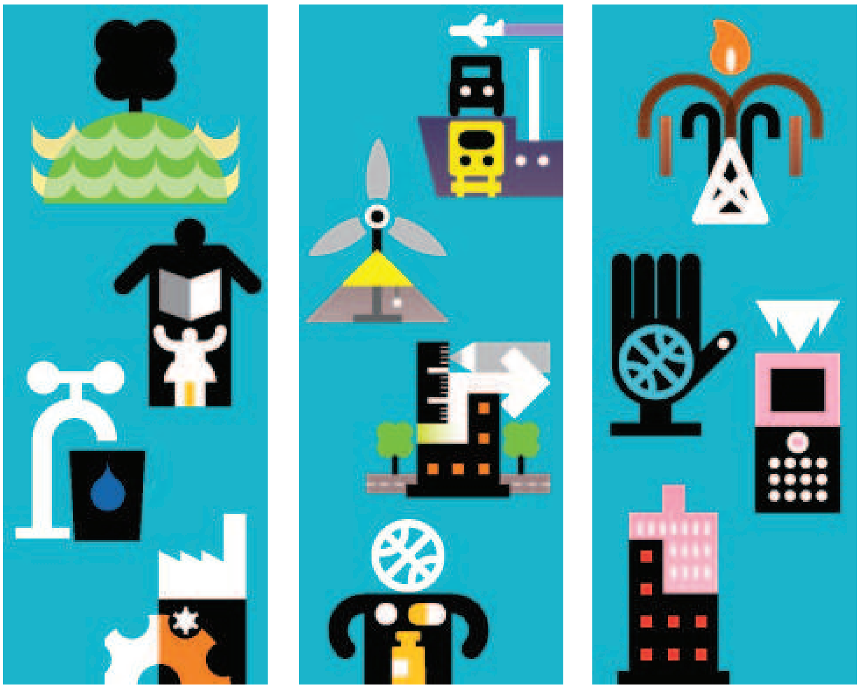
Appendix B



11 Hassall Street, Parramatta

Flood Impact Report

June 2014

Cowper Constructions Pty Ltd

Mott MacDonald

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1 Introduction

Mott MacDonald has been engaged by Cowper Constructions Pty Ltd to prepare this flood impact report in support of the proposed development works for the site identified as 11 Hassall Street, Parramatta.

It is proposed that the site be redeveloped with an end use of mixed commercial and high-rise residential activities.

Based on the findings of Parramatta City Council's *Lower Parramatta River Floodplain Risk Management Study* (*LPR-FRMS)*, including the MIKE-11 definition of flood levels, we understand the subject site to be flood affected by the adjacent Clay Cliff Creek flow regime.

A review of the Parramatta City Council flood maps (based on the *LPR-FRMS*) has indicated the following flood levels are relevant to the subject site:

- The 5% AEP flood level is approximately RL 8.02m AHD;
- The following 1% AEP flood levels are relevant at the two southern corners of the site;
  - South eastern Corner (facing Parkes Street) – RL 8.32m AHD;
  - South western Corner (facing Parkes Street) – RL 8.33m AHD
- The PMF level is RL 9.70m AHD.

These levels have been conservatively estimated by linear interpolation of the *LPR-FRMS* cross sectional flood levels in Parkes Street.

Parramatta's Local Floodplain Risk Management Policy divides land within the catchment into categories based on the level of potential flood risk. By incorporating the above mentioned flood levels and interpreting Council's flood risk map the site is categorised as a High Flood Risk Precinct – and therefore constitutes 'unsuitable land use' in accordance with Council policy. In order to justify the allowance of development on such a site, all flood related aspects of developing the site need to be carefully investigated to demonstrate why the project, based on merit, would represent 'suitable land use'

This report will address the immediate flooding issues associated with the proposed development through a detailed flood analysis as well as provide an assessment against the Flood Risk Matrix outlined in Parramatta Council's Local Flood Risk Management Plan. In addition to demonstrating compliance with the matrix principles, the analysis will be used to demonstrate the development presents no adverse impact on the flooding conditions of adjacent sites and the wider catchment.

The aim of this report is to:

- Analyse the extent and impact of flooding within the site in a pre-to-post scenario;
- demonstrate that the necessary requirements associated with floodplain risk management principles have been identified and that the proposed development complies with these requirements; and
- demonstrate the site, based on the outcomes of this study and appropriate risk management procedures, represents 'suitable land use' within the high flood risk precinct.

2 Site Location

2.1 The Existing Site

The existing site is situated at 11 Hassall Street, Parramatta. The site is comprised of the following:

- Lot 1; DP 951181

The existing site area of approximately 1,790m^2 is currently occupied by a two (2) storey brick church adjacent the northern boundary and a two (2) storey brick hall building adjacent the southern boundary. The site is subject to flooding constraints due to its close proximity to the existing Clay Cliff Creek flow regime.

The site is bounded by Hassall Street to the north, an open drainage channel adjacent Parkes Street to the south, existing mixed use commercial/residential buildings to the east and a vacant lot to the west.

Figure 2.1: Site Location

Source: *Six maps* Imagery (2013)

The site falls towards Parkes Street to the south. An existing drainage system conveys localised stormwater flows from the two storey building and the site to the drainage infrastructure in Parkes Street (Council's drainage network).

3 Preliminary Investigation of Flood Impacts

3.1 Flood Affectation of Third Parties

It is understood based on Council's adopted flood model and flood risk maps that flows pass the site along the southern boundary through the Parkes Street road reserve during large flooding events.

Council's flood risk/hazard map (attached in Appendix A) indicates the development site falls under the "*High Risk"* category during a 1% AEP storm event. For developments located within this category, evacuation problems are anticipated and it is expected that development would significantly and adversely affect flood behaviour in the area.

3.2 Flood Conveyance

Based on the current Council adopted flood study, the *Lower Parramatta River Floodplain Risk Management Study* (*LPR-FRMS* undertaken by Sinclair Knight Merz (SKM) in 2005), it appears that in large flooding events, flows overtop the existing Clay Cliff Creek stormwater drainage channel adjacent Parkes Street and cross into the development site. Modelled cross sections within the vicinity of the site, observed in the *LPR-FRMS* (SKM, 2005), indicate the peak flow rates for the 1% AEP storm event are equal to $24m^3/s$. The modelling results/peak flow rates from the *LPR-FRMS* (SKM, 2005) are attached in Appendix A.

Additional information was obtained from Parramatta City Council, including the Council commissioned *Clay Cliff Creek Catchment – Master Drainage Plan* (*CCC-MDP* - undertaken by Cardno Willing in 2007), which indicates active flowpaths also operate in the adjacent Parkes Street, with flow passing from west-to-east during the 1% AEP storm event. Given the additional focus on street drainage, currency and generally a more accurate representation of the catchment, it is considered that the 2007 Clay Cliff Creek study provides a more complete assessment of flooding in Parkes Street and the vicinity of the proposed development site. This study will form the basis of the detailed flood modelling which will be discussed in later sections of this report.

3.3 Flood Storage

It is acknowledged that there are substantial flood flows and flow velocities associated with the Parkes Street flowpath which will impact upon the flooding conditions through the subject site. The issue of flow conveyance will be addressed by the flood modelling that follows this section, but as a preliminary investigation, flood storage calculations were undertaken to determine the existing and proposed flood storage volumes within the site.

Flood storage for the pre and post-developed scenarios has been determined by calculating the volume of storage available within the flow area (area of ponded water within the site extents) during a flood event.

Utilising the 1% AEP flood levels obtained from the adopted Council studies (flood levels vary across site), volume calculations indicate the pre-developed flood storage available within the site area is approximately $43m^3$ (refer sketch SK01 in Appendix B).

Under the proposed layout, approximately 12m^3 of storage has been maintained south of the development, adjacent the Cliff Creek channel. This space had been dedicated to addressing the flood storage and conveyance requirements for the development (refer architectural plans for details, Appendix B).

There is a reduction in the overall flood storage of 32m^3 however, results of the flood assessment indicate there is no significant effect of this minor loss on flood affectation in the surrounding area and is therefore not considered critical to the development. Refer to Appendix B for pre and post development flood storage calculations.

4 Detailed Flood Assessment

4.1 Introduction

TUFLOW, a two-dimensional (2D) hydraulic modelling program has been used to perform a detailed assessment of the existing (pre-development) and proposed (post-development) flooding scenario for the 1% AEP flood event within the subject site.

The hydrological assessment has utilised existing results published in the *Clay Cliff Creek Catchment Master Drainage Plan* (*CCC-MDP*), previously undertaken by Cardno Willing (2007), but yet to be adopted by Parramatta City Council as part of their Floodplain Management policy.

Hydraulic terrain flood modelling (2-dimensional) has been undertaken for the subject site using the *TUFLOW* software, adopting data from the existing *CCC-MDP* (existing pipe networks, LiDAR survey, etc) to assess the flood affectation impacts the proposed development has on the surrounding area. A detailed description of the hydrological and hydraulic modelling assessment is provided in the following sections of this report.

The objectives of the flood assessment are to determine the effect the proposed development will have on flow conveyance within and adjacent to the subject site. This will be addressed by:

- assessing the impacts of contributing catchments to the existing (current) development site;
- assessing overland flow paths and downstream system constraints;
- assessing the impact the proposed development has on flooding on adjacent sites;
- assessing the impact the proposed development has on an 'Ultimate' scenario based on known future development in the direct vicinity;
- Identifying flood hazard/flood risk for the proposed development and minimising these risks through design or risk management protocols; and
- Running a sensitivity analysis on the partial (50%) blockage scenario of the Clay Cliff Creek channel.

This report will also demonstrate the proposed development addresses the objectives of the Floodplain Matrix controls outlined in Parramatta City Council's Local Flood Risk Management Plan. By doing so we aim to demonstrate that on merit, the development site does not constitute 'unsuitable land use' based on its location within a High Flood Risk zone.

4.2 Hydrologic Data

Hydrologic data was obtained from the *CCC-MDP* (2007). This study was commissioned by Parramatta City Council (PCC) in accordance with the NSW Government's Floodplain Management Manual. The report describes the data collection and flood study aspects of the larger Floodplain Risk Management Study.

The following data was extracted from the above mentioned report;

- Catchment node locations along the Clay Cliff Creek drainage channel and surrounding streets;
- Peak flow hydrographs associated with each of the utilised nodes. These hydrographs were extracted from the *CCC-MDP RAFTS* model.

The peak flow hydrographs and water levels associated with these nodes correspond reasonably with the data received from the Flood Enquiry application for the development site from PCC (attached in Appendix A). This data has therefore been used in the assessment.

4.3 Hydraulic Model

4.3.1 TUFLOW Software Package

The flooding impact at the subject site and within the adjacent precinct was modelled using the *TUFLOW* software.

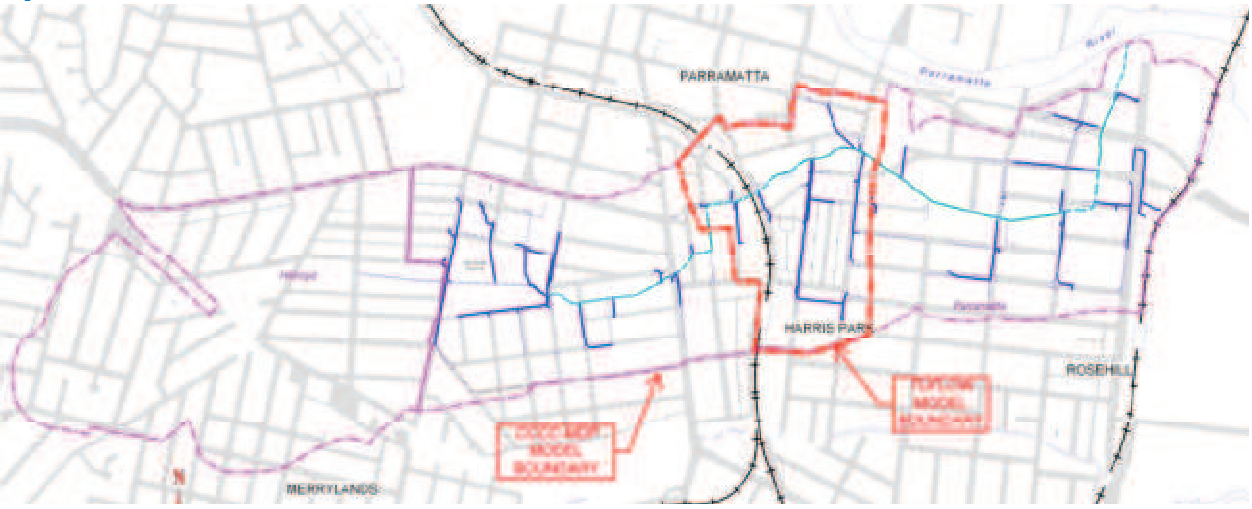
TUFLOW computes flow paths by dividing the floodplain into a grid of individual cells. The flow of water between cells is then computed repeatedly at regular time steps by solving two dimensional shallow water equations to estimate the flood spread and flow. As each cell contains information on water levels, flows are routed in the direction that will naturally follow the modelled topography.

4.3.1.1 Model Build

The *TUFLOW* model extents were selected to examine the area judged to be contributing to the flows affecting the site. Data from this selected area was extracted from the *CCC-MDP* model for use in the *TULFOW* model. This incorporated a number of nodes (and associated flow data), pipe networks and survey data from the *CCC-MDP*.

A truncated version of the *CCC-MDP* model was used to assess the site flooding. A section of the *CCC-MDP* model appropriate to the subject site was simulated. All pits, pipes, surface flows and hydrographs falling within the *TUFLOW* model boundary have been simulated in the same manner as in the *CCC-MDP* model. The model has been truncated upstream at the Railway Line underpass on Parkes Street and Robin Thomas Reserve downstream of the site. In order to accurately simulate the upstream flows entering the model, the total flow hydrograph at this pinch point (under the bridge) was taken from the *RAFTS* model and applied upstream of the Jubilee park headwall to simulate the culvert/surface flows.

Figure 4.1: Model Location within the lower Parramatta River catchment



Source: *CCC-MDP* (2007)

The flood assessment was modelled using *TUFLOW* build 2012_05_AE_64.

4.4 Pre Development Flood Assessment

4.4.1 Existing Flow Regimes

Based on initial investigations utilising the Council adopted *LPR-FRMS*, it was determined that flows from large storm events (i.e. 1% AEP storm event) were entering the subject site from the overtopping of the Clay Cliff Creek channel adjacent to the site (running in parallel with Parkes Street), and from overland flows conveyed from the west along Parkes Street.

Additional information was obtained from Council, including the Council commissioned *CCC-MDP* report (2007), which indicates active flowpaths also operate in Parkes Street, with flow passing from west-to-east during the 1% AEP storm event. Given the additional focus on street drainage, currency and generally a more accurate representation of the catchment, it is considered that the 2007 Clay Cliff Creek study provides a more accurate assessment of flooding in Parkes Street and the vicinity of the proposed development site. The data and results of this study will be utilised in the development of the TUFLOW model discussed below.

Further to the above additional information, a field inspection was undertaken on properties in the vicinity of the subject site that may have been developed since the CCC-MDP study was undertaken. Measurements were taken on floor levels in relation to finished ground levels and void spaces contained below podiums and slabs. This data was entered into the 'existing' conditions model.

Consideration has also been given in an ‘ultimate’ scenario to known future developments (20-24 Kendall Street) in the direct vicinity of the site.

4.4.2 Pre Development 2D Modelling *(TUFLOW)*

A *TUFLOW* two dimensional (2D, surface terrain) flood model was prepared for the existing scenario based on the CCC_MDP study and previously mentioned edits to account for development in the floodplain since the previous studies.

4.4.2.1 Digital Elevation Model

A digital elevation model (DEM) was generated using LiDAR (Light Detection and Ranging) aerial survey obtained from Parramatta City Council for the site and surrounding catchment area. The survey was undertaken in 2005 and obtained from the CCC-MDP study.

As the LiDAR survey is unable to accurately represent the finer details of the Clay Cliff Creek channel, existing cross-section data and available detailed survey was combined with the LiDAR information to more accurately represent the concrete lined channel. Channel cross-section data obtained from Council’s adopted MIKE11 model was used to represent the lengths of the channel, both upstream and downstream of the subject site. The MIKE11 model data set was originally used in the *LPR-FRMS* and was obtained from Parramatta City Council for the purposes of this study.

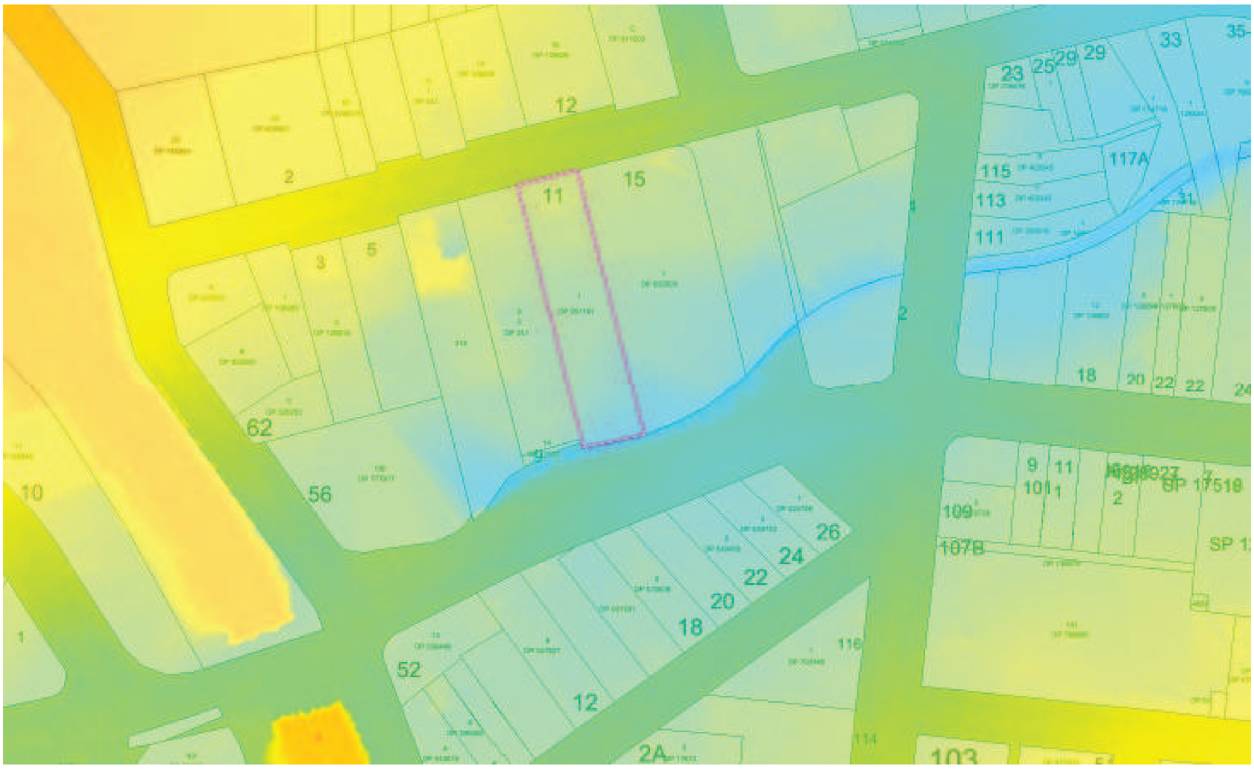
An additional detailed survey of the site prepared by SDG Land Development Solutions was supplied in order to provide greater definition of the existing surface profile within the site and council property immediately adjacent.

The cross sections and additional detailed survey levels were integrated into the DEM through the use of the ‘12d’ civil design program with the existing cross section data aligned with the channel banks from the LiDAR survey. The bed of the channel was then interpolated between the existing sections and known levels. A triangulation of the data points was then performed to create the DEM representing the existing scenario.

A comparison of the LiDAR and detailed survey was undertaken to determine the accuracy of the LiDAR information. LiDAR levels were generally within a -/+ 100mm tolerance of the detailed surveyed levels and therefore considered appropriate for use in this model.

Figure 4.1 below shows the LiDAR survey DEM colour gradient as a representation of the base elevations used in the model. This image was generated using MapInfo GIS software. Here the orange colours indicate high elevations with the blue representing lower lying terrain.

Figure 4.2: LiDAR Survey Digital Elevation Model



Source: Parramatta City Council LiDAR information 2005

4.4.2.2 Model Extent and Grid Generation

A *TUFLOW* modelling grid was generated for the model extents. The finite element grid forms the basis for *TUFLOW* modelling and creates a readable network of cells where each have applied characteristics such as elevation, slope, roughness etc.

A 1m x 1m grid size was selected for the model and was considered appropriate for urban catchments of this scale. This grid size allows a finer and more accurate representation of the flows adjacent to our site than a more conventional 5m x 5m grid.

The *TUFLOW* model extent is shown in Figure 4.3 below.

Figure 4.3: *TUFLOW* Model Extents

4.4.3 Key Assumptions

The following is a list of key assumptions used in development of the Hassall Street *TUFLOW* model;

- In accordance with the supplied data from the *CCC-MDP* study, all existing pipes of diameter 375mm and below have been excluded to keep the model to a reasonable size. Where flows are generated by catchments comprise of only 375mm pipes or smaller, these flows have been applied utilising Type SA boundaries. This will be discussed in greater detail in a following section of this report.
- Initial and Continuing Losses are accounted for in the existing *CCC-MDP* flood study. They have not been applied to the two dimensional (2D) model to avoid doubling up on the infiltration losses.
- Pipe/ channel blockage factors have not been accounted for in this hydraulic model. It is understood these factors have been applied within the previous studies of the area. Flow rates/hydrographs have been extracted directly from the results of these studies.

Assumptions have been assessed based on engineering design principles and industry standards. We consider these assumptions reasonable for the model development.

4.4.4 Roughness Coefficients

Manning's 'n' roughness coefficients were applied within the *TUFLOW* model to regions created in a *TUFLOW* Materials file. This file bounds regions within the model area and applies a bed resistance value, in this case, a Manning's 'n' value. *TUFLOW* adopts these values for each 1m x 1m cell within the specified regions. A plan of the *TUFLOW* Materials file regions can be found in Appendix C. Each of these regions has adopted the Manning's values set out below in Table 4.1.

Table 4.1: Materials File Values

Material Regions	Manning's 'n'
Buildings	NULL
Grassed Fields	0.035
Roads	0.013
Concrete Pavements/Asphalt/Parking Area/Concrete Drainage Channel	0.015

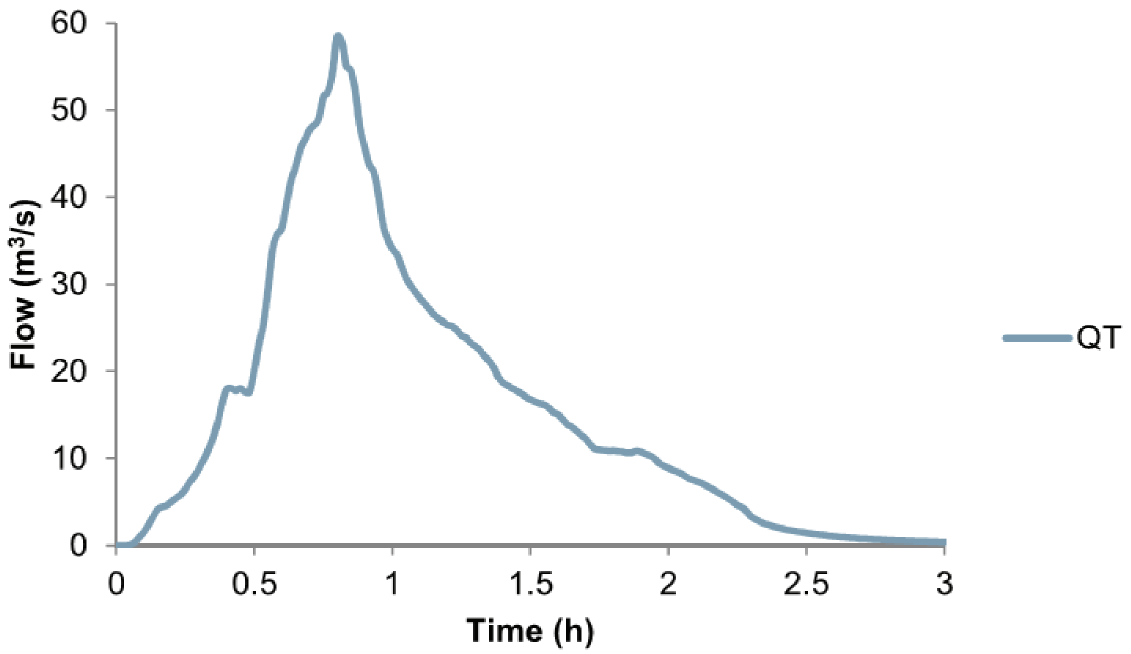
4.4.5 Boundary Conditions

The upstream boundary condition shown in Figure 4.4 below utilises a flow versus time relationship to model the passage of flows into the Hassall Street *TUFLOW* model. The boundary condition distributes flow in quantity and direction across the cells based on their topography, bed roughness and whether upstream or downstream conditions control the flow. A peak flow hydrograph was applied across the section labelled 'QT', on the model boundary based on the results of the *CCC-MDP* study. The hydrograph was determined based on the total combined flow of the catchments located upstream of the model boundary.

Figure 4.4: Model Boundary Conditions

Figure 4.5 below shows the total combined hydrograph for the upstream boundary condition utilised in the *TUFLOW* model. The hydrograph was applied as inflow at this location over a period of 3 hours.

Figure 4.5: 2D Boundary Total Inflow Hydrograph

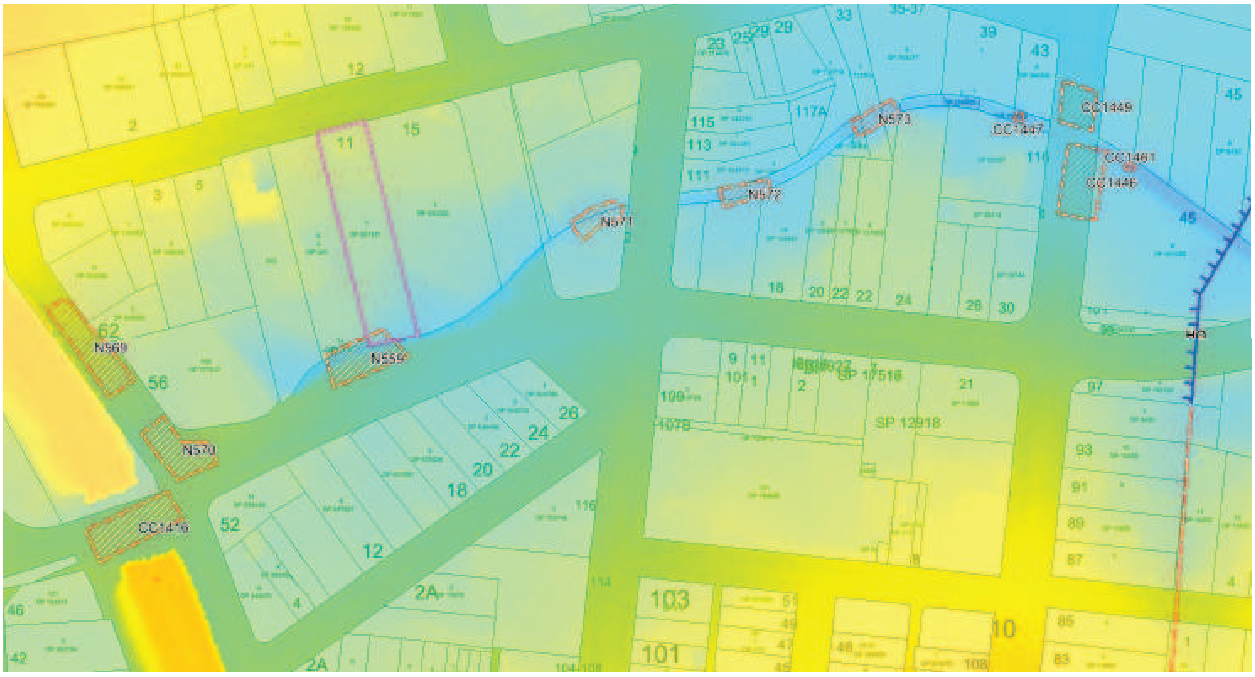


Source: *CCC-MDP* (2007)

Downstream boundary conditions were placed at the outlet of the *TUFLOW* model boundary extents as shown in Figure 4.4 above. The model assigns a water level to the cells based on a water level verses flow (stage discharge, HQ) curve. A slope is specified in the model data, and the *TUFLOW* program automatically generates the HQ curve, allowing flows to leave the model at the boundary extents without creating a dam like effect. The downstream boundary conditions were adjusted to calibrate the model against flood levels recorded in the *CCC-MDP* report.

Additional inflow conditions have been applied to the model within the model boundary to account for catchment flows within the model extents. Channel and localised overland flows extracted from the *CCC-MDP* study have been applied as flow (m^3/s) versus time hydrographs over an area (SA Type Boundary). Regions are created within the model (N569, CC1447, etc. shown in orange in Figure 4.6) and flows are applied directly onto the cells as an inflow source. Flows are directed to the lowest cell based elevations and are then distributed according to the topography.

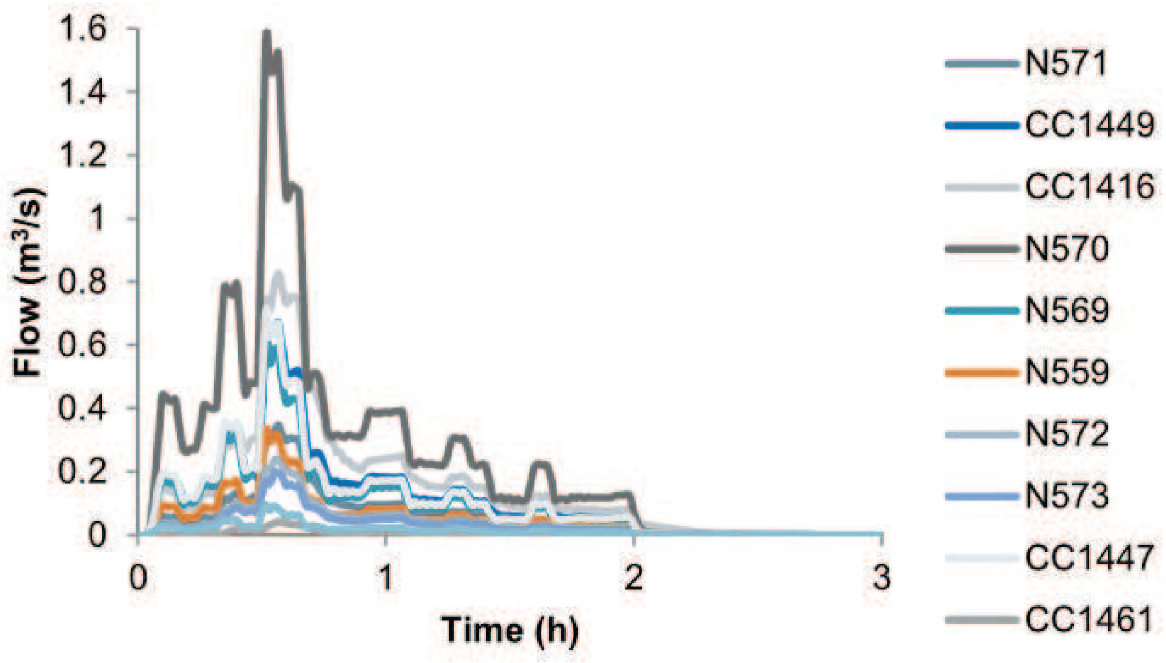
Figure 4.6: SA Boundary Inflow Locations



Source: *CCC-MDP* (2007)

The inflow hydrographs assigned to these regions are shown in Figure 4.7 below.

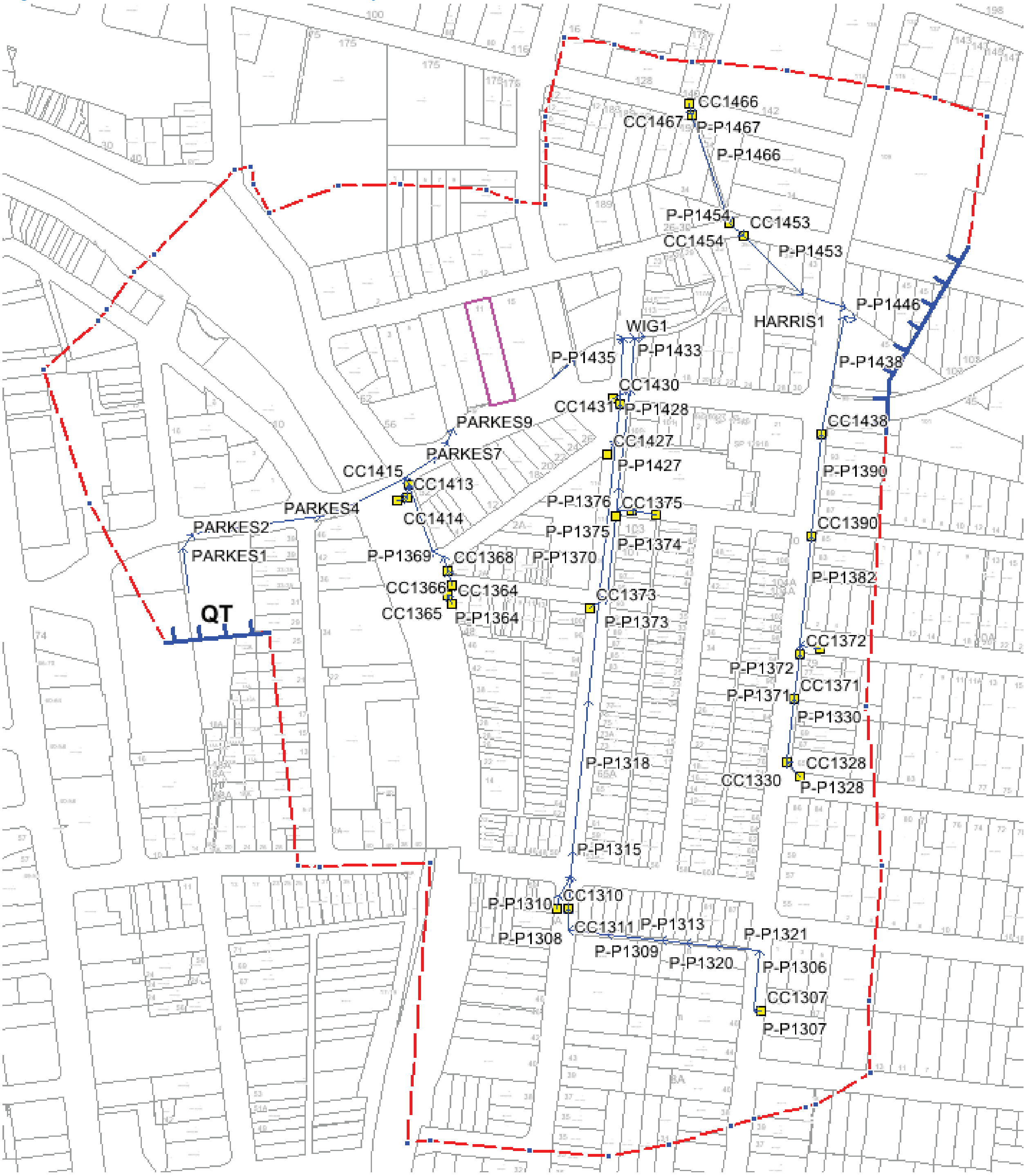
Figure 4.7: SA Boundary Inflow Hydrographs



Source: *CCC-MDP* (2007)

Boundary conditions for the 1D network were also added to the model to simulate the inflow hydrographs extracted from the *CCC-MDP* study. The 1D network layout and pit inflow locations can be seen in Figure 4.8. Node naming conventions are consistent between the *CCC-MDP* and Mott MacDonald report for clarity.

Figure 4.8: 1D Network and 1D Boundary Conditions



Source: *CCC-MDP* (2007)

4.4.6 Floodplain

The underlying digital elevation model (DEM) for the 2D model was created from the latest LiDAR data with a 0.5m resolution. However, the 2D model covering the floodplain is based on a fixed grid with a cell size of 1m x 1m. Each grid cell is assigned with attributes including ground elevation which determines the topographic base for the 2D model. The 1m grid is generally accepted as an industry standard when modelling urban catchments. It was considered that such a model grid size would give a reasonable balance between the accuracy of the model and the model run time.

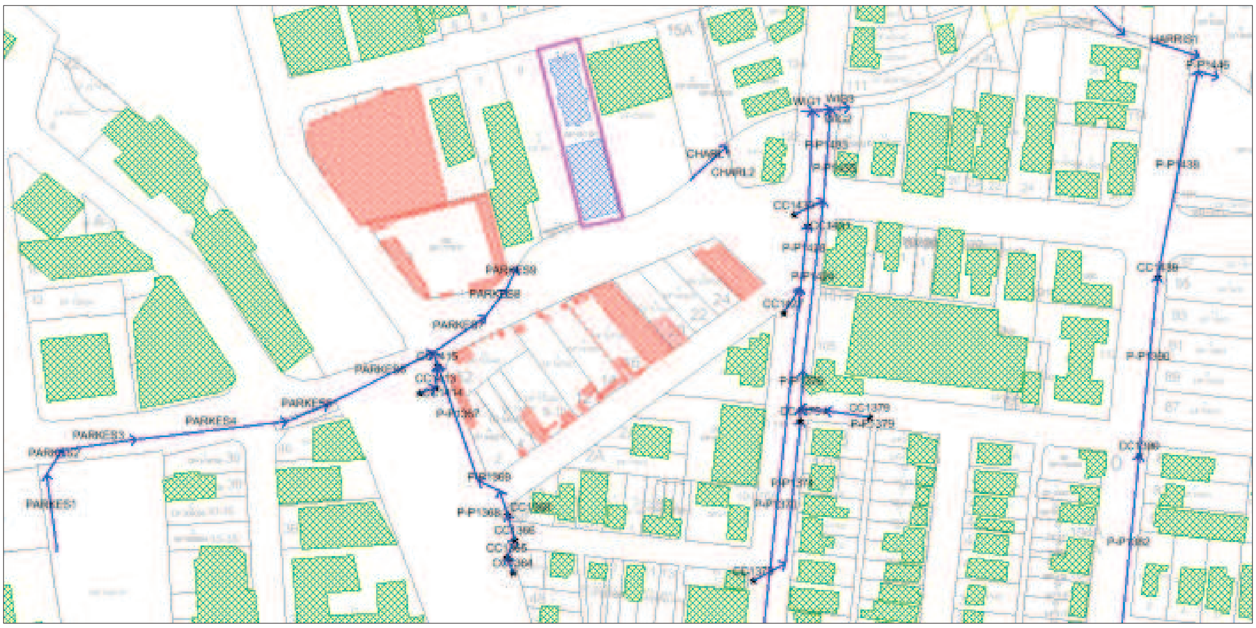
4.4.7 Clay Cliff Creek Channel Culverts (1D *ESTRY* Modelling)

The Clay Cliff Creek channel crosses under a number of roads along its path to the Parramatta River. These areas are deemed to be of critical concern to the modelling of flows in the vicinity of the subject site.

For multiple sections along the channel, the culvert structure has been digitised with GIS tools to be modelled by *ESTRY*. *TUFLOW* software dynamically integrates the *ESTRY* calculation engine to model 1D networks simultaneously with the 2D surface modelling.1D/2D linkages have been provided at the surface of the DEM (across the Clay Cliff Creek channel) to allow for the mass exchange between the surface flows and the piped/culvert flow system.

The channel crossings/culverts were modelled by extracting inverts and dimensions from the detailed survey of the structures. The GIS interface is shown below in Figure 4.9.

Figure 4.9: 1D ESTRY



4.4.8 Raised Buildings

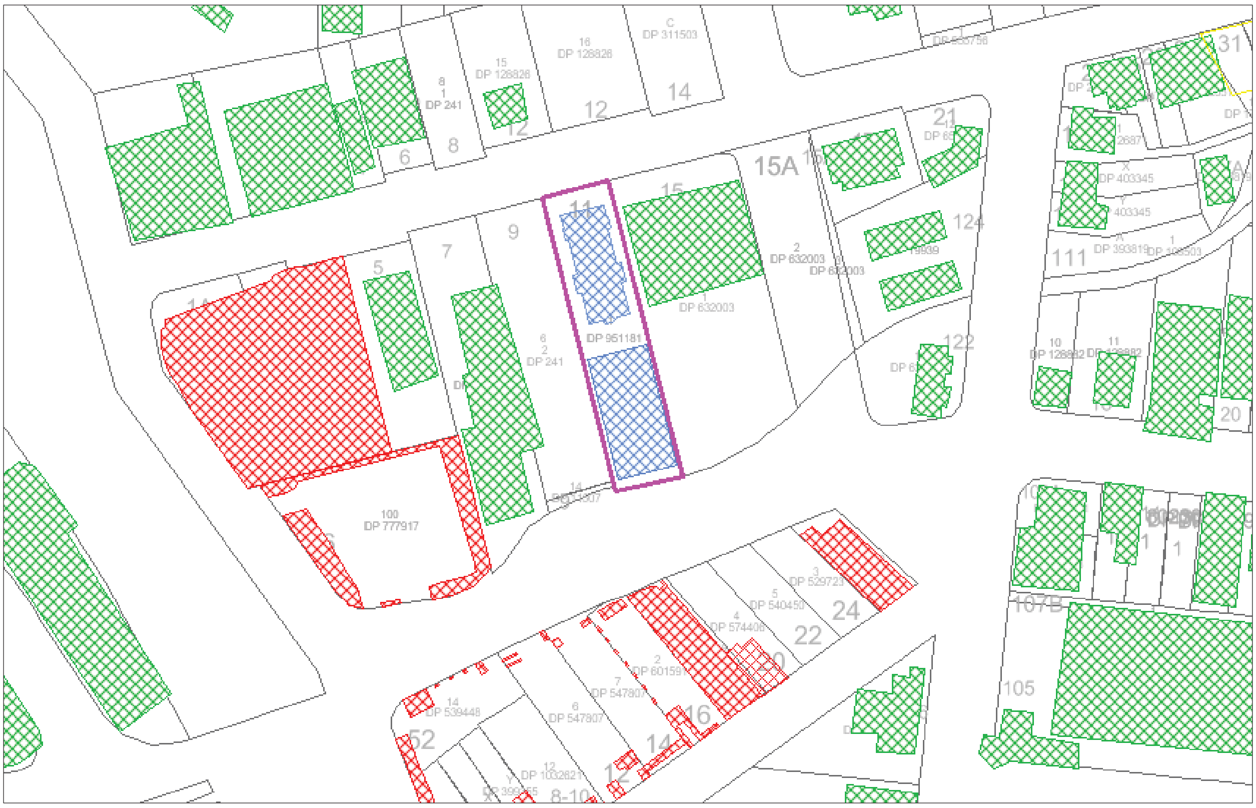
Due to the nature of localised flooding in the Parramatta precinct, a number of buildings within the vicinity of the development site incorporate a raised podium slab to achieve suitable freeboard above the 1% AEP flood event. Beneath this slab, a sub-floor void allows flows to pass freely under the building and minimise the loss of flood storage in the floodplain. These buildings within the vicinity of the proposed development have been identified and have been modelled to allow flows to pass under the building (no obstruction) in the *TUFLOW* model run. The building locations (obstructions) have been sourced from the *CCC-MDP* study for consistency and are shown as green in Figures 4.9 and 4.10.

4.4.9 Existing Scenario

Both of the existing two-storey brick buildings on site have been included in the model, adjacent the southern boundary of the site and towards the northern boundary (shown in blue in Figure 4.10 below). These areas have been treated as obstructions within the model and flows will be unable to pass through these areas.

As previously mentioned, a field inspection of other properties in the vicinity of the subject site was undertaken to account for development since the 2007 study. These were based on measurements relating to void spaces beneath podiums/slabs and depths of storages. The data obtained from the field inspections is shown in red in Figures 4.9 and 4.10. The remainder of the study area has been based on the LiDAR data obtained from Parramatta City Council and the client’s detailed topographic site survey to represent the existing ground surface levels throughout the site.

Figure 4.10: Existing Site Obstructions



4.4.10 Model Controls

Within a *TUFLOW* model, simulation time commands are entered to control all time dependant data. For 2D models these controls include a Start Time, End Time and a Timestep. The starting time and finishing times specify the period in hours for which calculations are made. The timestep is the calculation interval in seconds, which is dependent on various conditions such as grid size and hydrograph inputs.

The model was run for a 3 hour period at a timestep of 0.125 seconds. This was a suitable period in order for the flows to reach a maximum extent of inundation in the model before receding.

4.4.11 Model Calibration

The *TUFLOW* model was run utilising the peak flow hydrographs extracted from the 2007 *CCC-MDP* study for the 1% AEP storm event. As discussed, the base of the model (LiDAR, survey data, 1D pit, pipe and channel networks, etc.) was also extracted from the same study. The results of the model runs were processed using the previous model's Manning's values and boundary conditions. The results were similar to those found in the *CCC-MDP* flood study within the vicinity of the subject site. The following table (Table 4.2) below outlines the flood levels achieved within the model in comparison with the Council report.

Table 4.2: Water Levels – Extracted vs. Modelled

Site Locations	Water Level (m AHD) interpolated from LPR-FRMS	Modelled Water Level (m AHD)
South-western corner (facing Parkes Street)	8.33	8.42
South-eastern corner (facing Parkes Street)	8.32	8.30

Source: *LPR-FRMS* (SKM, 2005), *CCC-MDP* (Cardno Willing, 2007)

The flood levels generated by the *TUFLOW* model are generally within +/- 90mm of the results produced in the *LPR-FRMS* report across the flood extents within the vicinity of the subject site. As the two studies utilise different modelling approaches and varied data sources, we would expect some differences in water levels produced across the flood extents. The minor variations from the levels produced in the adopted SKM (2005) report indicate the *TUFLOW* model is a reasonable and acceptable representation of the existing scenario for the purposes of a flood affectation pre-to-post analysis.

Given that our revised modelling has included recent development sites in the vicinity of the subject site and detailed topographic survey on the subject site rather than LiDAR information we believe that it provides more accurate information. This will be used in the assessment for the determination of the relevant flood planning levels.

4.4.12 Model Runs and Results

The *TUFLOW* model was run for the 1% AEP event utilising peak flow hydrographs extracted from the *CCC-MDP*. The model was run for an event length of 3 hours to allow the flows to ‘fill’ the model and settle out before the peak extents were determined. Based on a review of the peak flood extents, flow velocities and depths it was determined that the 3 hour run duration was successful in producing the critical event affecting the subject site. The *TUFLOW* output results for the existing scenario have been attached in Appendix D.

4.4.12.1 Existing Model – Key Results

The following is a summary of key results from the pre-development scenario modelling;

- Results indicate the site is exposed to flood waters from the east, west and south. The flood extents cover approximately half the site; the southern portion in the immediate vicinity of the existing two (2) storey brick hall building only. Flood depths adjacent site boundaries vary, up to a maximum 1.5m in the south-eastern corner of the site next to Council’s drainage channel. The existing brick building does not appear to provide flood storage and has therefore been modelled as an obstruction (this methodology was also adopted in the CCC 2007 study).
- A minor flowpath travels through the site from the western to eastern boundaries; immediately north of the existing two (2) storey brick hall building. Flows through this area travel at low velocities (less than 0.3m/s) and shallow depths (up to 0.015m).
- Flood levels derived from the modelling are within reasonable tolerance of the existing Council studies. The results of the pre-development scenario are shown in Appendix D.

4.5 Post Development Flood Assessment

4.5.1 Proposed Development

The proposed site works consist of clearing the existing structures on site and constructing a new multi storey development. The proposed development is to include a mix of residential dwellings and commercial space, including basement car parking (refer architectural plans for details).

4.5.2 Post Development Model Build

The post development flood model builds on the pre-development model that has been outlined in Section 4.4.

To maintain the flow conveyance of the Parkes Street flow path, the ground floor extents of the proposed development have been limited to the location of the southern wall of the existing brick hall building. This will allow flood waters that exceed the adjacent Clay Cliff Creek channel to pass the site in a similar manner to the current situation in order to generally match pre-post flood levels.

The DEM of the site’s detailed survey data was overlaid over the existing LiDAR surface to create a model of the proposed scenario while maintaining the existing surrounds (shown below in Figure 4.11). The proposed footprint of the development was placed in the model as an inactive area of zero total flow. This enabled the measurement of the affect the proposed development would have on adjacent properties and the local setting.

The combined DEM for the proposed scenario was then run in the *TUFLOW* model to determine the impact the development had on flooding within the subject site and the local surroundings.

The outcomes of this investigation have been documented in Appendix D and summarised below.

Figure 4.11a: Proposed Digital Elevation Model

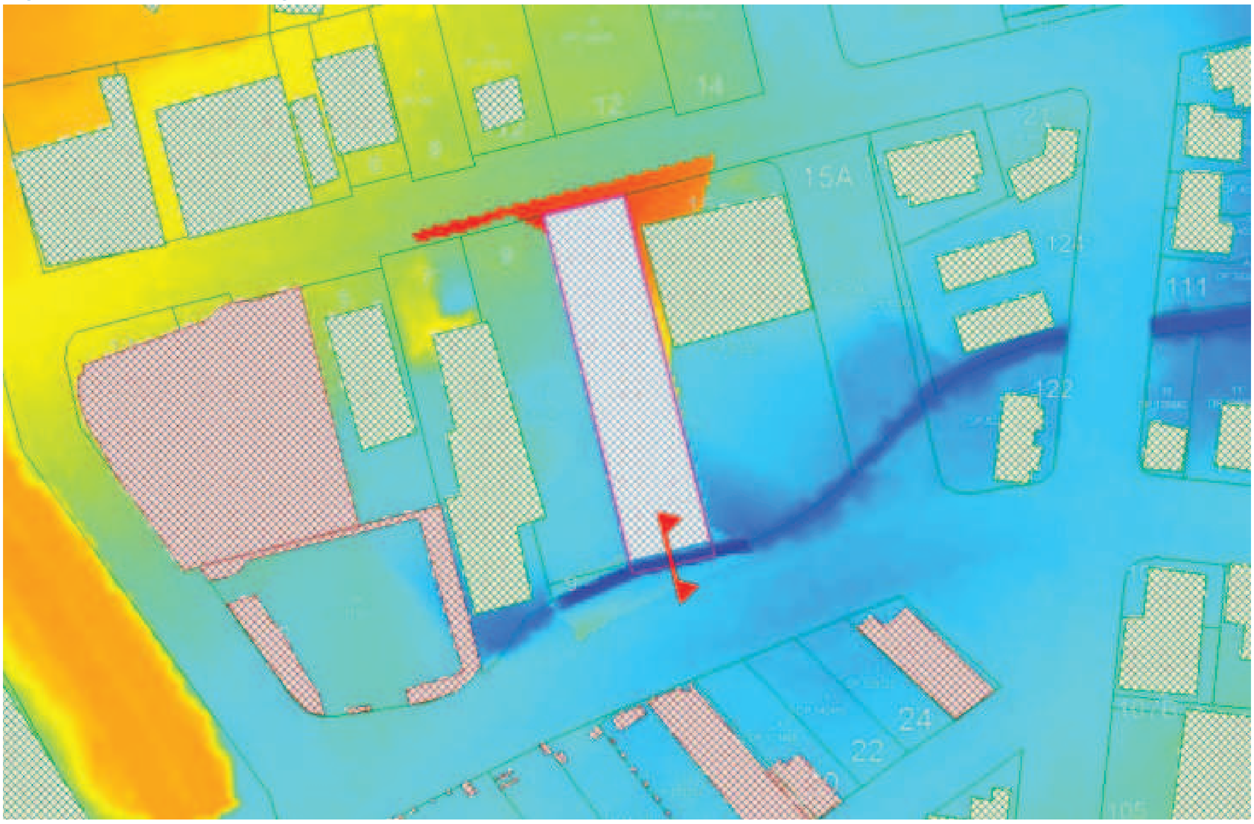
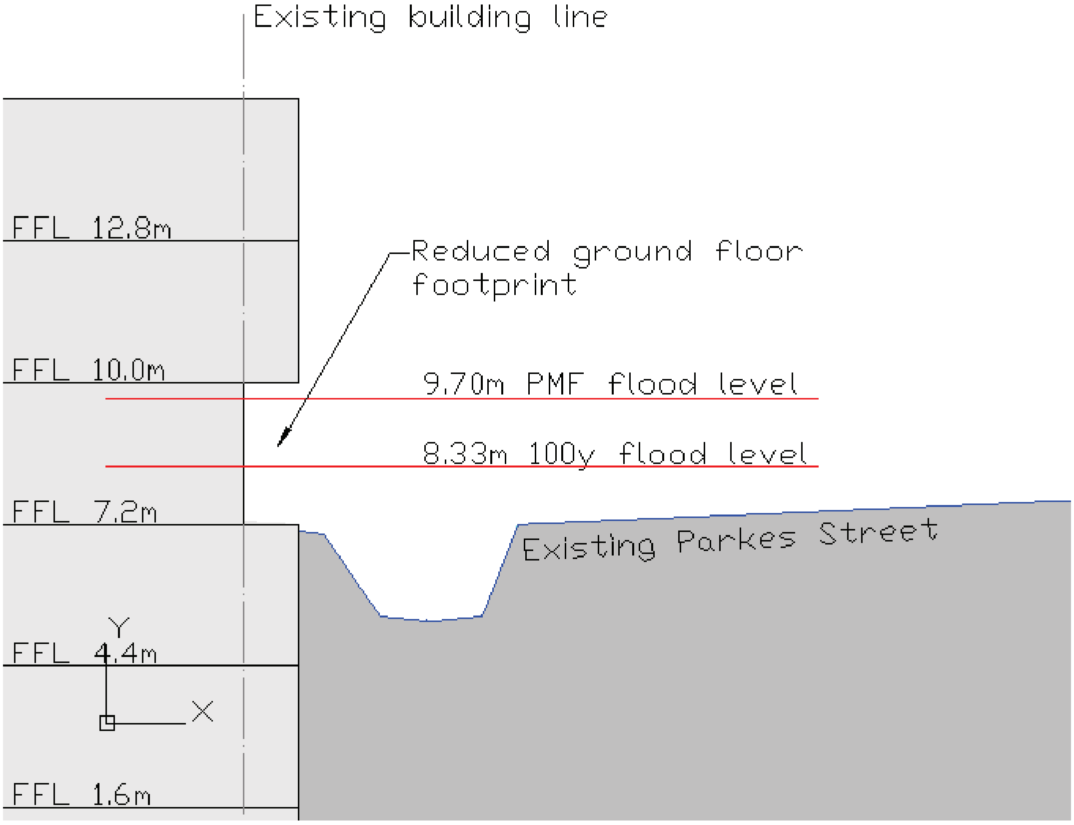


Figure 4.12b: Section through Proposed Digital Elevation Model



4.5.3 Post development Results

As the proposed development site does not impact greatly on the overall local catchment (within the extents of the *TUFLOW* model area) the same inflows were used for both the existing and proposed models. This in turn allows for direct comparisons to be made between the existing and proposed scenarios in determining flood affectation upstream and downstream of the site.

4.5.3.1 Proposed Model - Key Results

The provision of the ground floor setback to the existing building line has facilitated in generally maintaining flood levels across the site and within the surrounding area. Water surface level increases of approximately 0-7mm occur within the immediate vicinity and immediately downstream with overall flooding conditions of a similar magnitude to the existing Scenario.

Small, isolated areas of localised water level increase are present upstream of the development site where the shallow Parkes Street surface flows transition into the deeper main Cliff Creek channel flow. These increases of up to 17mm in flood level are limited to a 9 metre stretch immediately upstream of the Cliff Creek culvert-channel transition, and correspond with local undulations in the topography. The below figure identifies these minor areas of increased water level above 10mm and are not considered significant.

Figure 4.13: Parkes Street overland flow/open channel interface – Water Level Greater than 10mm

The following is a summary of key results and recommendations from the modelling;

- A restricted building footprint adjacent the southern boundary is proposed for the development. This allows flood waters to flow unimpeded past the southern wall of the building, as per the existing case.
- Basement/car park walls are to be designed to be flood tolerant (in both material and design).
- The basement carpark entry ramp from Hassall Street is above the PMF level and therefore sufficient.

- Flooding conditions within the local precinct are generally maintained, with variation in flood levels in the order of -/+ 7mm as flows balance out downstream of the development site. Overall, the Parkes Street flow path sees minimal impact based on the proposed development (less than 1-2mm difference).
- Upstream of the development site within the Parkes Street flow path, a small isolated area experiences a flood increase in the order of 0mm-17mm as discussed in Section 4.5.3.1. These isolated areas are generally within the creek/road corridor and are not considered significant.

4.5.3.2 Proposed Water Surface Levels

The water surface level results produced by the *TUFLOW* model are shown to be reasonably well calibrated to the *CCC-MDP* study, with minor variation to the results of the 2007 Cardno study. The flood levels across the site vary between the range of approximately 8.30m to 8.42m AHD.

Table 4.3: Water Levels – Extracted vs. Modelled

Site Locations	Water Level (m AHD) interpolated from LPR-FRMS	Existing Modelled Water Level (m AHD)	Proposed Modelled Water Level (m AHD)
South eastern Corner (facing Parkes Street)	8.32	8.30	8.31
South western Corner (facing Parkes Street)	8.33	8.42	8.42

Source: *LPR-FRMS* (SKM, 2005), *CCC-MDP* (Cardno Willing, 2007)

As the purpose of the *TULFOW* modelling is to assess the proposed development in a pre-to-post assessment, flood planning levels have been based on the current TUFLOW modelling contained within this report as the data used (including the field inspections and detailed site surveys) is more accurate. It will also have due regard to previous studies and the sensitivity analysis of blockage scenarios.

4.5.4 Pre-Development to Post-Development Comparison and Flood Affectation Analysis

The inflow hydrographs for the existing and proposed models were identical. This allowed the existing and proposed flood water surface levels to be directly compared against each other to assess flood affectation adjacent to the site.

Changes to the water surface level are identified in Figure 4.14 below.

Figure 4.14: Changes in Flood Levels due to the Proposed Development (Greater than 10mm)

4.5.4.1 Summary of Results

- Results of the flood comparison showed generally no significant increase in the flood level across the site and surrounding area.
- The small, isolated spots shown above in orange indicate the areas where water levels have increased by greater than 10mm, up to a maximum 17mm (flood level increase less than 10mm can be deemed negligible over the wider floodplain in a storm event of this magnitude).
- Areas of improvement in flood levels (where flood levels have decreased) across the precinct were also displayed in the modelling results. As there are some minor water level increases in some areas, they are balanced out by areas of improvements in other regions.
- The proposed development results have shown a minimal increase of flood levels in isolated areas upstream of the site. It is our opinion that these areas of increased flood level pose no adverse impact on any private properties or developable areas within the precinct.
- The minor reduction in flood storage has minimal effect on the flow conditions/flood level in Parkes Street.

4.5.5 Flood Planning Levels

The following table summarises the derived Flood Planning Levels (FPLs) in relation to the selected floor levels. While some elements are not exposed to the main Parkes St flow path and associated flood levels it is important to maintain proposed floor levels shown below to prevent local street runoff from entering the building. It is important to note that the ground floor levels relate to commercial and retail land uses and not habitable floor levels, with the most critical element being the basement entry ramp. The table below shows that all elements are above the required flood planning level.

Table 4.4: Summary of Floor Levels and Freeboard – 1% AEP/PMF

Building Element	Proposed Level (RL. AHD)	Proposed Scenario Flood Level (RL. AHD)	100yr Flood Planning Level (RL. AHD)	Distance Above FPL (m)	Distance Above PMF (RL 9.7) (m)
Ground Floor Fronting Hassall Street	10.00	8.42	8.92	1.08	0.3
Ground Floor Fronting Parkes Street	10.00	8.42	8.92	1.08	0.3
Lowest Habitable Floor Level	**16.10**	**8.42**	**8.92**	**7.18**	**6.4**
Basement Entry Ramp Hassal Street	10.00	8.42	8.92	1.08	0.3

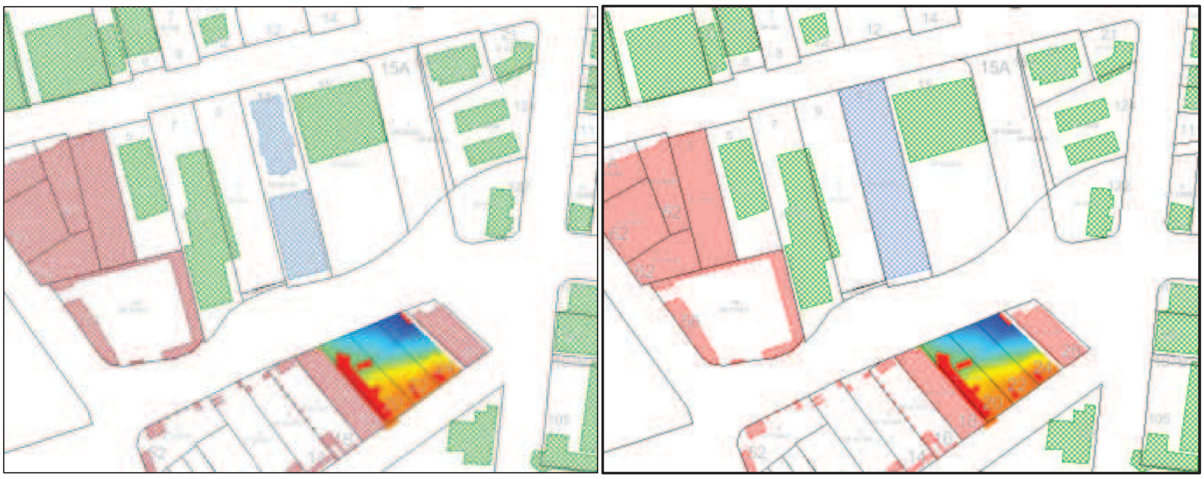
4.5.6 Additional Modelling Scenarios

At present, the vacant lot to the west of the site allows flood waters to pass freely without obstructions while the developed lot to the east includes a raised podium ground floor to allow the flood waters to pass underneath the building with minimal disruption. Future redevelopment of the neighbouring vacant lot is assumed to include a similar building form to this developed lot with a raised podium floor level to minimise the impacts on local flooding conditions in the High Flood Risk precinct.

Development is planned at 20-24 Kendall St, a future mixed use development across Parkes St from the subject site. Survey information supplied by Council includes surface levels and structures which are currently being modified through construction activities. To ensure validity of the advice in this report on flooding characteristics, data on the proposed development at 20-24 Kendall Street has been obtained and used to develop an “ultimate” ground model inclusive of both developments.

After modelling the existing and proposed scenarios, a third scenario was modelled to represent ultimate catchment conditions in which the 20-24 Kendall Street ground model has been introduced to better represent future redevelopment and validate advice on local flooding.

Figure 4.15: Existing Conditions (left) & Ultimate Condition (right)



4.5.6.1 Summary of Results

- The results of the model run indicate minor increases in flood depths downstream of the development site as well as improvements (reductions in flood levels) through the Parkes Street and Kendall Street flow paths. (changes less than 10mm have not been shown as they constitute insignificant differential considering the size of the model and the accuracies involved)
- Generally the results of the additional scenario follow closely the results of the existing vs proposed scenario. There is generally no significant increase in flood levels within or adjacent to the subject site and minimal impact of the local flood regime.

Figure 4.16: Change in Flood Levels due to the Ultimate Development (Greater than 10mm)

4.5.7 50% Clay Cliff Creek Blockage

In accordance with the DRAFT AR&R Project 11 guidelines, a 50% blockage factor has been applied to the Clay Cliff Creek Culvert in order to provide a sensitivity analysis on the potential blockage and give consideration to the potential impacts in relation to the proposed development, the results of which are summarised in Table 4.4 below showing the basic linear interpolation from the LPR-FRMS, the current detailed model of the proposed site and the sensitivity analysis of 50% blockage of the Clay Cliff Creek Culvert.