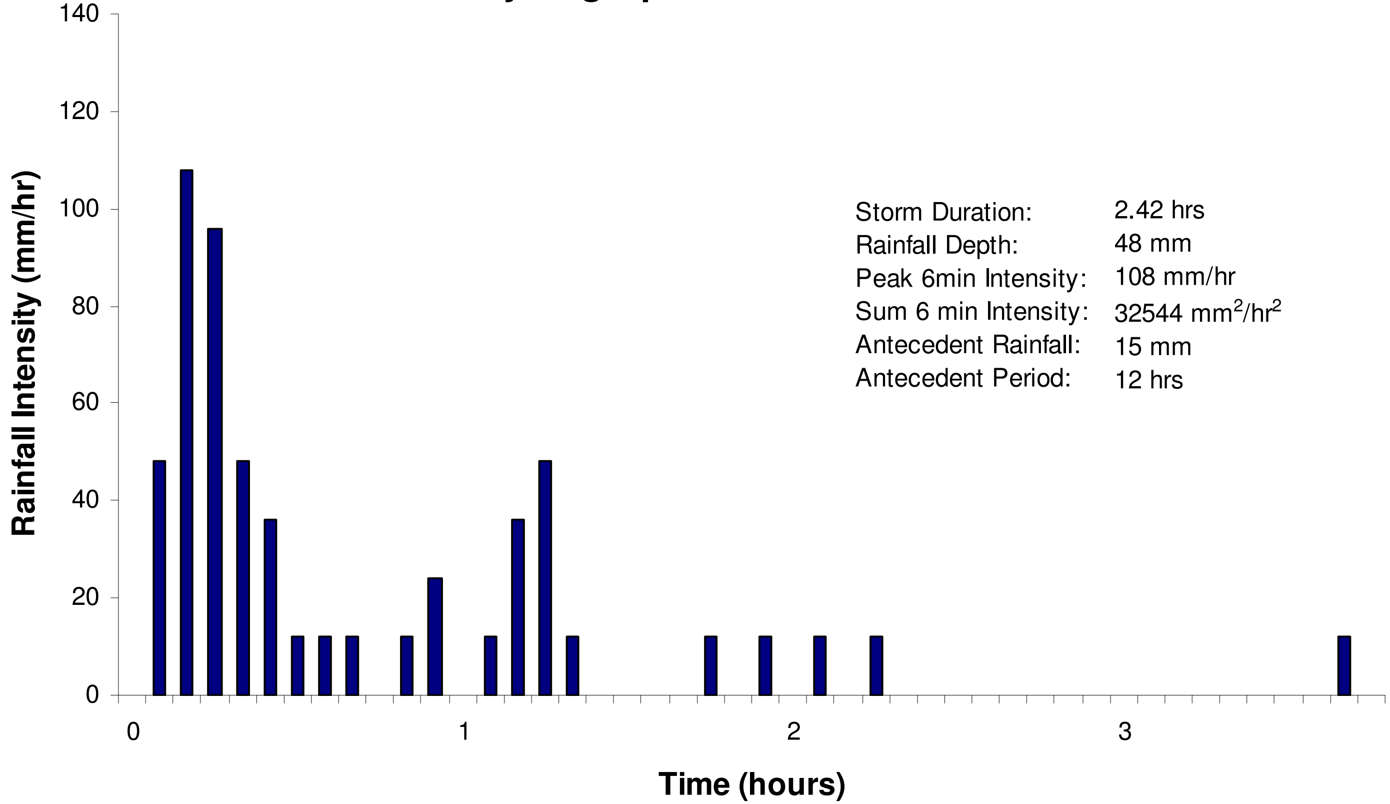
Sensitivity of Pit Pressure Loss Coefficient on Model Output
Correlation
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
y = 0.7317x^-0.0044
R^2 = 0.9135
y = 22.7
R^2 = #N/A
Total Runoff (m^3)
25
23
21
19
17
15
Correlation
Total Runoff
0
2
4
6
8
10
Pit Pressure Loss Coefficient

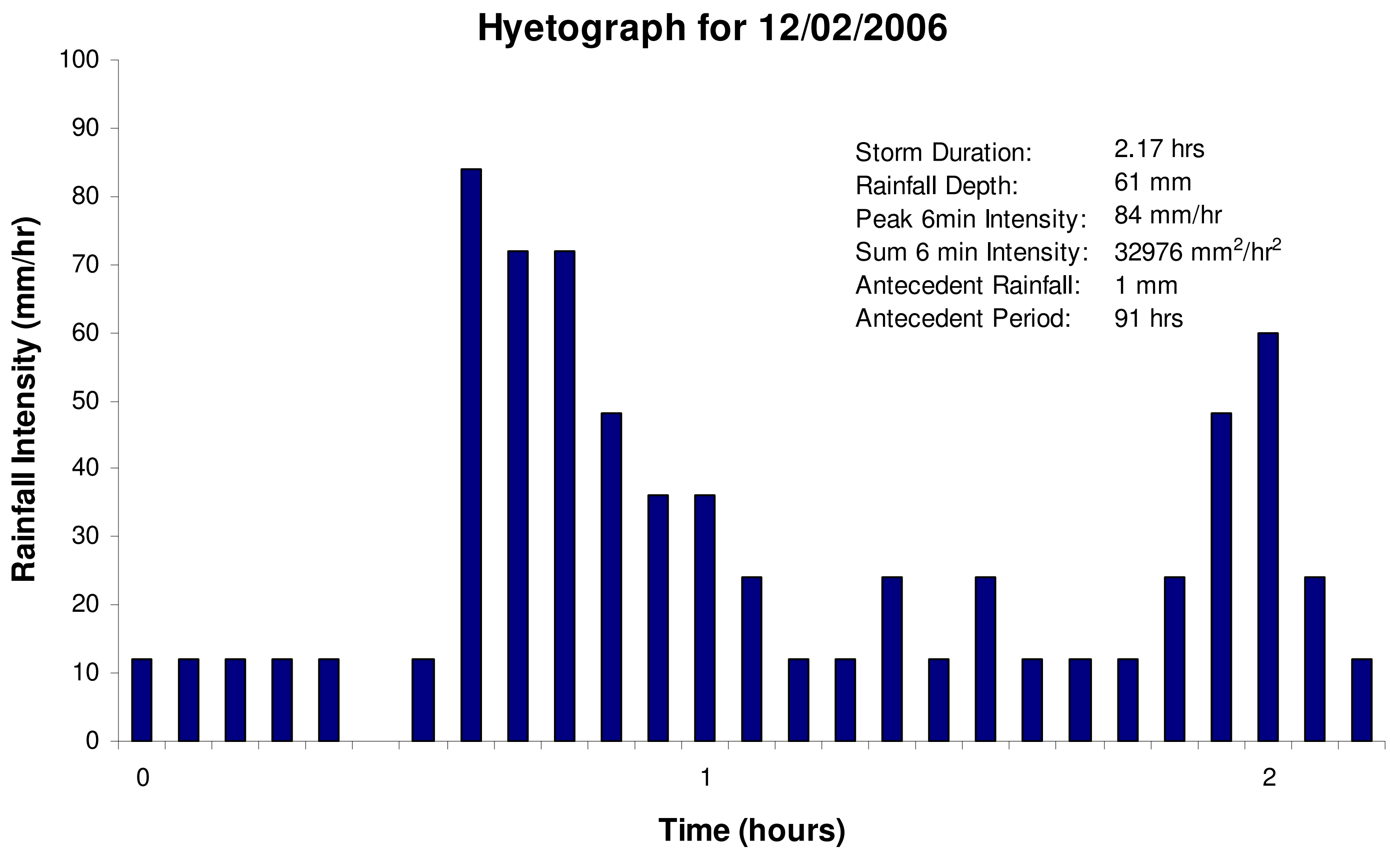

Sensitivity of Soil Type on Model Output
Correlation
Total Runoff (m3)
Soil Type
y = -0.0308x2 + 0.1172x + 0.7584
R2 = 0.9333
y = 1.45x2 - 5.51x + 21.25
R2 = 0.9333
Correlation
Total Runoff
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
15
17
19
21
23
25
1
1.5
2
2.5
3
3.5
4

APPENDIX L: Hyetographs for Rainfall Events used to test Mass Balance Model

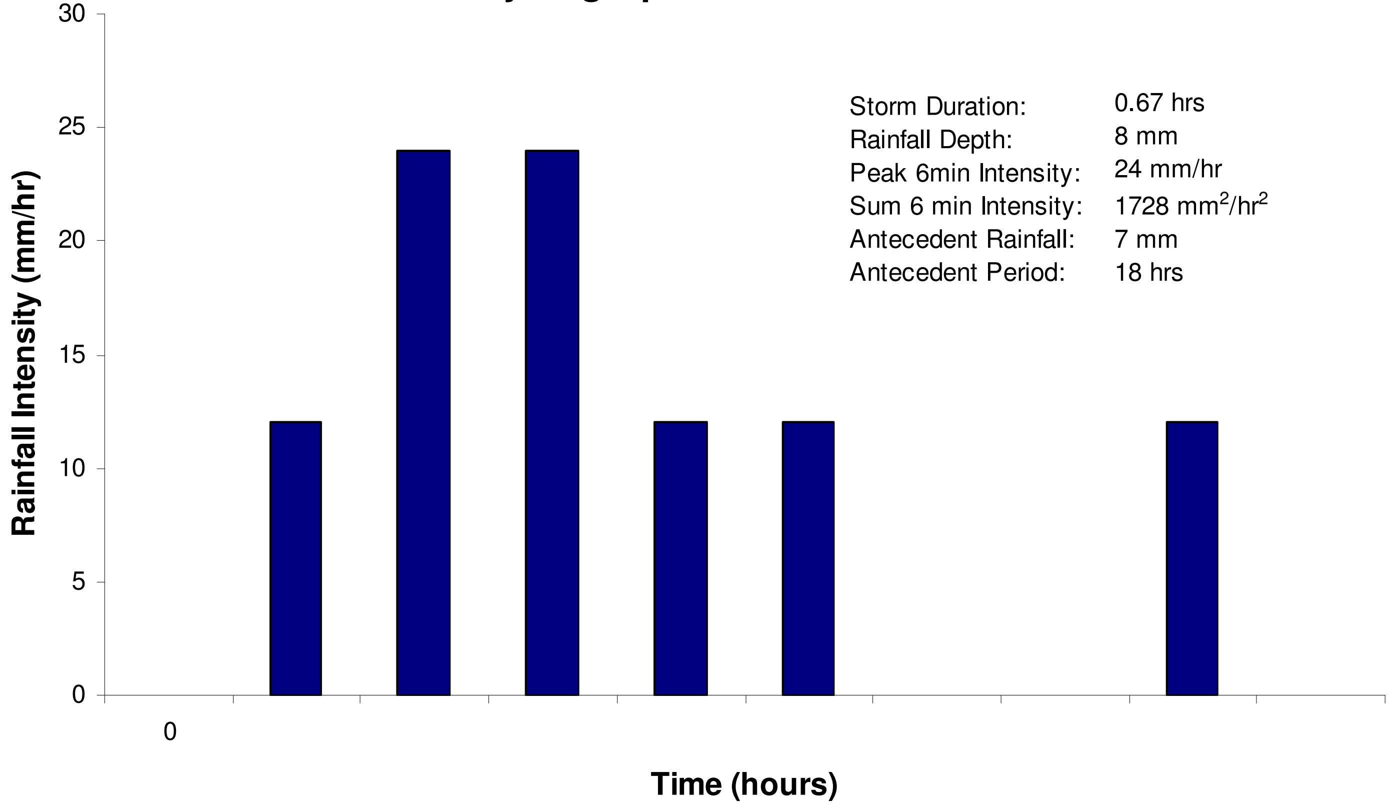


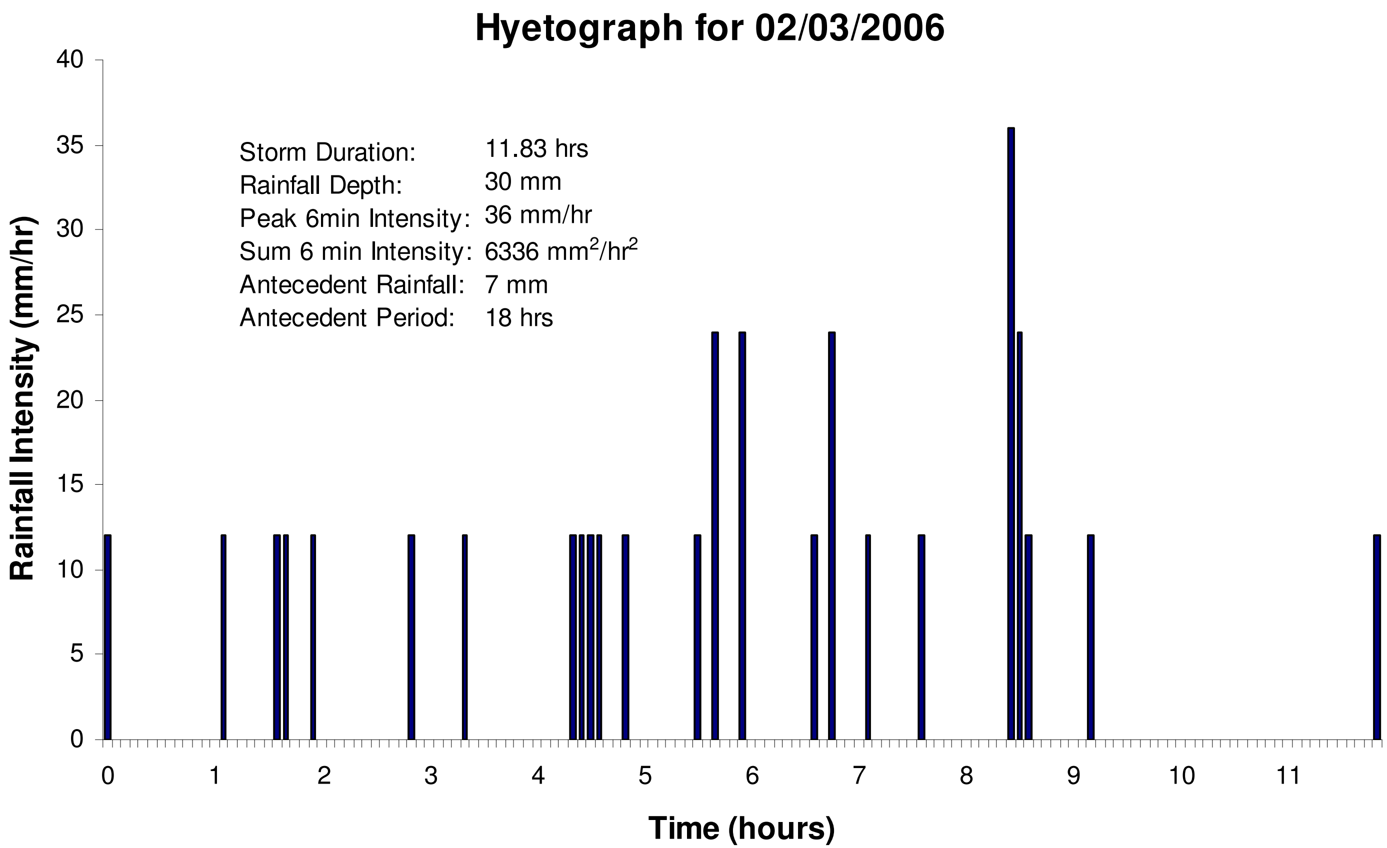
Hyetograph for 04/01/2006



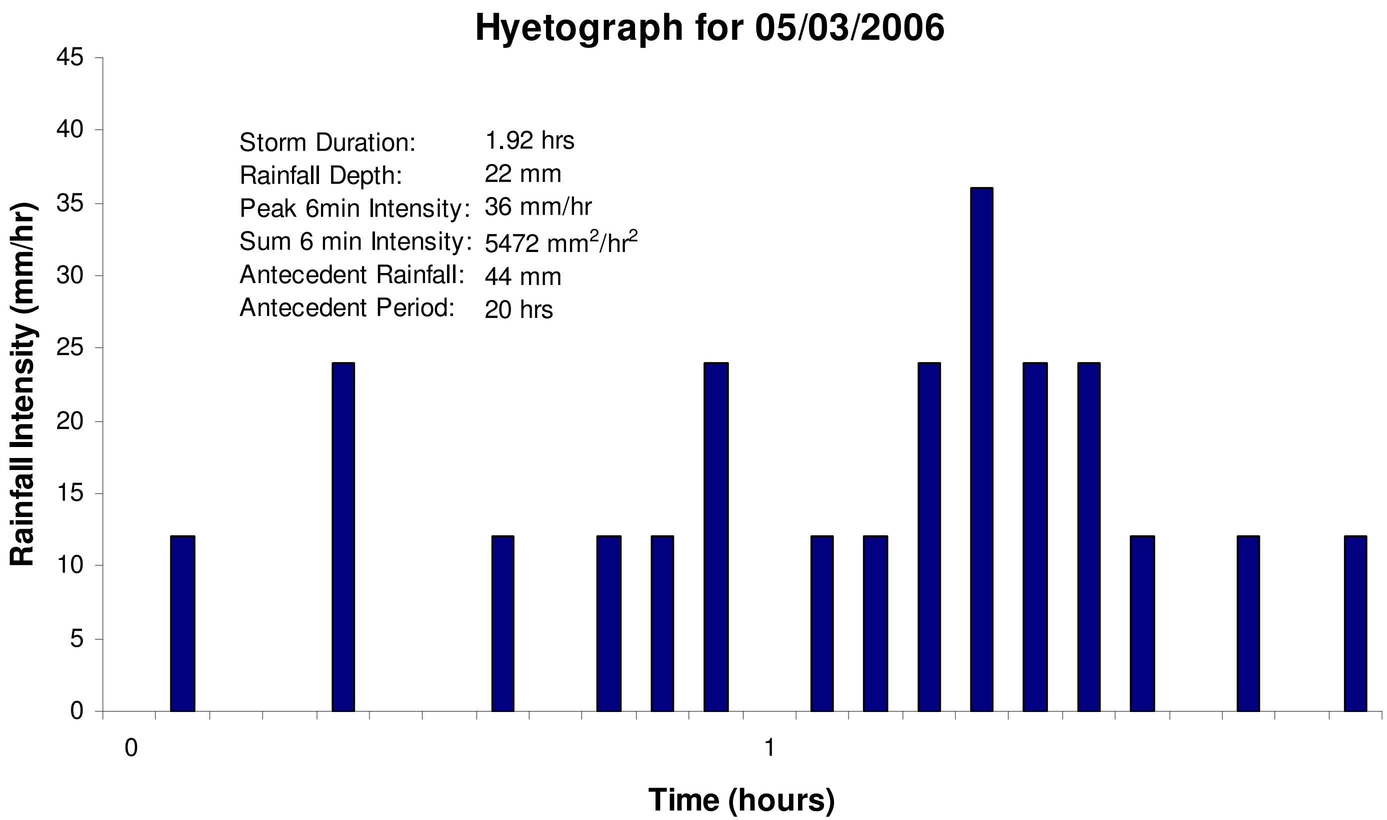

Hyetograph for 12/02/2006
Rainfall Intensity (mm/hr)
100
90
80
70
60
50
40
30
20
10
0
Storm Duration: 2.17 hrs
Rainfall Depth: 61 mm
Peak 6min Intensity: 84 mm/hr
Sum 6 min Intensity: 32976 mm2/hr2
Antecedent Rainfall: 1 mm
Antecedent Period: 91 hrs
0
1
2
Time (hours)

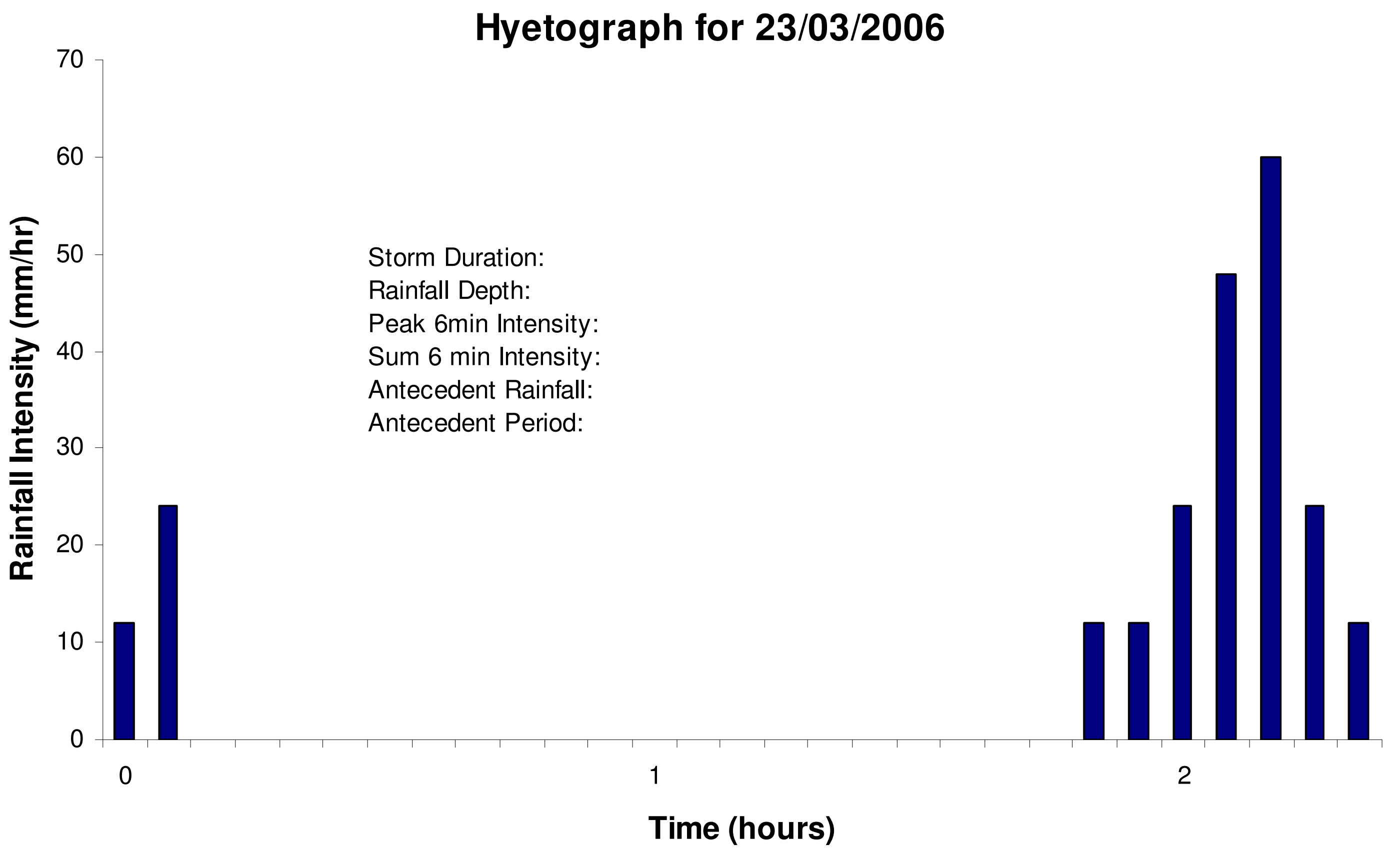
Hyetograph for 17/02/2006





Hyetograph for 02/03/2006
Storm Duration: 11.83 hrs
Rainfall Depth: 30 mm
Peak 6min Intensity: 36 mm/hr
Sum 6 min Intensity: 6336 mm2/hr2
Antecedent Rainfall: 7 mm
Antecedent Period: 18 hrs
Rainfall Intensity (mm/hr)
0
5
10
15
20
25
30
35
40
Time (hours)
0
1
2
3
4
5
6
7
8
9
10
11


Hyetograph for 05/03/2006
Storm Duration: 1.92 hrs
Rainfall Depth: 22 mm
Peak 6min Intensity: 36 mm/hr
Sum 6 min Intensity: 5472 mm2/hr2
Antecedent Rainfall: 44 mm
Antecedent Period: 20 hrs
Rainfall Intensity (mm/hr)
0
5
10
15
20
25
30
35
40
45
0
1
Time (hours)


Hyetograph for 23/03/2006
Rainfall Intensity (mm/hr)
70
60
50
40
30
20
10
0
Storm Duration:
Rainfall Depth:
Peak 6min Intensity:
Sum 6 min Intensity:
Antecedent Rainfall:
Antecedent Period:
0
1
2
Time (hours)

APPENDIX M: Mass Balance Model Spreadsheet Output

Catchment HSA

MASS BALANCE SPREADSHEET TO ESTIMATE NCP EVENT MEAN CONCENTRATION FROM URBAN CATCHMENTS
CATCHMENT HSA

Storm Event	RAINFALL DATA									
	Ant Rain (mm)	Ant Period (hrs)	Storm Dur (hrs)	Rain Depth (mm)	Sum Rain Depth for Storm (mm)	Mean I (mm/hr)	Peak I_6 (mm/hr)	Peak I_6^2	Sum I_6^2	SumI2/D
8/12/2005	14.00	132.00	0.25	11.00	11	44.0	60	3600	7344	29376
4/01/2006	15.00	12.00	2.42	48.00	48	19.8	108	11664	32544	13448
12/02/2006	1.00	91.00	2.17	61.00	61	28.1	84	7056	32976	15196
17/02/2006	7.00	18.00	0.67	8.00	8	11.9	24	576	1728	2579
2/03/2006	21.00	6.00	11.83	30.00	30	2.5	36	1296	6336	536
5/03/2006	44.00	20.00	1.92	22.00	22	11.5	36	1296	5472	2850
23/03/2006	3.00	4.00	2.33	19.00	19	8.2	60	3600	8208	3523

STATISTICAL DATA										
Ist quartile (25 %tle)	5.0	9.0	1.3	15.0	15.0	9.8	36.0	1296.0	5904.0	2714.6
Minimum	1.0	4.0	0.3	8.0	8.0	2.5	24.0	576.0	1728.0	535.6
Median	14.0	18.0	2.2	22.0	22.0	11.9	60.0	3600.0	7344.0	3522.7
Maximum	44.0	132.0	11.8	61.0	61.0	44.0	108.0	11664.0	32976.0	29376.0
3rd quartile (75 %tle)	18.0	55.5	2.4	39.0	39.0	24.0	72.0	5328.0	20376.0	14322.1
Mean	15.0	40.4	3.1	28.4	28.4	18.0	58.3	4155.4	13515.4	9644.0
Stand Dev	14.6	50.3	3.9	19.6	19.6	14.1	29.7	3970.2	13305.6	10417.6
COV	1.0	1.2	1.3	0.7	0.7	0.8	0.5	1.0	1.0	1.1
n	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Sum	105.0	283.0	21.6	199.0	199.0	126.0	408.0	29088.0	94608.0	67507.7

ROAD

TEdrain curve parameters		WEFP curve parameters	
TEmin	25.00%	WEFPmin	30.00%
Peaklmin	5.0	RPmin	40.0
Peaklcritical	15	RPcri	200
		RPDPcr	1,300.0

Max FPdry	1600	ARFPwet	2000.0	CP	25%
Max FPwet	6000	ARFPdry	1000.0		
MaxDPdry	2600	ARDPdry	30.0		
		LRRPdrain	0.4		

TEdrain (%)	WEFP (%)	Twet=IBP (hrs)	LFPwet (mg/m2)	Tdry (hrs)	Tdry x ARFPdry (mg/m2)	LDPsurf (mg/m2) 0	LDPdrain (mg/m2) 0	LFPi PreStorm	LFPsurf Storm	LRPdrain (mg/m2)	LFPdrain (mg/m2)	Ldrain (mg/m2)	L (mg/m2)	Sum L (mg/m2)	LRPdrain PostStorm 50	LRPsurf Post Storm 0
100%	100%	0.0	0	132.0	1600	2600	2600	1600	1600	24	1600	4224	4224	4224	0	0
100%	100%	1.1	2160	12.0	1600	360	360	1600	3760	0	3760	4120	4120	4120	0	0
100%	100%	1.4	2840	91.0	1600	2600	2600	1600	4440	0	4440	7040	7040	7040	0	0
100%	100%	0.0	0	18.0	1600	540	540	1600	1600	0	1600	2140	2140	2140	0	0
100%	100%	0.0	0	6.0	1600	180	0	1600	1600	0	1600	1600	1600	1600	0	0
100%	100%	0.0	0	20.0	1600	780	780	1600	1600	0	1600	2380	2380	2380	0	0
100%	100%	0.0	0	4.0	1600	120	120	1600	1600	0	1600	1720	1720	1720	0	0

CARPARK

TEdrain curve parameters		WEFP curve parameters	
TEmin	20.00%	WEFPmin	60.00%
Peaklmin	6.0	RPmin	40.0
Peaklcritical	25	RPcri	100
		RPDPcr	940.0

Max FPdry	500	ARFPwet	300.0	CP	30%
Max FPwet	500	ARFPdry	300.0		
MaxDPdry	1000	ARDPdry	5.0		
		LRRPdrain	0.5		

TEdrain (%)	WEFP (%)	Twet=IBP (hrs)	LFPwet (mg/m2)	Tdry (hrs)	Tdry x ARFPdry (mg/m2)	LDPsurf (mg/m2) 0	LDPdrain (mg/m2) 0	LFPi PreStorm	LFPsurf Storm	LRPdrain (mg/m2)	LFPdrain (mg/m2)	Ldrain (mg/m2)	L (mg/m2)	Sum L (mg/m2)	LRPdrain PostStorm 50	LRPsurf Post Storm 0
100%	100%	0.0	0	132.0	500	660	660	500	500	17	500	1177	1177	1177	0	0
100%	100%	1.1	324	12.0	500	60	60	500	500	0	500	560	560	560	0	0
100%	100%	1.4	426	91.0	500	455	455	500	500	0	500	955	955	955	0	0
96%	100%	0.0	0	18.0	500	90	90	500	500	0	500	590	565	565	25	0
100%	100%	0.0	0	6.0	500	30	0	500	500	24	500	524	524	524	0	0
100%	100%	0.0	0	20.0	500	130	130	500	500	0	500	630	630	630	0	0
100%	100%	0.0	0	4.0	500	20	20	500	500	0	500	520	520	520	0	0

ROOF

TEdrain curve parameters		WEFP curve parameters	
TEmin	5.00%	WEFPmin	80.00%
PeakImin	4.0	RPmin	10.0
PeakIcritical	25	RPcri	100

Max FPdry	160	ARFPwet	3.0	CP	30%
Max FPwet	250	ARFPdry	5.0		
MaxDPdry	0	ARDPdry	0.0		
		LRRPdrain	0.5		

TEdrain (%)	WEFP (%)	Twet=D (hrs)	LFPwet (mg/m2)	Tdry (hrs)	Tdry x ARFPdry (mg/m2)	LDPsurf (mg/m2) 0	LDPdrain (mg/m2) 0	LFPi PreStorm	LFPsurf Storm	LRPdrain (mg/m2)	LFPdrain (mg/m2)	Ldrain (mg/m2)	L (mg/m2)	Sum L (mg/m2)	LRPdrain PostStorm 50	LRPsurf Post Storm 0
100%	100%	0.3	1	132.0	160	0	0	160	161	17	161	178	178	178	0	0
100%	100%	2.4	7	12.0	60	0	0	60	67	0	67	67	67	67	0	0
100%	100%	2.2	7	91.0	160	0	0	160	167	0	167	167	167	167	0	0
95%	100%	0.7	2	18.0	90	0	0	90	92	0	92	92	88	88	4	0
100%	100%	11.8	35	6.0	30	0	0	30	65	4	65	70	70	70	0	0
100%	100%	1.9	6	20.0	100	0	0	100	106	0	106	106	106	106	0	0
100%	100%	2.3	7	4.0	20	0	0	20	27	0	27	27	27	27	0	0

EMC AND LOAD CALCULATIONS

Area (m2)	Road 5360		Carpark 292		Roof 285		Grass 4399		Total	Road Flow	Carpark Flow	Roof Flow (with 0.4	Grass Flow	Predicted Flow	Sum Pre Flow	Predicted EMC	Meas EMC	Modelled Flow	Predicted Load	Modelled Load
	(kg)	(mg/L)	(kg)	(mg/L)	(kg)	(mg/L)	(kg)	(mg/L)	(kg)	(ML)	(ML)	(ML)	(ML)	(ML)	(ML)	(mg/L)	(mg/L)	(ML)	(g)	(g)
	23	422	0	118	0	18	1.9	0	25	0.05	0.00	0.0011	0.0000	0.0577	0.0577	433.0	69	0.0046	########	317.4000
	22	88	0	12	0	1	8.4	110	31	0.25	0.01	0.0054	0.0768	0.3478	0.3478	88.3	190	0.0187	########	########
	38	117	0	16	0	3	10.7	96	49	0.32	0.02	0.0068	0.1123	0.4582	0.4582	106.5	170	0.0223	########	########
	11	306	0	81	0	13	1.4	0	13	0.04	0.00	0.0008	0.0000	0.0404	0.0404	323.8	69	0.0009	########	62.1000
	9	55	0	18	0	2	5.3	190	14	0.16	0.01	0.0033	0.0277	0.1949	0.1949	72.0	100	0.0105	########	########
	13	113	0	30	0	5	3.9	657	17	0.11	0.01	0.0024	0.0059	0.1270	0.1270	132.6	31	0.0071	########	220.0000
	9	96	0	29	0	1	3.3	0	13	0.10	0.01	0.0021	0.0000	0.1038	0.1038	122.6	190	0.0143	########	########
STATISTICAL DATA																				
Ist quartile	10.3	91.6	0.2	17.0	0.0	1.9	2.6	0.0	**161**						7.0	182.7	117.0	7.0		
Minimum	8.6	55.2	0.2	11.9	0.0	1.4	1.4	0.0												
Median	12.8	113.3	0.2	28.9	0.0	2.8	3.9	95.6												
Maximum	37.7	422.4	0.3	117.7	0.1	17.8	10.7	656.7												
3rd quartile	22.4	211.5	0.2	55.4	0.0	8.8	6.9	150.2												
Mean	17.78	171.02	0.21	43.32	0.03	6.21	5.00	150.40												
Stand Dev	10.51	137.59	0.08	40.19	0.02	6.41	3.44	234.68												
COV	0.6	0.8	0.4	0.9	0.5	1.0	0.7	1.6												
n	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0												
Sum	124		1		0		35													

Catchment HSB

MASS BALANCE SPREADSHEET TO ESTIMATE NCP EVENT MEAN CONCENTRATION FROM URBAN CATCHMENTS
CATCHMENT HSC

RAINFALL DATA

Storm Event	Ant Rain (mm)	Ant Period (hrs)	Storm Dur (hrs)	Rain Depth (mm)	Sum Rain Depth for Storm (mm)	Mean I (mm/hr)	Peak I_6 (mm/hr)	Peak I_6^2	Sum I_6^2	SumI2/D
8/12/2005	14.00	132.00	0.25	11.00	11	44.0	60	3600	7344	29376
4/01/2006	15.00	12.00	2.42	48.00	48	19.8	108	11664	32544	13448
12/02/2006	1.00	91.00	2.17	61.00	61	28.1	84	7056	32976	15196
17/02/2006	7.00	18.00	0.67	8.00	8	11.9	24	576	1728	2579
2/03/2006	21.00	6.00	11.83	30.00	30	2.5	36	1296	6336	536
5/03/2006	44.00	20.00	1.92	22.00	22	11.5	36	1296	5472	2850
23/03/2006	3.00	4.00	2.33	19.00	19	8.2	60	3600	8208	3523
STATISTICAL DATA										
Ist quartile (25 %tle)	5.0	9.0	1.3	15.0	15.0	9.8	36.0	1296.0	5904.0	2714.6
Minimum	1.0	4.0	0.3	8.0	8.0	2.5	24.0	576.0	1728.0	535.6
Median	14.0	18.0	2.2	22.0	22.0	11.9	60.0	3600.0	7344.0	3522.7
Maximum	44.0	132.0	11.8	61.0	61.0	44.0	108.0	11664.0	32976.0	29376.0
3rd quartile (75 %tle)	18.0	55.5	2.4	39.0	39.0	24.0	72.0	5328.0	20376.0	14322.1
Mean	15.0	40.4	3.1	28.4	28.4	18.0	58.3	4155.4	13515.4	9644.0
Stand Dev	14.6	50.3	3.9	19.6	19.6	14.1	29.7	3970.2	13305.6	10417.6
COV	1.0	1.2	1.3	0.7	0.7	0.8	0.5	1.0	1.0	1.1
n	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Sum	105.0	283.0	21.6	199.0	199.0	126.0	408.0	29088.0	94608.0	67507.7

ROAD

TEdrain curve parameters		WEFP curve parameters	
TEmin	25.00%	WEFPmin	30.00%
PeakImin	5.0	RPmin	40.0
PeakIcritical	15	RPcri	200
		RPDPcr	1,300.0

Max FPdry	1600	ARFPwet	2000.0	CP	25%
Max FPwet	6000	ARFPdry	1000.0		
MaxDPdry	2600	ARDPdry	30.0		
		LRRPdrain	0.4		

TEdrain (%)	WEFP (%)	Twet=IBP (hrs)	LFPwet (mg/m2)	Tdry (hrs)	Tdry x ARFPdry (mg/m2)	LDPsurf (mg/m2)	LDPdrain (mg/m2)	LFPi PreStorm	LFPsurf Storm	LRPdrain (mg/m2)	LFPdrain (mg/m2)	Ldrain (mg/m2)	L (mg/m2)	Sum L (mg/m2)	LRPdrain PostStorm	LRPsurf Post Storm
						0	0								50	0
100%	100%	0.0	0	132.0	1600	2600	2600	1600	1600	24	1600	4224	4224	4224	0	0
100%	100%	1.1	2160	12.0	1600	360	360	1600	3760	0	3760	4120	4120	4120	0	0
100%	100%	1.4	2840	91.0	1600	2600	2600	1600	4440	0	4440	7040	7040	7040	0	0
100%	100%	0.0	0	18.0	1600	540	540	1600	1600	0	1600	2140	2140	2140	0	0
100%	100%	0.0	0	6.0	1600	180	0	1600	1600	0	1600	1600	1600	1600	0	0
100%	100%	0.0	0	20.0	1600	780	780	1600	1600	0	1600	2380	2380	2380	0	0
100%	100%	0.0	0	4.0	1600	120	120	1600	1600	0	1600	1720	1720	1720	0	0

CARPARK

TEdrain curve parameters		WEFP curve parameters	
TEmin	20.00%	WEFPmin	60.00%
PeakImin	6.0	RPmin	40.0
PeakIcritical	25	RPcri	100
		RPDPcr	940.0

Max FPdry	500	ARFPwet	300.0	CP	30%
Max FPwet	500	ARFPdry	300.0		
MaxDPdry	1000	ARDPdry	5.0		
		LRRPdrain	0.5		

TEdrain (%)	WEFP (%)	Twet=IBP (hrs)	LFPwet (mg/m2)	Tdry (hrs)	Tdry x ARFPdry (mg/m2)	LDPsurf (mg/m2)	LDPdrain (mg/m2)	LFPi PreStorm	LFPsurf Storm	LRPdrain (mg/m2)	LFPdrain (mg/m2)	Ldrain (mg/m2)	L (mg/m2)	Sum L (mg/m2)	LRPdrain PostStorm	LRPsurf Post Storm
						0	0								50	0
100%	100%	0.0	0	132.0	500	660	660	500	500	17	500	1177	1177	1177	0	0
100%	100%	1.1	324	12.0	500	60	60	500	500	0	500	560	560	560	0	0
100%	100%	1.4	426	91.0	500	455	455	500	500	0	500	955	955	955	0	0
96%	100%	0.0	0	18.0	500	90	90	500	500	0	500	590	565	565	25	0
100%	100%	0.0	0	6.0	500	30	0	500	500	24	500	524	524	524	0	0
100%	100%	0.0	0	20.0	500	130	130	500	500	0	500	630	630	630	0	0
100%	100%	0.0	0	4.0	500	20	20	500	500	0	500	520	520	520	0	0

ROOF

TEdrain curve parameters		WEFP curve parameters	
TEmin	5.00%	WEFPmin	80.00%
PeakImin	4.0	RPmin	10.0
PeakIcritical	25	RPcri	100

Max FPdry	160	ARFPwet	3.0	CP	30%
Max FPwet	250	ARFPdry	5.0		
MaxDPdry	0	ARDPdry	0.0		
		LRRPdrain	0.5		

TEdrain (%)	WEFP (%)	Twet=D (hrs)	LFPwet (mg/m2)	Tdry (hrs)	Tdry x ARFPdry (mg/m2)	LDPsurf (mg/m2)	LDPdrain (mg/m2)	LFPi PreStorm	LFPsurf Storm	LRPdrain (mg/m2)	LFPdrain (mg/m2)	Ldrain (mg/m2)	L (mg/m2)	Sum L (mg/m2)	LRPdrain PostStorm	LRPsurf Post Storm
						0	0								50	0
100%	100%	0.3	1	132.0	160	0	0	160	161	17	161	178	178	178	0	0
100%	100%	2.4	7	12.0	60	0	0	60	67	0	67	67	67	67	0	0
100%	100%	2.2	7	91.0	160	0	0	160	167	0	167	167	167	167	0	0
95%	100%	0.7	2	18.0	90	0	0	90	92	0	92	92	88	88	4	0
100%	100%	11.8	35	6.0	30	0	0	30	65	4	65	70	70	70	0	0
100%	100%	1.9	6	20.0	100	0	0	100	106	0	106	106	106	106	0	0
100%	100%	2.3	7	4.0	20	0	0	20	27	0	27	27	27	27	0	0

EMC AND LOAD CALCULATIONS

	Road		Carpark		Roof		Grass		Total	Road Flow	Carpark Flow	Roof Flow (with 0.4	Grass Flow	Predicted Flow	Sum Pre Flow	Predicted EMC	Meas EMC	Modelled Flow	Predicted Load	Modelled Load
Area (m2)	1020		453		0		1497													
	(kg)	(mg/L)	(kg)	(mg/L)	(kg)	(mg/L)	(kg)	(mg/L)	(kg)	(ML)	(ML)	(ML)	(ML)	(ML)	(ML)	(mg/L)	(mg/L)	(ML)	(g)	(g)
	4	422	1	118	0	#DIV/0!	0.7	0	5	0.01	0.00	0.0000	0.0000	0.0147	0.0147	373.4	60	0.0009	5499.9330	54.0000
	4	88	0	12	0	#DIV/0!	2.9	110	7	0.05	0.02	0.0000	0.0261	0.0954	0.0954	76.9	220	0.0036	7330.3200	792.0000
	7	117	0	16	0	#DIV/0!	3.7	96	11	0.06	0.03	0.0000	0.0382	0.1266	0.1266	89.0	180	0.0042	11266.0950	756.0000
	2	306	0	81	0	#DIV/0!	0.5	0	3	0.01	0.00	0.0000	0.0000	0.0103	0.0103	283.0	60	0.0002	2917.8565	12.0000
	2	55	0	18	0	#DIV/0!	1.8	190	4	0.03	0.01	0.0000	0.0094	0.0521	0.0521	70.3	140	0.0020	3665.8159	280.0000
	2	113	0	30	0	#DIV/0!	1.3	657	4	0.02	0.01	0.0000	0.0020	0.0329	0.0329	122.4	15	0.0020	4030.3500	30.0000
	2	96	0	29	0	#DIV/0!	1.1	0	3	0.02	0.01	0.0000	0.0000	0.0265	0.0265	118.0	170	0.0039	3127.6800	663.0000
STATISTICAL DATA																				
Ist quartile	2.0	91.6	0.2	17.0	0.0	#DIV/0!	0.9	0.0	**38**						7.0	161.8	120.7	7.0		
Minimum	1.6	55.2	0.2	11.9	0.0	#DIV/0!	0.5	0.0												
Median	2.4	113.3	0.3	28.9	0.0	#DIV/0!	1.3	95.6												
Maximum	7.2	422.4	0.5	117.7	0.0	#DIV/0!	3.7	656.7												
3rd quartile	4.3	211.5	0.4	55.4	0.0	#DIV/0!	2.3	150.2												
Mean	3.38	171.02	0.32	43.32	0.00	#DIV/0!	1.70	150.40												
Stand Dev	2.00	137.59	0.12	40.19	0.00	#DIV/0!	1.17	234.68												
COV	0.6	0.8	0.4	0.9	#DIV/0!	#DIV/0!	0.7	1.6												
n	7.0	7.0	7.0	7.0	7.0	0.0	7.0	7.0												
Sum	24		2		0		12													

Catchment HSC

MASS BALANCE SPREADSHEET TO ESTIMATE NCP EVENT MEAN CONCENTRATION FROM URBAN CATCHMENTS
CATCHMENT HSC

Storm Event	RAINFALL DATA									
	Ant Rain (mm)	Ant Period (hrs)	Storm Dur (hrs)	Rain Depth (mm)	Sum Rain Depth for Storm (mm)	Mean I (mm/hr)	Peak I_6 (mm/hr)	Peak I_6^2	Sum I_6^2	SumI2/D
8/12/2005	14.00	132.00	0.25	11.00	11	44.0	60	3600	7344	29376
4/01/2006	15.00	12.00	2.42	48.00	48	19.8	108	11664	32544	13448
12/02/2006	1.00	91.00	2.17	61.00	61	28.1	84	7056	32976	15196
17/02/2006	7.00	18.00	0.67	8.00	8	11.9	24	576	1728	2579
2/03/2006	21.00	6.00	11.83	30.00	30	2.5	36	1296	6336	536
5/03/2006	44.00	20.00	1.92	22.00	22	11.5	36	1296	5472	2850
23/03/2006	3.00	4.00	2.33	19.00	19	8.2	60	3600	8208	3523

STATISTICAL DATA	Ant Rain	Ant Period	Storm Dur	Rain Depth	Sum Rain Depth for Storm	Mean I	Peak I_6	Peak I_6^2	Sum I_6^2	SumI2/D
Ist quartile (25 %tle)	5.0	9.0	1.3	15.0	15.0	9.8	36.0	1296.0	5904.0	2714.6
Minimum	1.0	4.0	0.3	8.0	8.0	2.5	24.0	576.0	1728.0	535.6
Median	14.0	18.0	2.2	22.0	22.0	11.9	60.0	3600.0	7344.0	3522.7
Maximum	44.0	132.0	11.8	61.0	61.0	44.0	108.0	11664.0	32976.0	29376.0
3rd quartile (75 %tle)	18.0	55.5	2.4	39.0	39.0	24.0	72.0	5328.0	20376.0	14322.1
Mean	15.0	40.4	3.1	28.4	28.4	18.0	58.3	4155.4	13515.4	9644.0
Stand Dev	14.6	50.3	3.9	19.6	19.6	14.1	29.7	3970.2	13305.6	10417.6
COV	1.0	1.2	1.3	0.7	0.7	0.8	0.5	1.0	1.0	1.1
n	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Sum	105.0	283.0	21.6	199.0	199.0	126.0	408.0	29088.0	94608.0	67507.7

ROAD

TEdrain curve parameters		WEFP curve parameters	
TEmin	25.00%	WEFPmin	30.00%
Peaklmin	5.0	RPmin	40.0
Peaklcritical	15	RPcri	200
		RPDPcr	1,300.0

Max FPdry	1600	ARFPwet	2000.0	CP	25%
Max FPwet	6000	ARFPdry	1000.0		
MaxDPdry	2600	ARDPdry	30.0		
		LRRPdrain	0.4		

TEdrain (%)	WEFP (%)	Twet=IBP (hrs)	LFPwet (mg/m2)	Tdry (hrs)	Tdry x ARFPdry (mg/m2)	LDPsurf (mg/m2)	LDPdrain (mg/m2)	LFPi PreStorm	LFPsurf Storm	LRPdrain (mg/m2)	LFPdrain (mg/m2)	Ldrain (mg/m2)	L (mg/m2)	Sum L (mg/m2)	LRPdrain PostStorm	LRPsurf Post Storm
						0	0								50	0
100%	100%	0.0	0	132.0	1600	2600	2600	1600	1600	24	1600	4224	4224	4224	0	0
100%	100%	1.1	2160	12.0	1600	360	360	1600	3760	0	3760	4120	4120	4120	0	0
100%	100%	1.4	2840	91.0	1600	2600	2600	1600	4440	0	4440	7040	7040	7040	0	0
100%	100%	0.0	0	18.0	1600	540	540	1600	1600	0	1600	2140	2140	2140	0	0
100%	100%	0.0	0	6.0	1600	180	0	1600	1600	0	1600	1600	1600	1600	0	0
100%	100%	0.0	0	20.0	1600	780	780	1600	1600	0	1600	2380	2380	2380	0	0
100%	100%	0.0	0	4.0	1600	120	120	1600	1600	0	1600	1720	1720	1720	0	0

CARPARK

TEdrain curve parameters		WEFP curve parameters	
TEmin	20.00%	WEFPmin	60.00%
Peaklmin	6.0	RPmin	40.0
Peaklcritical	25	RPcri	100
		RPDPcr	940.0

Max FPdry	500	ARFPwet	300.0	CP	30%
Max FPwet	500	ARFPdry	300.0		
MaxDPdry	1000	ARDPdry	5.0		
		LRRPdrain	0.5		

TEdrain (%)	WEFP (%)	Twet=IBP (hrs)	LFPwet (mg/m2)	Tdry (hrs)	Tdry x ARFPdry (mg/m2)	LDPsurf (mg/m2)	LDPdrain (mg/m2)	LFPi PreStorm	LFPsurf Storm	LRPdrain (mg/m2)	LFPdrain (mg/m2)	Ldrain (mg/m2)	L (mg/m2)	Sum L (mg/m2)	LRPdrain PostStorm	LRPsurf Post Storm
						0	0								50	0
100%	100%	0.0	0	132.0	500	660	660	500	500	17	500	1177	1177	1177	0	0
100%	100%	1.1	324	12.0	500	60	60	500	500	0	500	560	560	560	0	0
100%	100%	1.4	426	91.0	500	455	455	500	500	0	500	955	955	955	0	0
96%	100%	0.0	0	18.0	500	90	90	500	500	0	500	590	565	565	25	0
100%	100%	0.0	0	6.0	500	30	0	500	500	24	500	524	524	524	0	0
100%	100%	0.0	0	20.0	500	130	130	500	500	0	500	630	630	630	0	0
100%	100%	0.0	0	4.0	500	20	20	500	500	0	500	520	520	520	0	0

ROOF

TEdrain curve parameters		WEFP curve parameters	
TEmin	5.00%	WEFPmin	80.00%
Peaklmin	4.0	RPmin	10.0
Peaklcritical	25	RPcri	100

Max FPdry	160	ARFPwet	3.0 CP		30%
Max FPwet	250	ARFPdry	5.0		
MaxDPdry	0	ARDPdry	0.0		
		LRRPdrain	0.5		

TEdrain (%)	WEFP (%)	Twet=D (hrs)	LFPwet (mg/m2)	Tdry (hrs)	Tdry x ARFPdry (mg/m2)	LDPsurf (mg/m2)	LDPdrain (mg/m2)	LFPi PreStorm	LFPsurf Storm	LRPdrain (mg/m2)	LFPdrain (mg/m2)	Ldrain (mg/m2)	L (mg/m2)	Sum L (mg/m2)	LRPdrain PostStorm	LRPsurf Post Storm
						0	0								50	0
100%	100%	0.3	1	132.0	160	0	0	160	161	17	161	178	178	178	0	0
100%	100%	2.4	7	12.0	60	0	0	60	67	0	67	67	67	67	0	0
100%	100%	2.2	7	91.0	160	0	0	160	167	0	167	167	167	167	0	0
95%	100%	0.7	2	18.0	90	0	0	90	92	0	92	92	88	88	4	0
100%	100%	11.8	35	6.0	30	0	0	30	65	4	65	70	70	70	0	0
100%	100%	1.9	6	20.0	100	0	0	100	106	0	106	106	106	106	0	0
100%	100%	2.3	7	4.0	20	0	0	20	27	0	27	27	27	27	0	0

EMC AND LOAD CALCULATIONS

	Road		Carpark		Roof		Grass		Total	Road Flow	Carpark Flow	Roof Flow (with 0.4	Grass Flow	Predicted Flow	Sum Pre Flow	Predicted EMC	Meas EMC	Modelled Flow	Predicted Load	Modelled Load
Area (m2)	1020		453		0		1497													
	(kg)	(mg/L)	(kg)	(mg/L)	(kg)	(mg/L)	(kg)	(mg/L)	(kg)	(ML)	(ML)	(ML)	(ML)	(ML)	(ML)	(mg/L)	(mg/L)	(ML)	(g)	(g)
	4	422	1	118	0	#DIV/0!	0.7	0	5	0.01	0.00	0.0000	0.0000	0.0147	0.0147	373.4	60	0.0009	5499.9330	54.0000
	4	88	0	12	0	#DIV/0!	2.9	110	7	0.05	0.02	0.0000	0.0261	0.0954	0.0954	76.9	220	0.0036	7330.3200	792.0000
	7	117	0	16	0	#DIV/0!	3.7	96	11	0.06	0.03	0.0000	0.0382	0.1266	0.1266	89.0	180	0.0042	11266.0950	756.0000
	2	306	0	81	0	#DIV/0!	0.5	0	3	0.01	0.00	0.0000	0.0000	0.0103	0.0103	283.0	60	0.0002	2917.8565	12.0000
	2	55	0	18	0	#DIV/0!	1.8	190	4	0.03	0.01	0.0000	0.0094	0.0521	0.0521	70.3	140	0.0020	3665.8159	280.0000
	2	113	0	30	0	#DIV/0!	1.3	657	4	0.02	0.01	0.0000	0.0020	0.0329	0.0329	122.4	15	0.0020	4030.3500	30.0000
	2	96	0	29	0	#DIV/0!	1.1	0	3	0.02	0.01	0.0000	0.0000	0.0265	0.0265	118.0	170	0.0039	3127.6800	663.0000
STATISTICAL DATA																				
Ist quartile	2.0	91.6	0.2	17.0	0.0	#DIV/0!	0.9	0.0	**38**						7.0	161.8	120.7	7.0		
Minimum	1.6	55.2	0.2	11.9	0.0	#DIV/0!	0.5	0.0												
Median	2.4	113.3	0.3	28.9	0.0	#DIV/0!	1.3	95.6												
Maximum	7.2	422.4	0.5	117.7	0.0	#DIV/0!	3.7	656.7												
3rd quartile	4.3	211.5	0.4	55.4	0.0	#DIV/0!	2.3	150.2												
Mean	3.38	171.02	0.32	43.32	0.00	#DIV/0!	1.70	150.40												
Stand Dev	2.00	137.59	0.12	40.19	0.00	#DIV/0!	1.17	234.68												
COV	0.6	0.8	0.4	0.9	#DIV/0!	#DIV/0!	0.7	1.6												
n	7.0	7.0	7.0	7.0	7.0	0.0	7.0	7.0												
Sum	24		2		0		12													

APPENDIX N: Mass Balance Model Input Error Analysis

	Mass Balance Parameters	Units	Multiplication Factor	HSA		HSB		HSC		TOTAL		Percentage Change in Total Error		Average Percentage Change in Total Error	
				Cumulative EMC Error	Maximum EMC Error	Cumulative EMC Error	Maximum EMC Error	Cumulative EMC Error	Maximum EMC Error	Cumulative EMC Error	Maximum EMC Error	Cumulative EMC Error	Maximum EMC Error	Cumulative EMC Error	Maximum EMC Error
	Unmodified	-	-	56%	528%	35%	475%	34%	716%	41%	716%	0%	0%	0%	0%
Rainfall Parameters	Antecedent Rainfall Total	mm	0.5	56%	528%	35%	475%	34%	716%	41%	716%	0%	0%	0%	0%
			2	56%	528%	35%	475%	34%	716%	41%	716%	0%	0%		
	Antecedent Rainfall Period	hrs	0.5	40%	444%	20%	396%	21%	629%	27%	629%	-35%	-12%	34%	18%
			2	71%	527%	48%	472%	46%	889%	54%	889%	32%	24%		
	Storm Duration	hrs	0.5	56%	528%	35%	475%	34%	713%	41%	713%	0%	0%	6%	8%
			2	50%	528%	29%	475%	30%	827%	36%	827%	-13%	16%		
	Rainfall Depth	mm	0.5	226%	1241%	186%	1145%	171%	1426%	193%	1426%	369%	99%	267%	78%
			2	-19%	207%	-32%	178%	-28%	316%	-27%	316%	-164%	-56%		
	Peak 6 min Intensity	mm/hr	0.5	50%	528%	29%	475%	28%	713%	35%	713%	-14%	0%	7%	0%
			2	56%	528%	35%	475%	34%	716%	41%	716%	0%	0%		
	Sum of the Square of all 6 min Intensities	mm^2/hr^2	0.5	50%	528%	29%	475%	30%	827%	36%	827%	-13%	16%	6%	8%
			2	56%	528%	35%	475%	34%	713%	41%	713%	0%	0%		
	Interburst Period	hrs	0.5	52%	528%	31%	475%	31%	716%	38%	716%	-9%	0%	11%	0%
			2	62%	528%	41%	475%	38%	716%	47%	716%	14%	0%		
Particle Accumulation and Washoff Parameters	Maximum Free Particle Load Prior to Storm	mg/m^2	0.5	19%	417%	1%	371%	5%	528%	8%	528%	-81%	-26%	119%	36%
			2	129%	744%	102%	681%	86%	1046%	106%	1046%	156%	46%		
	Maximum Free Particle Load During Storm	mg/m^2	0.5	52%	525%	31%	474%	28%	693%	37%	693%	-11%	-3%	6%	2%
			2	56%	528%	35%	475%	34%	716%	41%	716%	0%	0%		
	Maximum Detained Particle Load Prior to Storm	mg/m^2	0.5	39%	369%	19%	325%	22%	716%	26%	716%	-36%	0%	35%	0%
			2	72%	711%	49%	650%	45%	716%	55%	716%	33%	0%		
	Wet Weather Accumulation Rate of Free Particles During the Storm	$mg/m^2/hr$	0.5	52%	528%	31%	475%	31%	716%	38%	716%	-9%	0%	11%	0%
			2	62%	528%	41%	475%	38%	716%	47%	716%	14%	0%		
	Dry Weather Accumulation Rate of Free Particles During the Storm	$mg/m^2/hr$	0.5	56%	528%	35%	475%	34%	716%	41%	716%	0%	0%	0%	0%
			2	56%	528%	35%	475%	34%	716%	41%	716%	0%	0%		
	Dry Weather Accumulation Rate of Detained Particles Before the Storm	$mg/m^2/hr$	0.5	40%	439%	20%	394%	21%	629%	26%	629%	-36%	-12%	34%	18%
			2	71%	530%	48%	475%	46%	889%	55%	889%	32%	24%		
	Dry Weather Loss Rate of Retained Particles in the Drain Before the Storm	%/hr	0.5	56%	530%	35%	476%	34%	716%	41%	716%	0%	0%	0%	0%
			2	56%	530%	35%	476%	34%	716%	41%	716%	0%	0%		
	Adjustment Factor for Total Particle Load in Lateral Drain	%	0.5	56%	528%	35%	475%	34%	716%	41%	716%	0%	0%	0%	0%
			2	56%	528%	35%	475%	34%	716%	41%	716%	0%	0%		
	Particle Washoff Multiplier for Grassed Areas	-	0.5	44%	503%	27%	460%	18%	582%	29%	582%	-28%	-19%	43%	28%
			2	81%	576%	49%	503%	66%	982%	65%	982%	57%	37%		