

Coffs Harbour Flood Warning System

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Abstract

Coffs Harbour suffered major flooding in 1996 and again in 2009.

There is little warning of these events as Coffs Creek has a relatively small, steep catchment of approximately 24km², falling from over 400m to sea level. East coast lows are the main culprit and they can setup quickly with recorded rainfall of over 350mm falling in 6 hours in 2009.

This paper will describe how Council designed and constructed flood warning stations and the technology to send the real time data to the Bureau of Meteorology, local State Emergency Service as well as Council's own response team.

The stations include tipping bucket rain gauges, water level recorder, data logger, solar power, batteries, and radio telemetry components in a safe and secure unit.

A total of twelve stations have been installed throughout the local government area at key locations, some on the creek system and others on elevated areas to pick up the orographic effects on rainfall intensities that are evident in our coastal catchments. Gauges have been installed at detention basins so Council and SES can monitor the basins performance during a major rainfall event.

The Flood Warning System combined with recently constructed detention basins assist Council and the SES provide a safer place for the Coffs community.

We have received positive feedback both from the SES and residents who live in the affected areas and this has enabled quick and targeted response to storms we have experienced since installation of the stations.

The comprehensive system has the necessary built in redundancy that is necessary in these emergency events and the data has also helped with the modelling of flood behaviour in our catchments.

Background

In the Coffs Harbour Local Government Area (LGA) the Great Dividing Range passes very close to the coast. The proximity of the coastal ranges to the ocean determines that the coastal plain has no major river systems. Instead coastal waterways are characterised by numerous small creek systems, overall there are 16 major coastal creeks. The area experiences a high rainfall, averaging 1700mm annually, with most rain falling in late summer and early autumn.

Landform exerts a strong influence on rainfall within the area. Higher rainfall occurs east of the coastal range. This is due to the orographic effect which is where onshore winds force moist maritime air over the land forcing it to rise when it reaches the coastal range resulting in precipitation and can lead to high intensity storms.

The physical nature of these catchments, being relatively small in area, steep and subject to high rainfall intensities cause what is termed 'flash flooding'. Flash flooding is often defined as flooding that peaks within six hours of the causative rain, thus it is sudden with little warning of its coming and is characterised by rapid rises of stream levels with elevated levels experienced for short periods of time. Local experience has demonstrated that flash flooding has occurred well within a 6 hour period, sometimes as quickly as 3 hours.

In particular Coffs Creek catchment is approximately 25km² and incorporates the central urban area of the city of Coffs Harbour. Boambee – Newport's Creek catchment is located immediately south of the Coffs Creek catchment and is approximately 50km². Elevation in the catchments rises from sea level to approximately 410m AHD.

There is a history of flooding on Coffs Coast with significant flood events having occurred in 1917, 1938, 1950, 1963, 1974, 1977, 1989 and 1991. Extreme flood events were experienced in November 1996 and March 2009.

On 31 March 2009 the Coffs Creek, Boambee – Newport's Creek and Bonville - Middle Creek catchments experienced heavy rainfall leading to major flooding. The flooding caused inundation of residential, commercial and industrial areas and blocked local roads and the Pacific Highway. The events caused severe damage to private and public infrastructure and lead the State Government into declaring the event a 'Natural Disaster'. In the immediacy of the event the SES responded to 968 requests for assistance with 111 identified as priority one jobs. 80 people were evacuated from their homes and spent the night at the Coffs Ex-Services Club Evacuation Centre.

Approximately 2500 homes were affected across both Coffs Harbour and Bellingen LGA's. This included above floor flooding, contamination with sewerage due to loss and damage to sewer pumping stations, loss of personal property, and damage to gardens, fences, retaining walls, private roads and culverts. Approximately 100 houses were uninhabitable after the event. The Insurance Council of Australia has reported 93 critical property claims and 1345 minor claims. A further 1060 claims have been submitted for car inundation. The Department of Housing reported 54 dwelling affected with a further 33 pensioner units remaining uninhabitable.

A second flood event was experienced in Coffs Harbour in 2009 on the 7th November. Fortunately the rainfall pattern and distribution was significantly different to the March event and flooding and damages to the urban areas were much less. While the 24 hours rainfall totals were very high and often comparable to the March flood the majority of gauges experienced less rainfall in the 3 and 6 hour peaks. The 3 and 6 hour totals are more critical for flooding in the Coffs Creek and Boambee – Newport's Creek catchments as they are reflective of the response time or time of concentration for the catchments. The exceptions to this are the gauges at the BOM Airport site and the Perry Drive that had very high 3 hour totals and more localised flooding was experienced around these gauges.

2009 was a very wet year for Coffs Harbour with a total of 2957mm recorded at the BOM airport site that at that stage had 61 years of records. The first BOM recording site in

Coffs Harbour, the old Post Office, has highest annual rainfall of 3375.7 in 1950. Records for this site are from 1899 to 1967.

An indicator of how wet a year 2009 was and how the rainfall was distributed over the year can be seen in the water level record for the Orara River gauge at Glenreagh. Glenreagh is a small rural village approximately 35kms northwest of Coffs Harbour. It is located on the Orara River, a tributary of the Clarence River. The headwaters of the Orara River are located over the range west of Coffs Harbour. In 2009 the Orara River experienced 6 flood events, see Figure 1- Orara River Gauge at Glenreagh 2009.

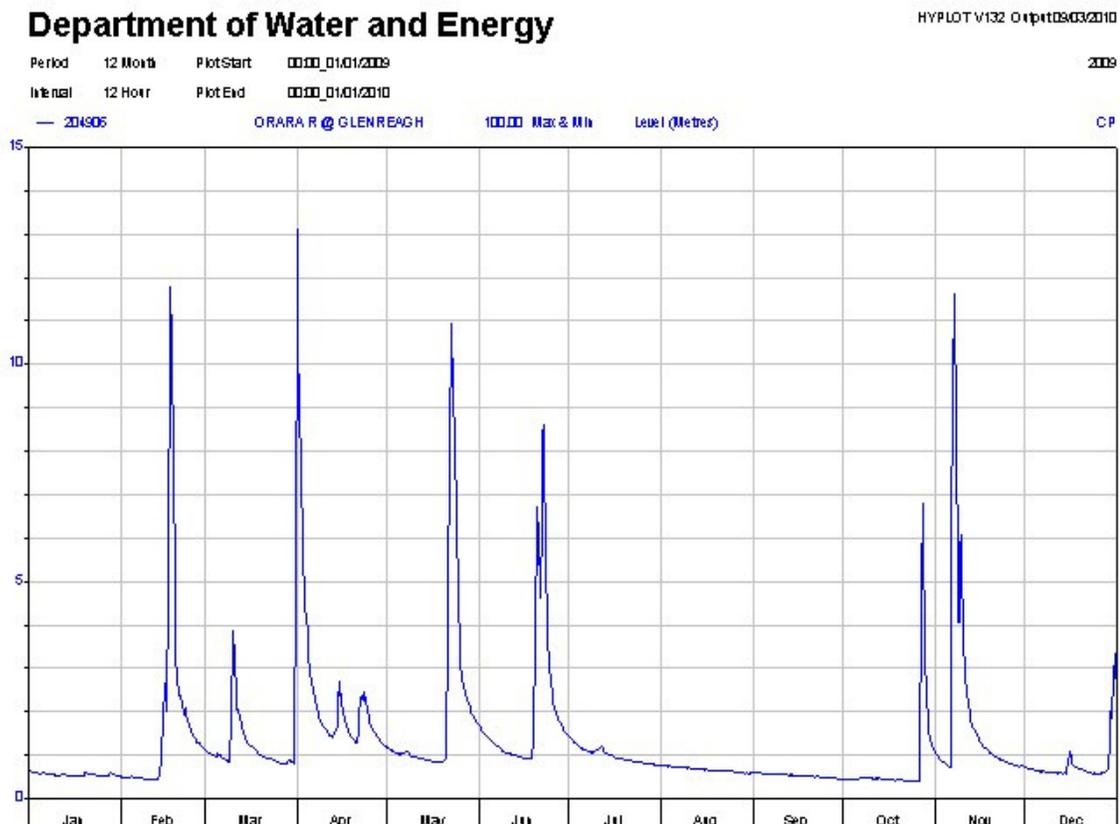


Figure 1. Orara River Gauge at Glenreagh 2009

In November 1996, a natural disaster was also declared when Coffs Harbour experienced major flash flooding with some 800 properties flood affected. The storm event caused inundation above floor level of over 250 residential properties and 210 commercial or public properties with 300 persons evacuated. This prompted Council to commission a revised *Flood Study* to further investigate the cause and severity of this flood. The review indicated that the magnitude of flood problems within the catchment was greater than had previously been understood. Council subsequently commissioned a *Floodplain Risk Management Study* to investigate and recommend measures to either manage or reduce flooding problems within the catchment.

Gauge	Time Period	1996	Mar-09		Nov-09	
		Total (mm)	Total (mm)	ARI	Total (mm)	ARI
Coffs BoM	24 hr	163.2	166.4	2 yr	405.8	> 50 yr
	6 hr	151.6	73.0	1 yr	271.6	50 yr
	3 hr	117.8	39.2	< 1 yr	192.8	200 yr
	1 hr	53.0	23.0	< 1 yr	97.0	> 50 yr
Perry Drive ¹	24 hr	499.0	377.5	50 yr	460.0	> 100yr
	6 hr	413.0	256.5	100-200yr	252.0	100-200yr
	3 hr	270.0	136.0	< 50 yr	140.0	< 50 yr
	1 hr	150.0	80.5	20 yr	66.5	8 yr
Shepard's Lane	24 hr	500 ³	439.5	100 yr	376.5	< 50 yr
	6 hr		315.0	> 500 yr	182.5	< 50 yr
	3 hr		222.5	> 500 yr	100.5	< 10 yr
	1 hr		113.0	200 yr	54.5	< 5 yr
Red Hill	24 hr	475 ²	484.5	200 yr	434.0	> 100yr
	6 hr		359.5	> 500 yr	207.0	< 50 yr
	3 hr		263.5	> 500 yr	122.5	15 yr
	1 hr		119.5	200-500yr	65.0	< 10 yr
Newports Ck	24 hr	463.5	460.0	100-200yr	201	< 5 yr
	6 hr	365.0	345.0	> 500 yr	89	< 2 yr
	3 hr	224.0	266.0	> 500 yr	79	< 5 yr
	1 hr	83.5	106.0	100 yr	43.5	< 2 yr
Middle Boambee	24 hr	439.5	518.0	200-500yr	425.5	~ 100 yr
	6 hr	347.0	398.5	> 500 yr	181.5	20 yr
	3 hr	208.5	322.0	> 500 yr	141	< 50 yr
	1 hr	77.5	148.0	> 500 yr	89.5	40 yr
South Boambee	24 hr	554.5	542.5	200-500yr	358	< 50 yr
	6 hr	446.5	422.0	> 500 yr	140.5	< 10 yr
	3 hr	272.2	337.0	> 500 yr	123.5	< 20 yr
	1 hr	111.5	149.0	> 500 yr	65.5	< 10 yr
North Bonville	24 hr	520.5	456.0	100-200yr	334.5	< 50 yr
	6 hr	375.0	302.0	> 500 yr	130	< 10 yr
	3 hr	233.5	227.0	> 500 yr	102.5	< 10 yr
	1 hr	125.5	97.5	50-100yr	58.5	5 yr

Table 1. Rainfall intensities 1996 and 2009 events.

Note: Perry Dr, Shephards Lane and Red Hill gauges were installed following the 1996 event making direct comparisons difficult.

1 1996 readings from nearby Sandra Close, private gauge with some increments.

2 1996 private reading to 9:00am, not peak 24hrs.

3 From flood study isohyetal map.

Following the 1996 flood event pluviographs (rain gauges) and water level recorders were installed in Coffs Creek, Newport's Creek and Boambee Creek catchments. Three pluviographs were installed in the Coffs Creek catchment and one each in Newport's Creek and Middle and South Boambee valleys. Water level recorders were installed in Coffs Creek, Newport's Creek and Boambee Creek.

The 3 pluviographs installed in west Coffs Creek are alert gauges. If rainfall exceeds a pre-set threshold then an automated "heads up" warning is issued to the SES and Council, after which the real-time data is monitored and appropriate response initiated. A comparison of the rainfall intensities from the different flood events is provided in 'Table 1. Rainfall intensities 1996 and 2009 events'.

Flood Mitigation and Funding

The flood events of 1996 and 2009 highlighted how many properties and how vulnerable the Coffs community is to flood events. So by the end of 2009 flooding had a very high profile and priority, within the community and Council, as an issue that needed to be addressed. Subsequently Council gave flood mitigation a very high priority and developed a major 'Flood Mitigation Works Program' to reduce the impacts of flooding in the community. Having funds is central to any such program and Council secured \$12M through two loans. This consisted off a \$6M loan over 20 years with repayments coming from Council's 'Stormwater Management Charge' (stormwater levy) and a second \$6M loan over 10 years with repayments funded through a 'Special Rate Variation' (SRV). Council's Flood Mitigation Program is also supplemented by funding under the NSW Flood Program for eligible projects that secure grant funding.

Following the 2009 flood events Council undertook a data collection exercise plus received extensive feedback from the community on flood issues. One of the main issues raised by the community was the lack of warning for the flood events. Taking the community feedback on board plus information from the 'Coffs Creek Floodplain Risk Management Study and Plan' Council developed the Flood Mitigation Program which included the following:-

- Construct Coffs Creek detention basin as per the Coffs Creek Floodplain Risk Management Study and Plan:
 - Bennett's Road detention basin – constructed;
 - Spagnolos Road detention basin – constructed;
 - Upper Shephard's Lane Detention basin – detailed design complete, applied for grant funding;
- Early Flood warning system - installed;
- 2D modelling of Coffs Creek – currently underway;
- Various local drainage works – ongoing;
- Creek maintenance and improvement works – ongoing;
- Short term works:-
 - Increase waterway area under Pacific Highway bridge, Coffs Creek – completed;
 - Remove old piers Orlando Street, Coffs Creek – completed.

- Boambee – Newport’s Creek flood mitigation works – completing Boambee – Newport’s Creek Floodplain Risk Management Study and Plan;
- Overland flow path improvements – requires detailed investigation.

Council has also constructed the Baker’s Road detention basin recommended in the Coffs Creek Floodplain Risk Management Plan. Funding for this basin was secured prior to the flood events of 2009 and the establishment of the \$12M Flood Mitigation Works Program’.

The major works associated with the Flood Mitigation Program has been the construction of detention basins in the Coffs Creek catchment as listed above. All four basins had individual economic benefit / cost ratios greater than 1.0. Construction of all four basins could reduce flood level by up to 0.4m directly downstream of the basin to the Pacific Highway. This would reduce the number of houses flooded above floor level in the 100-year flood from 308 to 114, and the number of commercial / industrial buildings from 112 to 29, see Figure 2 Flood detention Basin. Flood warning stations are also being installed at each of the detention basins. This is so the flood level in the basin can be monitored during a flood event to determine how much storage capacity has been used and how much is left before possible over topping of the basin. Also due to the basins being located in an urban area the basin have to satisfy Dam Safety Committee criteria that includes a requirement to have water level monitoring.

Securing the funding for the Flood Mitigation Program and the community feedback on the lack of flood warning was the catalyst for Council to develop a flood warning system.

Flood Warning System

Council developed a brief and went to the market for the design and costing of a flood warning system for the Coffs Creek and Boambee – Newport’s Creeks catchments. The brief for the flood warning system requested the consultant undertake the following:-

- Design and cost a flood warning system for Coffs Creek and Boambee – Newport’s Creek catchments;
- Provide details of ongoing maintenance and operational requirements and costs of the system;
- Determine the best methodology for predicting flood levels and extents from live rainfall and water level data and predicted or different scenario rainfalls for the flood warning system; Investigate incorporating existing pluviographs and water level recorders into the system;
- Investigate need, if any, for additional gauges and water level recorders and their location;
- Costing of any additional gauging including installation and ongoing operational and maintenance costs and regimes;
- Investigate opportunities to utilize / augment Councils sewer telemetry (SCX) into the flood warning system;
- Investigate monitoring stormwater system;
- Determine how best to interact with the Bureau of Meteorology and incorporate rainfall and flood predictions;

- Determine how to provide flood warning and updates on flood and weather conditions to the SES;
- Determine how to provide flood warning and conditions update to the different stakeholders including Council, Coffs Harbour Health Campus, schools, emergency services, residents and businesses at high risk and the public. This may include an number of different systems for the different stakeholders such as text message, email, media, sirens, PA systems etc;
- Review the Enviromon system operated by the Bureau of Meteorology;
- Design a system that is robust and flexible, ensuring that the system works in extreme weather conditions, is not susceptible to power outages, can handle periods of high demand on data and quick response to a flood event with long periods of relatively low use of data and has flexibility so that different segments of the system can function independently of each other and can make data available to other users;
- Look at the opportunity to use the 'Floodwise' web interface developed by Brisbane City Council;
- Provide an Operational System Checking Procedure that is undertaken at regular intervals to check that all the different components of the system are functioning and the system will work when required.
- Provide Tender Documents suitable for calling tender (technical specifications, detailed drawings, schedule of quantities).

The deliverables for the project included, but were not limited to the following: -

- Details and costs of proposed Flood Warning System;
- Proposed additional gauging, if any, with proposed location and costs associated with each gauge;
- Details of how the system is to be supported, accessed and maintained;
- Details of how the system will provide flood warning to different users;
- Details on how robust the system is;
- Estimates of flood warning time and accuracy of predictions;
- Details of the flexibility in the system such as ability to incorporate additional gauge inputs, use of the data for area other than flooding i.e. sewer or environmental assessment or link with other flood mitigation projects or how the warning system could be adapted for other disasters such as bushfire;
- Timeline for delivering the design of the system and likely construction and installation timeline;
- Details of ongoing technical support for system including but not limited to ongoing support for software / firmware upgrades or manufacturers warranties for equipment required to fulfil the scope of the flood warning system.
- Tender documents suitable for calling tender (technical specifications, detailed drawings, schedule of quantities)

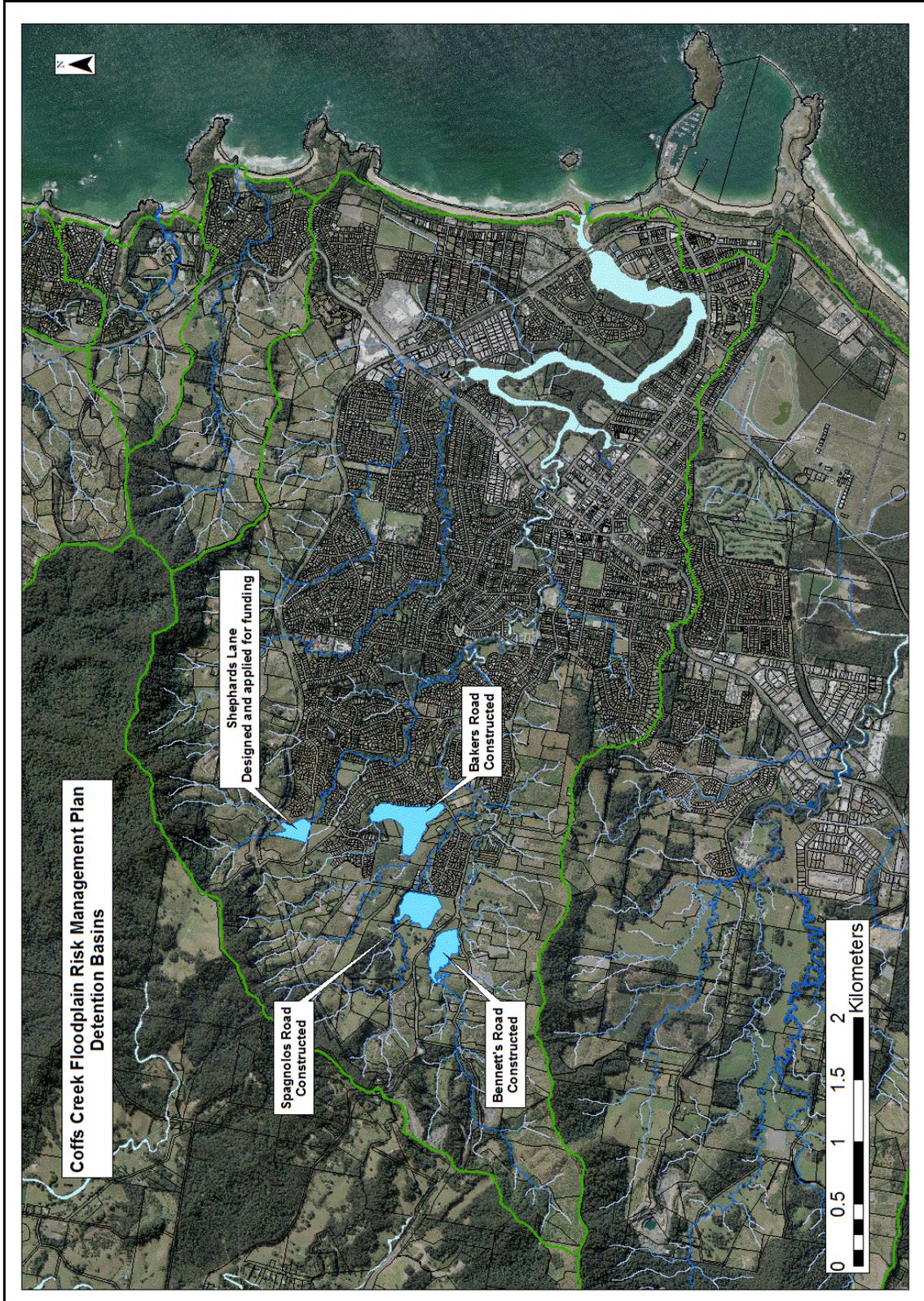


Figure 2 Flood detention basins

Three companies submitted proposal for the design of the flood warning system and a local Coffs Harbour company, Greenspan Technologies, was successful. Council received a draft Concept Design for the Coffs Harbour Flood Warning System from Greenspan Technology, with proposed stages of detailed design and construction and estimated costs in November 2010.

The Concept Design Flood Warning system has an estimated total cost of \$1.06M with four stages to the project, see table 2 'Concept Design Flood Warning System' below. The majority of Stage 1 and part of Stage 2 of the project is the installation of the hardware that is required for the system consisting of rain gauges and water level recorders and associated telemetry and software. Part of Stage 2 and the majority of Stage 3 and 4 is the development of the predictive flood model and installation of warning stations.

The total cost of the draft system proposed exceeded Council's budgeted funds for the project. There were a number of options available to carry out the detailed design and construction of the Flood Warning System, including Council utilising its in-house expertise, particularly in telemetry systems such as has been utilised for its water and wastewater infrastructure. Council then proceeded with a more detailed analysis of options for the Flood Warning System, including identifying the preferred method of procurement and construction and prioritising the different components of the system.

Item	1	2	3	4	Total	Description
Rain Gauges	98,267	66,067	13,467		177,801	14 rain gauge stations
Warning Stations	43,067	153,200	91,600	108,466	396,333	9 locations
Water Level Gauges	22,467	32,333	-	57,267	112,067	4 Detention basins plus Newport's Ck
Radio Bases	23,375	23,375	-	-	46,750	Macauley's and Boambee repeater sites
SCADA eng and software	120,000	20,000	10,000	10,000	160,000	Software licences, engineering hardware
Predictive Flood Modelling	-	90,000	10,000	10,000	110,000	Flood modelling software development
Misc	-	54,276	-	-	54,276	
Totals	307,176	439,251	125,067	185,733	1,057,227	

Table 2 'Concept Design Flood Warning System'

The highest priority was given to the installation of rain gauges and water level recorders with associated telemetry. The aim of this was to give SES, Council and BOM greater real time data in flood events. Note that there were already some rain gauges and water level recorders in the catchments and Council's proposed gauges were chosen to complement these. The information from all the gauges, Council and non- Council, would be available to the SES so they could determine when and where to activate their response crews and assist the BOM on determining when to issue flood warnings. This data will also provide a solid base for reviewing flood modelling and determine better relationships between rainfall intensity and distribution to the rate of rising flood waters and flood levels with the information being integral to the development of flood prediction models.

A substantial portion of the cost of the concept designed system involves the 'third step' that includes audible public warning infrastructure comprising loudspeaker based systems located at each of the hotspots. The use of this type of warning would require extensive public consultation and education, both initially and annually, costs of which have not been included in the estimates. The use of audible warning is an aspect of the system that requires further assessment and consideration of the advantages and disadvantages of this type of warning. This was given a low priority by Council.

Council decide to take a staged approach to the installation of the Flood Warning System that better matched allocated funds by installing high priority hardware and mainly using in-house expertise. The system Council determined to install consisted of 2 radio bases with SCADA telemetry system and software, 5 stand-alone rain gauges and 7 combination water level recorder / rain gauge stations, see Figure 4 Flood Warning Station Locations.

Council secured grant funding through the '2010-11 Natural Disaster Resilience Grants Scheme' and the '2011-12 Floodplain Risk Management Grants Scheme'. The final costs for the design and installation of the project under the grants were:-

2010-11 Design	\$101,486
2010-11 Installation	\$106,266
2011-12 Installation	\$264,411
Total	\$472,163

Council's total contribution was 1/3 or \$157,388.

The flood warning gauge stations were designed by Council staff. The stations are 4.5 metre hot dipped galvanized and painted steel pole, lower section is 400mm diameter which houses the electronic enclosure, batteries and cable management, upper section is 160mm diameter and is used to mount the tipping rain bucket, solar panel and antenna, The bottom of the pole have a large baseplate used to secure the pole to a standard Essential Energy CE3B starfin anchor footing.



Photograph 1 Rain gauge station



Photograph 2 Starfin anchor footing.

The stations electronics are powered by two 12v batteries and a solar panel, this will supply power for up to 2 weeks without sunlight. The electronics enclosure houses the data logger, water level sensor, radio/modem and solar regulator, photograph 3.

Rainfall is measured using a Hydrological Services TB3 1mm tipping bucket, water level is measured using a OTT CBS bubble sensor, the data logger is a Campbell CR800. Communication is by either Coffs Harbour Council's private 450mhz data radio system or Government Wide IP 3g modems (GWIP) depending on the location of the station.



Photograph 3 Electronics enclosure

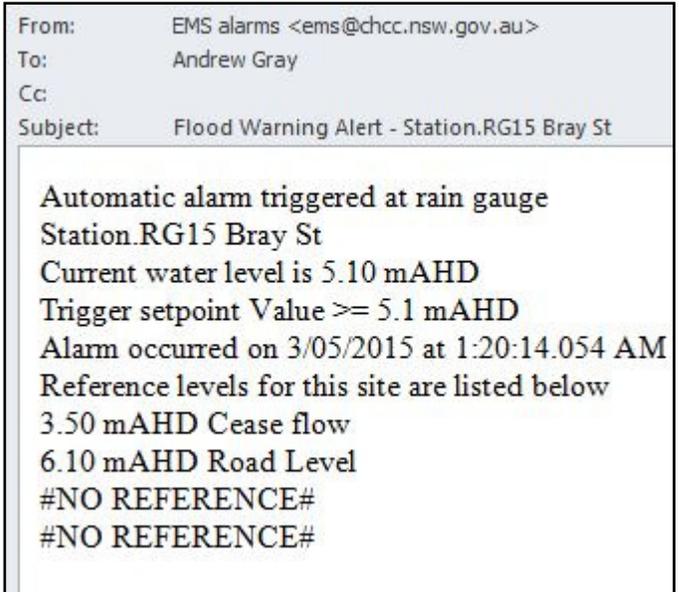


Figure 3 SMS alert

Installation of the water sensor bubble chamber is done using 20mm galvanized steel conduit, secured to the ground with star pickets and heavy duty U bolts and brackets. The installation of the complete system can be achieved in less than one day including the anchor footing and commissioning. All levels (bubble chamber, pole, reference structures) are surveyed and recorded in the scada database

The stations collect all the environmental data and communicate to Councils Clearscada system. Rainfall intensity, water level heights and other operational data is stored in the scada database. Each scada point has a pre-set alarm trigger level, when this level is reached an alarm is generated and sent to SES and Council personal via SMS and/or email. Information in the message contains the nature of the warning, for example a water level alarm would have, see Figure 3 SMS alert :-

- Station name and location;
- Alarm description;
- Trigger level and current water level in both “m AHD” and “m” above cease to flow;
- Reference levels to known structures e.g. road levels, culverts or house floor levels.

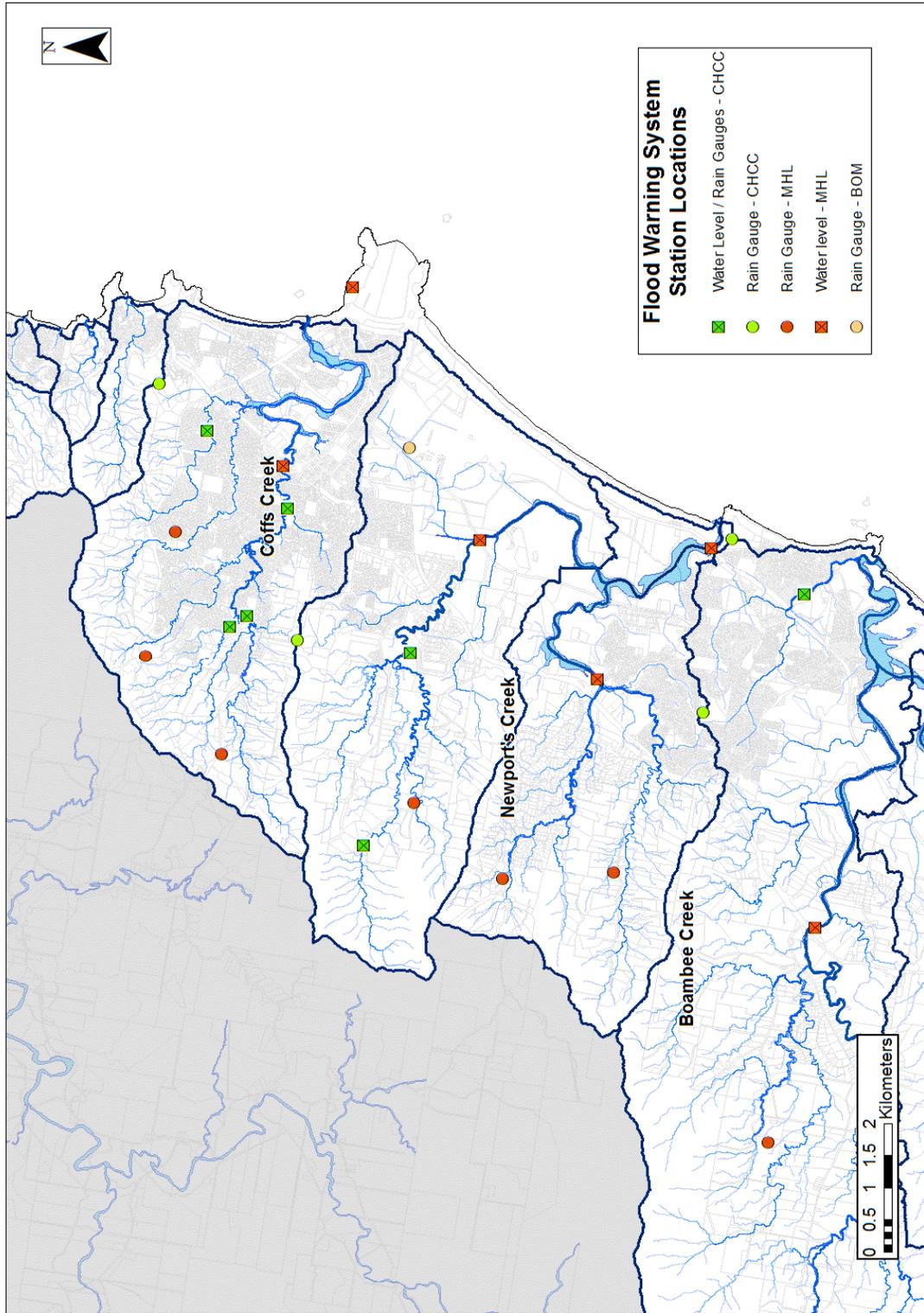


Figure 4 Flood Warning Station Locations

Rainfall and water level data collected in the scada system is also sent, via FTP to the BoM and local SES Enviromon software system. Data received by the BoM is formatted and displayed on the BoM webpage. Council personnel can access the scada using ViewX, Microsoft remote desktop connection or team viewer.

A maintenance schedule has been developed and a maintenance/OH&S checklist is filled in for each station. Maintenance is done on each station every 3 months this includes:

- Tipping rain bucket calibration and changing funnel filter;
- Purging airline and clean bubble chamber;
- Ant proofing and re-checking cable glands;
- Check batteries;
- Clean solar panels.

Maintenance costs are approximately \$50 per unit per visit. All maintenance data collected from the station are stored in the scada database allowing Council to audit results and verify routine maintenance has been performed.

Conclusions

The flood warning system is up and operational. The main goals of providing the SES and BOM real time rainfall and water level data have been achieved. This data is also used by Council operational staff and flood engineer. The information from the system is also available to the general public via the BOM web page though this is not in real time is the BOM currently only update rainfall and water level data approximately every 40 minutes, see figure 5 Coffs Flood warning data on BOM web page.

Council has worked closely with the SES in developing the system and the feedback from them has been very positive. The flood warning system has provided the SES with the following advantages: -

- They receive SMS messages when 60mm of rain has been recorded in a 3 hour period giving them a 'heads up' that flooding may occur;
- They have updated their flood intelligence data to match in with the additional real time data now available and can monitor rainfall and flood levels centrally from their local headquarters or remotely from their homes;
- They have found that they are in a much better position to make operational decisions such as when to activate teams and where to concentrate their efforts.

The system is also being extended into other catchments with a rain gauge installed at Woolgoolga and 2 combination rain gauge / water level recorders being installed in the Corindi River catchment. There are still improvements that can be made to the system such as better distribution of the data to the general public incorporating flood awareness and preparedness and if applicable evacuation. Council is also currently undertaking a flood study review for the whole of the Coffs Creek catchment. The review is a 2D Tuflow model and incorporates the detention basins and improved overland flow

path flood modelling. The modelling when completed will also enable Council and the SES to refine the flood intelligence data.

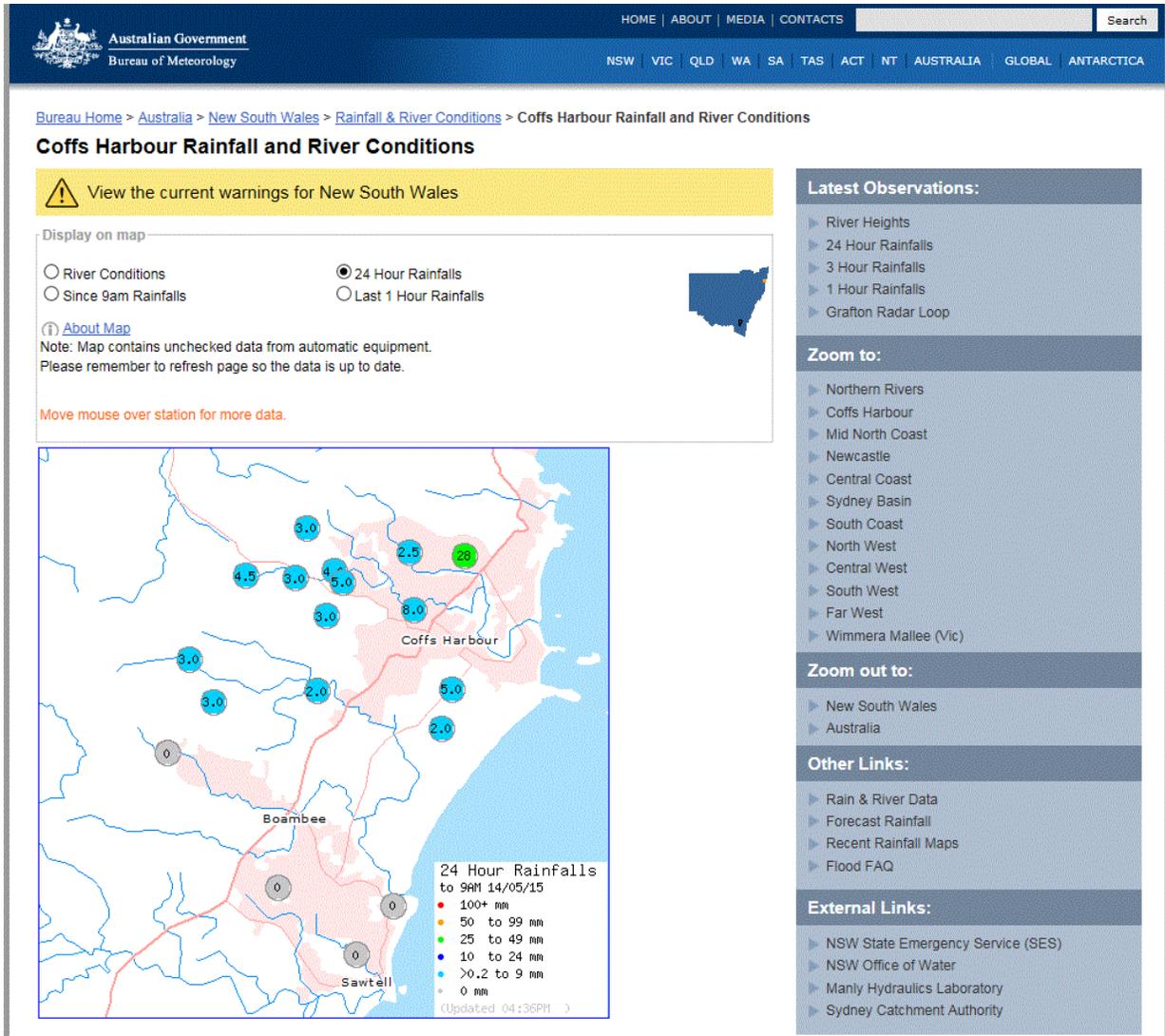


Figure 5 Coffs Flood warning data on BOM web page