3. AVAILABLE DATA

3.1. Overview

The first stage in the investigation of flooding matters is to establish the nature, size and frequency of the problem. On larger urban river systems such as the Hawkesbury River there are generally stream height and historical records dating back a considerable period, in some cases over one hundred years. However, in smaller urban catchments stream gauges and/or official historical records are generally not available, and there is more uncertainty about the frequency and magnitude of flood problems. Additionally, overland flooding in urban areas is highly dependent on localised changes to development, intensification of development (i.e. increased building sizes and more paved surfaces), and localised drainage features such as kerbs and guttering in roadways. These features are subject to relatively frequent modification and renewal, making it difficult to compare flood behaviour over time.

There are several pluviometers surrounding the catchment. There is one pluviometer situated within the catchment, at Curl Curl Lagoon, which was installed in 2014 and captured data for the November 2018 event. Two nearby pluviometers were also available to the south-west of the catchment for this event.

An understanding of historical flooding was obtained from an examination of Council's records, previous flood assessment reports, rainfall records and local knowledge obtained through community consultation (see Section 4).

Airborne Light Detection and Ranging (LiDAR) data in urbanised areas and detailed bathymetry survey of lower Greendale Creek and Curl Curl Lagoon (collected as part of previous studies) was available for modelling. A relatively high quality GIS database of surveyed pits and pipes was also available. This data required slight corrections to some invert levels and dimensions before incorporation into the hydraulic model. As part of this study, analysis of the available data along with site visits were undertaken to address the limitations of the data in key areas.

It should be recognised that while the information about the drainage system for this study is not perfect, this is often not a critical issue, since the majority of runoff cannot usually be contained within the formal drainage network for the types of flood events being considered. Sub-surface drainage networks in metropolitan Sydney are typically only designed to cater for the 20% to 10% AEP flow. Therefore, caution must be exercised when applying the broad catchment modelling results at individual properties, particularly for smaller floods or in areas where the pit/pipe drainage network plays a significant role in the flood behaviour.

3.2. Data Sources

Data utilised in the study has been collated from a variety of sources. Table 1 provides a summary of the type of data sourced, the supplier, and its application for the study.

Table 1: Data Sources

Type of Data	Source	Application
Ground levels from LiDAR data (2013)	Digital Elevation Model - DEM (LPI)	Hydrologic and hydraulic models
Curl Curl Lagoon Bathymetric Data	MHL	Hydraulic model
Pits, Pipes and Hydraulic Structures	Northern Beaches Council	Hydraulic model
GIS Information (Cadastre)	Northern Beaches Council	Hydraulic model
Historic Flood Level Data	MHL, Northern Beaches Council, Local Residents	Hydraulic model
Rainfall Gauge (Pluviometer)	MHL	Hydrologic model
Rainfall Gauge (Daily)	BoM	Hydrologic model
ARR Design Rainfalls, Temporal Patterns and Loss Rates	BoM	Hydrologic model

3.3. Topographic Data

Airborne Light Detection and Ranging (LiDAR) survey of the catchment and its immediate surroundings was obtained from Land and Property Information (LPI), which is a division of the Department of Finance, Services and Innovation (NSW Government). The LiDAR survey was collected in 2013. The typical accuracy of this dataset is:

- +/- 0.15 m (for 70% of points) in the vertical direction on clear, hard ground; and
- +/- 0.75 m in the horizontal direction.

The accuracy of the LiDAR data can be influenced by the presence of open water or vegetation (tree or shrub canopy) at the time of the survey. The 1 m by 1 m Digital Elevation Model (DEM) generated from the LiDAR, which formed the basis of the two-dimensional hydraulic modelling for the study, is shown in Figure 2.

Council provided additional information for the following two developments which took place after the LIDAR capture date and the model topography was modified accordingly:

- St Augustine's School (ground levels and building footprints); and
- 40 Chard Road (building footprints only).

Furthermore, modifications to the DEM were made to include features observed during the site inspection at "The Kilns" development (see Section 6.6.9).

3.4. Hydraulic Structures

Structures including bridges and culverts can have a significant impact on flood behaviour. Therefore, appropriate representation of these structures is essential for the accuracy of the hydraulic model. Data for hydraulic structures was primarily obtained from:

- Northern Beaches Council (Works-As-Executed drawings); and

- Measurements obtained during site visits.

During the inspection of the study area WMAwater obtained photographs and additional measurements of key hydraulic structures in the catchment. The locations of these structures are shown on Figure 12.

3.5. Bathymetric Survey

Within Curl Curl Lagoon and lower Greendale Creek, the bathymetry is not accurately captured by LiDAR data, since LiDAR is unable to penetrate the water surface. A bathymetric DEM within the lagoon was provided by Northern Beaches Council (obtained from MHL). The DEM was constructed from detailed survey of Curl Curl Lagoon, sampled at a regular grid cell size of 5 m.

3.6. Pit and Pipe Data

A database of surveyed stormwater pits and pipes within the catchment was provided by Northern Beaches Council (see Figure 3). The pits and pipes data generally contained inverts and dimensions for most pits and pipes. Where data was not available pit inlets and pipe sizes were determined from the following principles:

- Pipes were assumed to have a depth of cover of 0.5 m to the top of the pipe below the recorded ground level at pits and junctions;
- Pit inlets were modelled as having the inlet level at the LIDAR ground level;
- Where inlet pit dimensions were not provided a lintel opening width of 1.2 m was assumed;
- Where unavailable pipe sizes were estimated based on the sizing of connected upstream and downstream pipes.

Following this initial estimation, further corrections to pit inverts were undertaken to correct pipes with negative slope or pipes that were located above ground in the model.

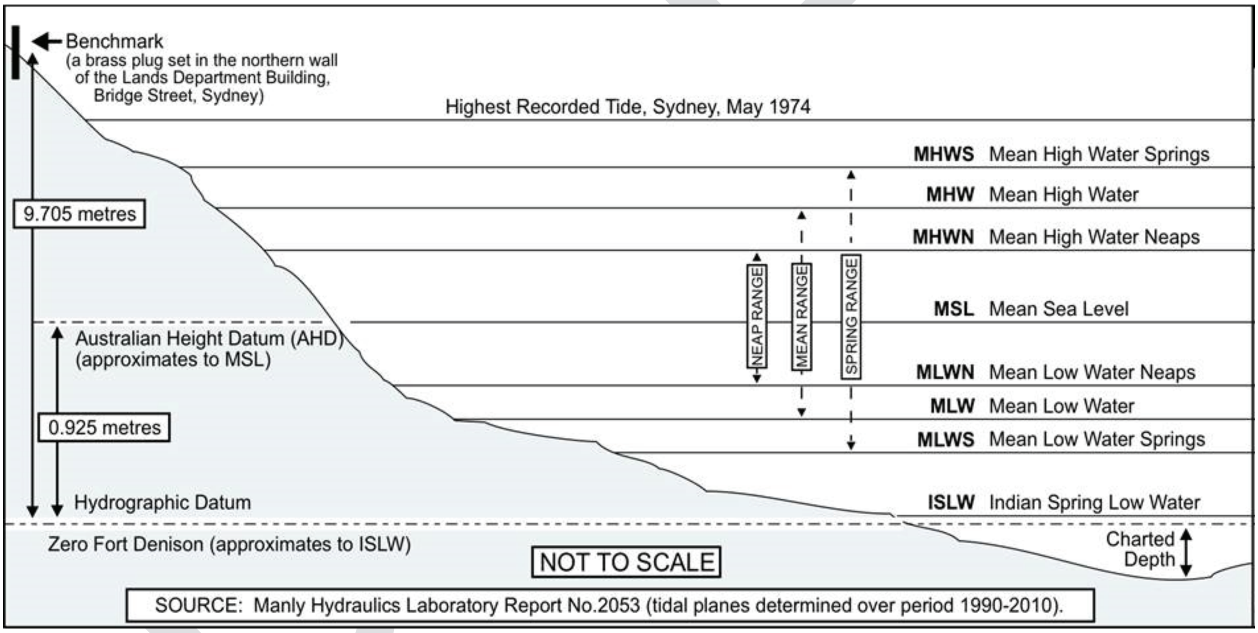
3.7. NSW Tidal Planes Analysis

Manly Hydraulics Laboratory prepared the *NSW Tidal Planes Analysis: 1990-2010 Harmonic Analysis* report on behalf of OEH (Reference 7). It was released in October 2012 and was based on data from 188 tidal monitoring stations from 1st July 1990 to the 30th June 2010. Data from the relevant stations are shown in Table 2 with a tidal plane diagram shown as Diagram 1. Curl Curl Lagoon may be subject to tidal influence in large flood events when lagoon breakout occurs however due to the elevation of the entrance berm, peak flood levels will not generally be affected by the tidal conditions, unless there is a major storm surge and wave action accompanying the rainfall.

Table 2: Tidal Planes Analysis Results (MHL, 2012)

Tidal Planes	Annual Average Amplitude (mAHD)		
	Ocean Tide Gauge Port Jackson (213470)	Ocean Tide Gauge Port Hacking (213473)	Cooks River at Tempe Bridge (213415)
High High Water Solstices Springs (HHWSS)	1.00	1.04	1.06
Mean High Water Springs (MHWS)	0.65	0.68	0.70
Mean High Water (MHW)	0.52	0.56	0.57
Mean High Water Neaps (MHWN)	0.40	0.44	0.45
Mean Sea Level (MSL)	0.02	0.07	0.06
Mean Low Water Neaps (MLWN)	-0.36	-0.31	-0.33
Mean Low Water (MLW)	-0.48	-0.43	-0.46
Mean Low Water Springs (MLWS)	-0.61	-0.55	-0.58
Indian Spring Low Water (ISLW)	-0.86	-0.81	-0.84

Diagram 1: Tidal Planes Diagram



3.8. Stream Gauge Data

Historical stream gauge data is available from the Greendale Creek Brookvale gauge (213499) at Harbord Road and Curl Curl gauge (213426) located on Griffin Road Bridge. Recordings at Curl Curl gauge (213426) were available from August 1991. A subset of these recordings is shown in Figure 13. This gauge provides water level information but not flow information, as a rating curve cannot be developed due to the influence of the berm.

Recordings at Greendale Creek Brookvale (213499) were available from MHL for April 2013 to July 2018 as shown in Figure 14. This gauge provides discharge information but the data period ends prior to the November 2018 calibration event. Hence a water level hydrograph was available for the November 2018 event for use in hydraulic model calibration (at gauge 213426) however no flow measurement data was available.

The water level gauge in Curl Curl Lagoon (213426) provides sufficient information to characterise the regularity of breakouts, and the nature of the lagoon water level response after a breakout. This includes the lagoon response to the November 2018 event, during which a breakout occurred. However there is insufficient data to determine design flows for the catchment.

3.9. Historical Rainfall Data

3.9.1. Overview

Rainfall data is recorded either daily (24-hour rainfall totals to 9:00 am) or continuously (pluviometers measuring rainfall in small increments – less than 1 mm). Daily rainfall data has been recorded for over 100 years at many locations within the Sydney basin. However, pluviometers have generally only been installed for widespread use since the 1970s. Together these records provide a picture of when and how often large rainfall events have occurred in the past.

Care must be taken when interpreting historical rainfall measurements. Rainfall records may not provide an accurate representation of past flooding due to a combination of factors including local site conditions, human error or limitations inherent to the type of recording instrument used.

Examples of limitations that may impact the quality of data used for the present study are highlighted in the following:

- Rainfall gauges frequently fail to accurately record the total amount of rainfall. This can occur for a range of reasons including operator error, instrument failure, overtopping and vandalism. In particular, many gauges fail during periods of heavy rainfall and records of large events are often lost or misrepresented.
- Daily read information is usually obtained at 9:00 am in the morning. Thus if a single storm is experienced both before and after 9:00 am, then the rainfall is “split” between two days of record and a large single day total cannot be identified.
- In the past, rainfall over weekends was often erroneously accumulated and recorded as a combined Monday 9:00 am reading.
- The duration of intense rainfall required to produce overland flooding in the study area is typically less than 6 hours (though this rainfall may be contained within a longer period of rainfall). This is termed the “critical storm duration”. For a larger catchment (such as the Parramatta River) the critical storm duration may be greater (say 9 hours). For the study area a short intense period of rainfall can produce flooding but if the rain starts and stops quickly, the daily rainfall total may not necessarily reflect the magnitude of the intensity and subsequent flooding. Alternatively, the rainfall may be relatively consistent throughout the day, producing a large total but only minor flooding.
- Rainfall records can frequently have “gaps” ranging from a few days to several weeks or even years.
- Pluviometer (continuous) records provide a much greater insight into the intensity (depth vs. time) of rainfall events and have the advantage that the data can generally be

analysed electronically. This data has much fewer limitations than daily read data. Pluviometers, however, can also fail during storm events due to the extreme weather conditions.

Intense rainfall events which cause overland flooding in highly urbanised catchments are usually localised and as such are only accurately represented by a nearby gauge, preferably within the catchment. Gauges sited even only a kilometre away can show very different intensities and total rainfall depths.

The rainfall data described in the following sections pertains to information that was used in model calibration.

3.9.2. Rainfall Stations

There are a number of rainfall stations located across the Sydney metropolitan area, including daily read and pluviometer gauges. The continuous pluviometer stations record rainfall in sub-daily increments (with output typically reported approximately every 5 minutes). These records were used to create detailed rainfall hyetographs, which form the model input for historical events against which the model was calibrated. The nearby continuous pluviometers used in the calibration process are shown in Table 3 with locations shown on Figure 4 (daily-read gauge locations are also shown). Only one pluviometer gauge at Curl Curl is located within the catchment.

Table 3: Pluviometer Rainfall Stations

Station Number	Station Name	Authority
213426	Curl Curl	MHL
566152	Allambie Heights	MHL
566151	North Manly	MHL

3.9.3. Analysis of November 2018 Rainfall Event

The daily rainfall depths recorded at nearby gauges are shown in Table 4. The November 2018 storm event (the sole event used for model validation in this study) comprised an intense rainfall burst between approximately 4:30 am and 7 am on 28/11/2018, which was then followed by less intense sporadic rain over the next 24 hours. This storm was captured by the three nearby pluviometers. One of these pluviometers, the Curl Curl gauge at Griffin Road Bridge (213426) is located within the catchment. The total depths recorded at nearby rainfall gauges over the 2 day period ranged from 53.6 mm to 168 mm.

Table 4: Daily Rainfall Depths (mm) for the November 2018 Event

Station Number	Station Name	Type	28-Nov 2018 Rainfall (mm)	29-Nov 2018 Rainfall (mm)
66126	Collaroy (Long Reef Golf Club)	Daily	27.2	26.4
66188	Belrose (Evelyn Place)	Daily	42.6	27.6
66080	Castle Cove (Rosebridge Ave)	Daily	75	35
66011	Chatswood Bowling Club	Daily	135	33
66059	Terry Hills AWS	Daily	36.4	44.2
66141	Mona Vale Golf Club NSW	Daily	51.8	39
66209	Dover Heights (Portland St)	Daily	59.8	27.8
66206	St Ives (Richmond Avenue)	Daily	51.6	33.8
66006	Sydney Botanic Gardens NSW	Daily	106.6	31.4
66214	Sydney (Observatory Hill Comparison)	Daily	104.2	29.8
66062	Sydney (Observatory Hill) NSW	Daily	105.6	30.2
566151	North Manly	Pluviometer	61.5	13.5
566152	Allambie Heights	Pluviometer	62.5	11.5
213426	Curl Curl	Pluviometer	51	19

Rainfall isohyets which describe the spatial distribution of rainfall for this event are shown on Figure 5. Cumulative rainfall data which describes the temporal pattern of rainfall recorded at the nearby pluviometers is shown on Figure 6.

The total rainfall depths were generally higher further inland, for example at Chatswood and Sydney Observatory Hill, and lower towards the coast. The areas around the Sydney CBD and Manly received the most intense short duration rainfalls (i.e. over the period of 30 minutes to 60 minutes), with intensities approximating a 1% AEP at some locations.

A comparison of the peak recorded rainfall bursts with design rainfall curves taken at the Curl Curl (213426) gauge is shown on Figure 7. This indicates that the rainfall approximated a 2% AEP event for the 15 minute duration, and a 5% AEP event for the 30 minute to 1 hour duration. The North Manly and Allambie Heights gauges indicated slightly rarer AEPs.

4. COMMUNITY CONSULTATION

4.1. Overview

A newsletter/questionnaire was distributed to residents in the study area to inform them about the study, and to obtain information about historical flooding. 113 responses relating to flooding in the Greendale Creek catchment were received, with 34 respondents indicating they had experienced flooding of their home or business due to flood water or stormwater. One respondent indicated that they had experienced above floor flooding of the main building on their property with the remainder of respondents indicating that flooding had affected their garage, yard or other parts of their property.

Respondents identified flooding in streets, parks or other public areas as primarily occurring in the suburbs of Curl Curl, Brookvale and North Curl Curl. Half of the flood affected respondents indicated that they noticed blocked drains or culverts during the flood. 14 respondents provided additional comments which raised obstruction of drains and waterways as a concern.

The results of the community consultation process, indicating the locations of flood affected respondents are shown in Figure 8. The results from the community consultation questionnaire are summarised in Figure 9.

4.2. Community Responses

A selection of photographs provided by the community is shown below (Photo 1 to Photo 4)

Photo 1: The Kilns (March 2013)

Photo 2: Flooding near Unit 6, The Kilns (2014)

Photo 3: Stirgess Reserve (March 2011)

Photo 4: Flooding at The Kilns (September 2013)

Community consultation responses indicate that flows exceeding the capacity of the channels around The Kilns occurred several times between 2013 and 2014 due to a landslide which caused blockage of a section of the channel. The rocks from this landslide were removed from the channel in early 2015, which the respondent suggests has lowered the flood risk in this area.

Photo 3 indicates that ponding of water in Stirgess Reserve is likely to occur relatively frequently.

The following issues were raised by the respondents:

- Several respondents expressed concerns that development in the catchment is exacerbating flooding;
- Some respondents were concerned about debris and blockage of drains due to vegetation and rubbish;
- Most reported flood observations related to yards, streets, parks or Curl Curl Lagoon, rather than overfloor flooding;
- One respondent suggested the berm on Frank Gray Oval was particularly effective in mitigating flooding;
- Few residents raised concerns about above floor level flooding on their property. This observation is reflected in previous studies (Reference 2 to Reference 4) which found that most affected properties in the Greendale Creek catchment are located in industrial areas such as the Brookvale industrial area.

4.3. Public Exhibition

Section to be added after exhibition is completed. Appendix to be included with copy of community consultation materials and other relevant material.