

# Integration of Roadway Flood Information into an ITS Traffic Management System – an Example from Queensland, Australia

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## Introduction

In the State of Queensland, Australia, flooding, rather than snow and ice, is the most prominent weather related hazard to impact road users, and figures show that more than half of flood-related deaths in Queensland are a result of driving through floodwater (Department of Transport and Main Roads, 2016a). There is now a concerted effort underway in Queensland to integrate existing and new Roadway Flood Monitoring Stations into the STREAMS Intelligent Transportation System (ITS) Traffic Management System used by the Queensland Government Road Agency. Using a case study Roadway Flood Monitoring System located in the city of Townsville, North Queensland, this paper explores the system architecture behind a STREAMS integrated Roadway Flood Monitoring System, and examines the operational benefits of having real-time roadway flood information available to Traffic Management Centers (TMCs) through an integrated Traffic Management System.

Queensland has over 33,000 kilometres of state-controlled roads which are managed by the Department of Transport and Main Roads. During the 2010/2011 Queensland floods, where 33 flood-related deaths were recorded, many roads became inundated and had to be closed. Based on Department of Transport and Main Roads Guidelines at the time, the road closure process involved the following steps (Queensland Government, 2012):

- the road is assessed by transport department officers or police officers
- after consulting others including the department's website operators, local police and affected residents, the officer closes the road or imposes conditions on access
- road access information is submitted to the transport department and, following an approval process, the road condition is published on the transport department's website.

The same process is also used when roads are reopened.

Following the tragic Queensland flood events of 2010/2011, the Queensland Floods Commission of Inquiry recommended that the Department of Transport and Main Roads, in its capacity as primary provider of information about road conditions to the public, should continue to improve the accuracy of road condition information and the timeliness of its distribution to the public and other agencies (Queensland Government, 2012).

## Automated Road Flood Monitoring Systems

Automated Roadway Flood Monitoring Systems have existed in Queensland for a number of years, but a lack of central governance regarding the specification of such systems has resulted in a range of ad-hoc systems being deployed by hardware integrators, each with their own hardware, communications and software solutions. Whilst these existing in-situ monitoring systems undoubtedly provide valuable information to road authorities and the general public, they typically use proprietary software and communications protocols which have prevented the integration of roadway flood data into an ITS Traffic Management System. Hence, the Department of Transport and Main Roads State-wide TMCs have no visibility of these systems within their ITS software platform, and local councils are typically left having to fund costly ongoing third party software and data hosting fees to maintain such systems at a time of huge cuts to public finance.

In an effort to address such issues, local councils together with the Department of Transport and Main Roads are now making a concerted effort to integrate new and existing Roadway Flood Monitoring Systems into the STREAMS ITS software platform used by the Queensland Government Road Agency. In 2015 the Department of Transport and Main Roads published a new Technical Specification for Roadway Flood Monitoring Systems (MRTS 233), within which the operational requirements for a Roadway Flood Monitoring System specify that the monitoring system shall support remote TMC head end flood height backhaul data within Transport and Main Road's Traffic Management System (STREAMS) to enable departmental operators to centrally monitor Road Flood Monitoring System sites directly via the STREAMS User Interface (Queensland Government, 2015).

## STREAMS Intelligent Transportation System

Most ITS software platforms run on an inter-operability model, where multiple ITS systems work in parallel, each performing a discrete function. As an integration platform, STREAMS provides the ability to integrate both discrete ITS field devices and third party ITS sub-systems together into a single coherent system with a unified User Interface (UI), operational workflow and cross-functional coordination and control capability.

STREAMS' approach to ITS integration utilises a distributed computing architecture (Figure 1) with the following components:

- **Client Workstations** – Rich client UI deployed in the TMC and Engineers offices
- **Application Server(s)** – Central monitoring and control services that coordinate the operations of the system, deployed centrally
- **STREAMS Connect** – Distributed computing layer that provides device abstraction and distributed communications & processing for ITS field devices, deployable both centrally and in the field
- **BI Server** – Data Analytics and warehousing platform, deployed centrally

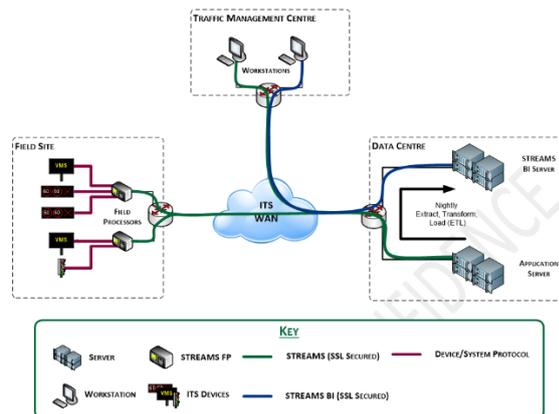


Figure 1: STREAMS distributed computing architecture.

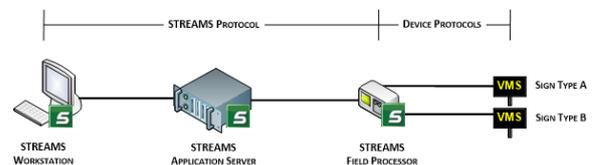


Figure 2: STREAMS Connect Layer

The STREAMS Connect layer (Figure 2) is key to the flexibility of STREAMS for integration of ITS field devices. It supports multiple vendors for devices of a specific type (e.g. weather stations or vehicle detectors) through the use of a device driver model. Vendor specific implementations of a device type are handled in a STREAMS Connect driver and abstracted to a generic device type model for communication back to the Application Server which consumes the generic model's data homogeneously

in its various higher-level functional services. By integrating functions such as traffic signal management, motorway management, road weather information, incident and event management, vehicle priority systems, traveller information, network video management and parking guidance systems into one integrated system, STREAMS offers road authorities a total solution to their ITS needs. It provides significant benefits including:

- synergy between existing systems and equipment – no vendor lock-in
- secure, flexible data communications
- reduced training and resourcing costs associated with a single ITS platform
- optimised road network performance through a single user interface
- cost savings through easy to enter policies and third party interfaces
- modular, scalable architecture facilitating streamlined migrations and system upgrades
- efficient data management

### Case Study – Glendale Drive Roadway Flood Monitoring System

Campbell Scientific Australia were approached by Townsville City Council to provide a non-invasive Roadway Flood Monitoring System with full data integration into the Department of Transport and Main Roads (Northern Region) STREAMS ITS Traffic Management System. The floodway, located in the residential Townsville suburb of Annandale, is a constant flooding hotspot during the Northern wet season when rain waters from the surrounding mountains rapidly fill the tributaries and flood mitigation channels that feed into the Ross River. A risk of flash flooding to motorists exists where roads intersect these channels, and council determined an automated Road Flood Monitoring System integrated into the city's ITS Traffic Management System was required for the Glendale Drive floodway in Annandale.

The Roadway Flood Monitoring System (Figure 3) consists of a 20 Watt solar powered Campbell Scientific CR1000 datalogging system with 12V, 24Ahr power supply, measuring a Campbell Scientific CS475 radar water level

sensor mounted 7.934 metres above the road surface using an 8m ITS traffic pole with radar mounting bracket. The CS475 radar sensor emits short microwave pulses and measures the elapsed time between the emission and return of pulses to calculate the distance between the sensor face and the target surface. The distance value calculated is then compared to a baseline road surface distance measurement, recorded at the time of system installation, to determine water depth. The CR1000 datalogger interrogates the radar sensor for water depth readings every 10 seconds, and passes the measured data through traffic filtering algorithms within the datalogger to prevent false alarming due to vehicles passing under the radar sensor.



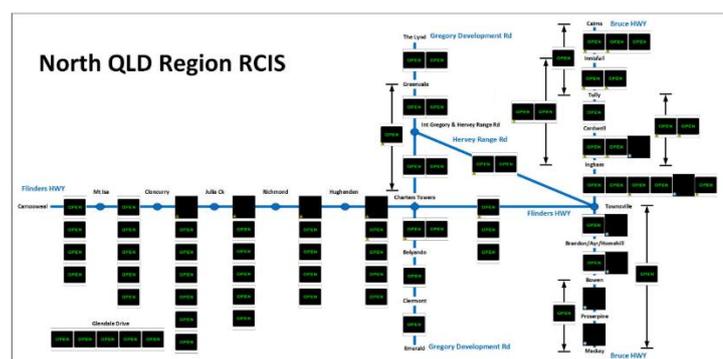
**Figure 3: Radar Roadway Flood Monitoring System installed at the Glendale Drive floodway in Townsville.**

This monitoring system communicates via RF411 radio (922 MHz) to a nearby (< 100m) mains powered Campbell Scientific CR800 datalogger with IP connection into the Department of Transport and Main Roads Private IP network via a Telstra UC-372SP3GE modem. The STREAMS ITS Traffic Management Software communicates with the Campbell Scientific CR800 datalogger via a Communications Processor located within the TMC using the Modbus TCP protocol over port 502. Modbus is a simple and robust openly published and royalty-free protocol which has become a de facto standard communication protocol for connecting industrial electronic devices.

Within the Communications Processor (CP), the STREAMS Connect driver handles the Modbus communication to the CR800 datalogger, polling for water depth and other parameters (e.g. system battery voltage) on a configurable interval. This data is sent in an event driven manner from the CP to the Application Server (AS) and presented to the system as a Simple Device value.

Simple Devices are STREAMS' generic representation of Modbus or PLC style devices where each 'device' has the ability to Read or Read/Write a configurable register and raise alarms. By abstracting to this generic representation, any semantically similar device can be consumed in a consistent manner within STREAMS' response engines, presented on a geographic Map or custom Schematic in the User Interface and monitored for faults in Alarm Manager.

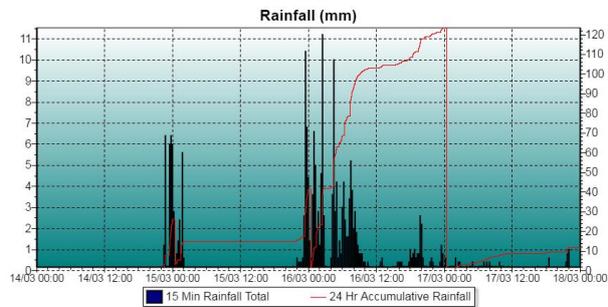
Figure 4 shows a schematic view of the flood monitoring and response deployment used in the Queensland Northern Region TMC. It provides a concise overview all the relevant ITS equipment including roadway flood sensors, IP video cameras and Road Condition Information Signs (RCIS) providing operational awareness of the entire situation. Operators may view video feeds, manually set messages on the signs and initiate automated Response Plans from the schematic. The schematic background and visual representation of the sensor devices are user configurable, with options such as map overlays that provide geolocation of ITS equipment with colour coded road conditions to assist with traffic management operations.



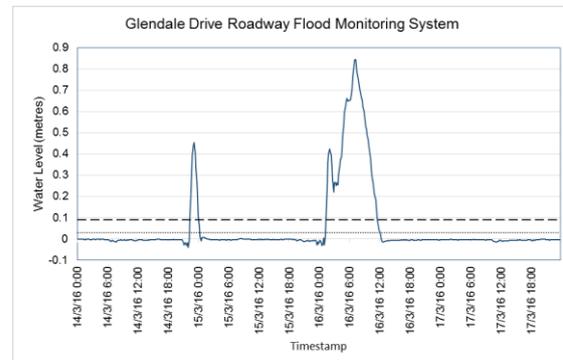
**Figure 4: Example STREAMS user interface for a Roadway Flood Monitoring System.**

## Example Flood Event – 16<sup>th</sup> March 2016

On the 15<sup>th</sup> March 2016 a tropical low located over the Gulf of Carpentaria tracked rapidly east and crossed the western Peninsula coast of North Queensland just below cyclone strength around 4pm local time. The tropical low was attached to a strong upper level trough which funnelled moisture from the main monsoon trough located over North Queensland through to the North East Queensland coast. In the 24 hours that followed, the North East Queensland coast experienced widespread monsoonal rainfall which led to localised flooding in many towns and cities including Townsville where over 120 mm of rainfall was recorded within a 24-hour period (Figure 5).



**Figure 5: Rainfall data (14/03/16 00:00 to 18/03/16 00:00) from a weather station located 5.6 km North West of the Glendale Drive Roadway Flood Monitoring System. Right axis indicates 24 Hour Accumulative Rainfall totals. (Campbell Scientific Australia, 2016).**



**Figure 6: Radar water level data (14/03/16 00:00 to 18/03/16 00:00) measured by the Glendale Drive Roadway Flood Monitoring System.**

Figure 5 shows rainfall data from a Campbell Scientific MET200 weather station located 5.6 km North West of the Glendale Drive floodway, and Figure 6 displays water level data recorded at the floodway during the 16<sup>th</sup> March flood event. The dotted line on Figure 6 indicates the 0.03 m threshold at which the Glendale Drive RCIS automatically displays “Caution”, and the dashed line indicates the 0.09 m “Closed” threshold. The rapid rise in water level just after midnight on 16<sup>th</sup> March illustrates the dangerous nature of flash flooding at these floodways, with the road condition during this flood event rapidly changing from a road “Open” state to a road “Closed” state within just 20 minutes. Within one hour the water level during this flood event increased from 0 to 0.4 m, with a maximum level of 0.85 m recorded at 07:10am.

## Benefits of an ITS Integrated Road Flood Monitoring System

The Glendale Drive Roadway Flood Monitoring System is the first in Queensland to be integrated into the State-wide STREAMS ITS software platform using a non-proprietary open communications protocol instead of a vendor specific implementation. The system has set a precedent upon which other ‘hotspot’ floodway locations around the state are now being reviewed. For the first time TMCs have the systems available to provide full visibility of roadway flood conditions, which can be automatically responded to through their ITS Traffic Management software.

Real-time delivery of water level data from roadway flooding hotspots into an ITS Traffic Management System ensures the timely distribution of road condition information to commuters as recommended by the Queensland Floods Commission of Inquiry. Indeed, the quick distribution of flood information is critical in deterring commuters from making the wrong decisions when confronted with a flooded roadway and driving through potentially hazardous flood waters.

Road authorities now have the systems and technology available within a common ITS platform to confidently move towards a policy of automated road closures during flood events, without the delays and costly overheads associated with manual site inspections. In locations where road authorities continue to conduct manual on-site visual inspections prior to any road closure, the timeliness of these road closures can now be optimised since the STREAMS ITS platform is monitored 24-hours by the Department of Transport and Mains Roads TMCs. In these instances, RCIS can be automatically activated through STREAMS (based on water level data) to provide a “Caution” warning to commuters prior to any manual road “Closed” state being activated by a TMC operator. Likewise, once flood waters have receded STREAMS now has the real-time water level information available to notify engineers in a timely manner of when to perform structural inspections of roadways and bridges prior to their reopening (Department of Transport and Main Roads, 2016b). Without this information, structural inspection teams are often on standby for many hours, undertaking multiple visits to site until flood waters have receded to a level which enables full inspection of critical structures such as the road surface and bridge abutments. These

improvements in operational efficiency can now allow roads and bridges affected by flooding to be reopened to traffic in a timely manner to minimise inconvenience to commuters, without compromising safety standards.

## Summary

The integration of roadway flood information into an active ITS Traffic Management System (STREAMS), using an industry standard communications protocol, provides significant operational benefits to road authorities. Local councils and the Department of Transport and Main Roads are no longer locked to specific hardware vendors when sourcing road weather monitoring systems. The ability to integrate road condition information into a single, modular and scalable ITS platform used by TMCs, enables optimised road network performance and future costs savings through reduced training and resourcing costs, and efficient data management. The Glendale Drive floodway in Townsville, North Queensland, has provided a case study of a Roadway Flood Monitoring System with a non-proprietary communications interface into the STREAMS ITS Traffic Management System. This system has set a precedent upon which other roadway flood locations around the State of Queensland are now be reviewed, and a larger scale role out of such systems is anticipated over the coming months and years.

Whilst this paper has focused on Roadway Flood Monitoring Systems, the same core hardware and network infrastructure can be (and is being) used to integrate more “traditional” road weather data into STREAMS. A recently installed Campbell Scientific environmental monitoring system in Cardwell, North Queensland, provides visibility, rainfall, wind speed and wind direction data directly into STREAMS to assist in warning commuters of hazardous driving conditions over the Cardwell mountain range via VMS. In more southerly States with colder winter climates, road weather information such as snow and ice detection and surface friction data can be integrated into STREAMS using the same core hardware and system architecture described in this paper, allowing TMCs to monitor and control winter road maintenance with their other ITS assets as a fully coordinated traffic management response.

Whilst the operational benefits of traditional Road Weather Information Systems in many Northern Hemisphere countries are well documented, the benefits from integrating road weather information into State-wide ITS Traffic Management Systems in Australia are only just starting to be fully realised. It is envisaged that further collaboration between the Department of Transport and Main Roads, Transmax Pty Ltd (as the developer of STREAMS) hardware vendors and the Australian Bureau of Meteorology (BoM) can result in the addition of data from thousands of existing ALERT river gauging stations around Australia into the STREAMS ITS Traffic Management System. The integration of rainfall and water level data from these ALERT stations into STREAMS could be of great benefit to TMCs, providing additional data from upstream locations to enable the forecasting of road floodway closures and the subsequent re-routing of traffic prior to a flood event occurring. This type of “meteorologically optimised” road network performance, once realised, could further help in preventing a repeat of the tragic roadway flood events experienced in 2010/2011 in Queensland.

An extended version of this paper is available at the following web address:

[https://s.campbellsci.com/documents/au/technical-papers/road\\_flood\\_monitoring\\_systems.pdf](https://s.campbellsci.com/documents/au/technical-papers/road_flood_monitoring_systems.pdf)

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