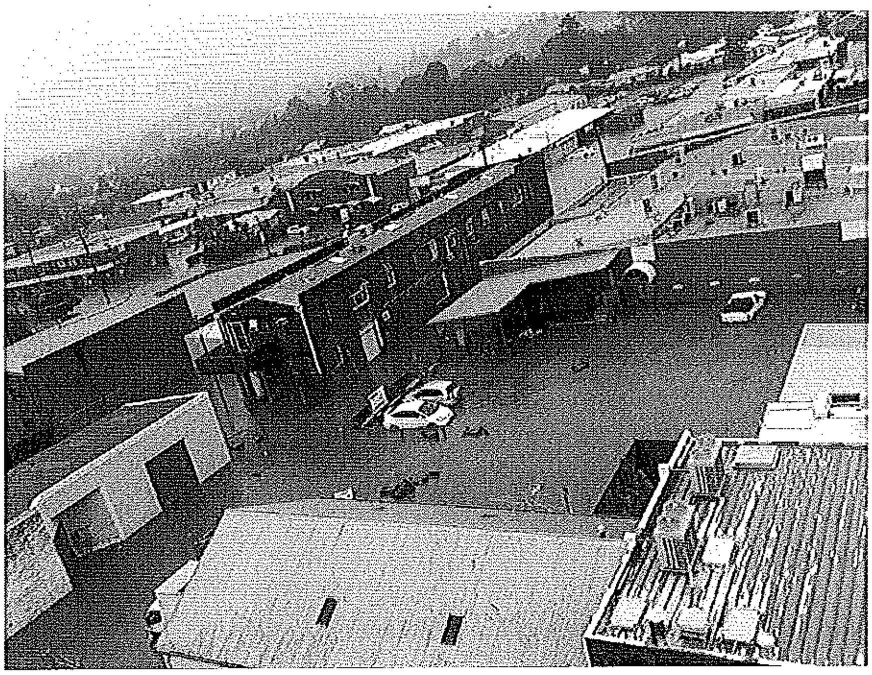
Submission to the Flood Commission



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April 6, 2011

1. Executive Summary

The aim of this submission is to share valuable information relating to flood forecasting and warning -specifically the essential system components and engineering required to deliver accurate and reliable flood forecasts to support the activation of warning systems and making tactical decisions in real time.

The information contained within this document is based on the authors (*bio: Attachment 1*) more than 30 years of expertise gained designing and installing such systems in Australia and abroad:

- China – Yangtze Three Gorges Dam System
- Indonesia – Jakarta, South Java, North and Central Sumatera Systems
- Iran – Karun River, Khuzestan
- Malaysia - Kuala Lumpur SMART
- Oman - Muscat
- Philippines – San Roque, PAGASA

(refer to Attachment 2:for further information).

Discussion regarding the use of forecast enhancement tools such as rainfall estimation from weather satellites/ radar systems has not been included as the focus of this document is on the establishment of ground based systems and associated systems.

1.1 Australian Experience

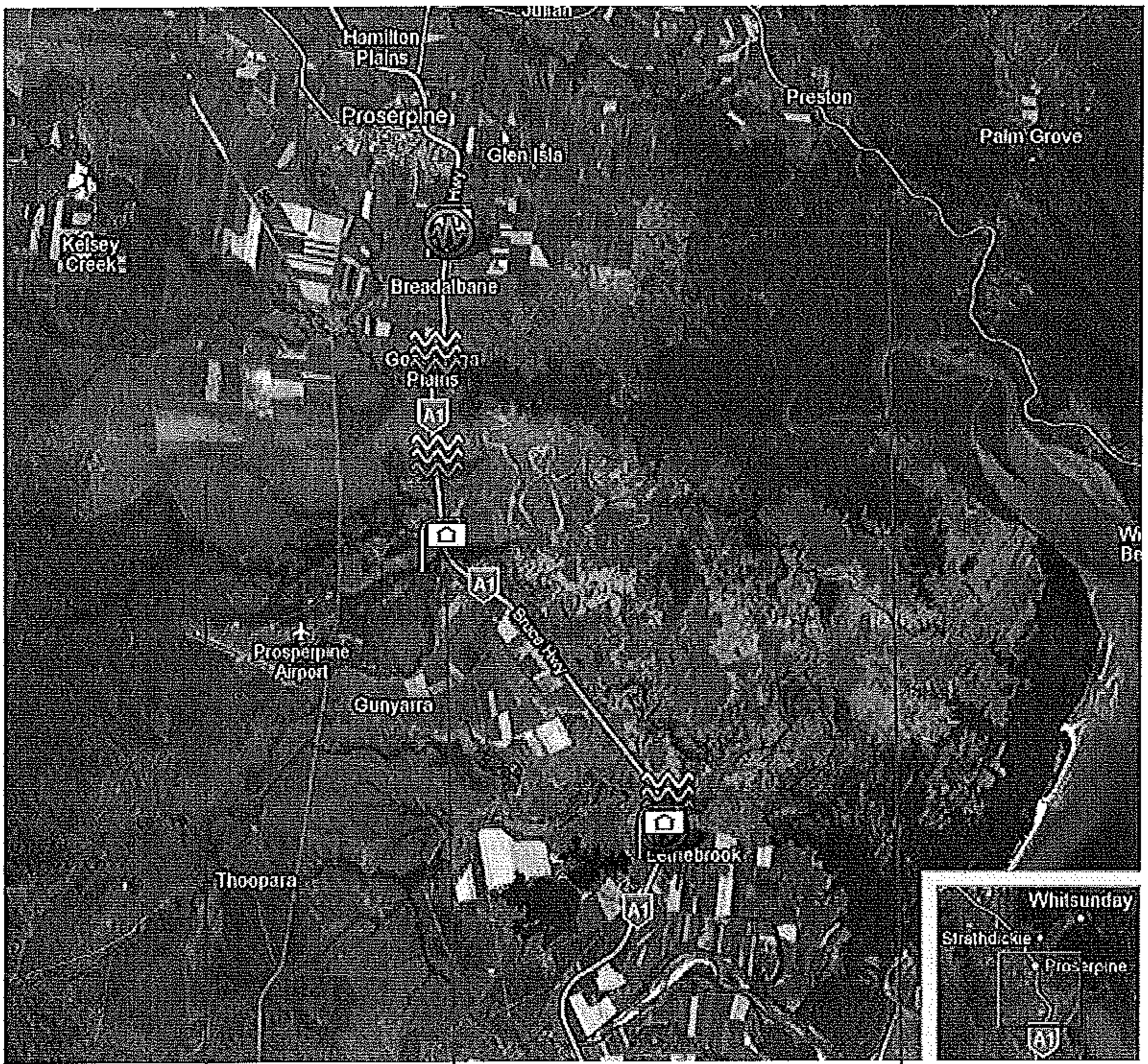
Within NSW Greenspan has worked on the: Kempsey, Scone, Nambucca, Hastings, and Tenterfield Flood Warning Systems. Within Queensland we have installed more than 1000 flood warning and catchment monitoring stations for Councils, Mining Consortia and Government Authorities including:

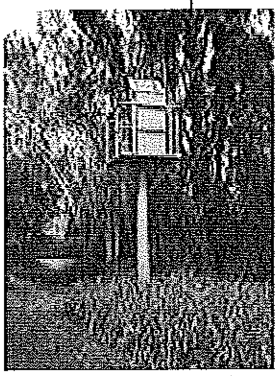
- Emerald
- Barcaldine
- Moreton Bay
- Sunshine Coast
- Isaac
- Southern Downs
- Cairns
- DERM
- Queensland Main Roads
- Intergen
- Others directly for the BoM
- SEQW - Catchments
- EPA

1.2 Signature Projects

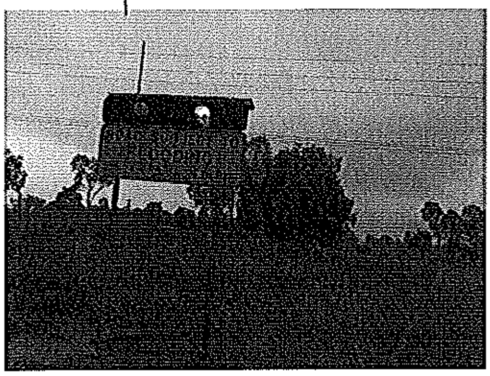
Queensland Main Roads – Bruce Highway Flood Protection System

Greenspan in conjunction with Queensland Main Roads have designed and installed a $0.5m flood warning system for the Bruce Highway South of Proserpine. This system monitors water levels at three locations (creeks that flow under the highway) to determine if flooding is likely. Data is available to QMR and the SES via Greenspan's web based ENVAULT system plus via radio to QMR. Warning signs at the northern and southern ends of the highway (15km apart) and on the airport link road are automatically activated to warn motorists of flooding. This system has been operating since 2010 and helped to ensure that motorists were not endangering their lives and the lives of their passengers and others! Flood Warning is not just about protecting towns and cities, it is all encompassing and extends to highways and roads, buildings etc.

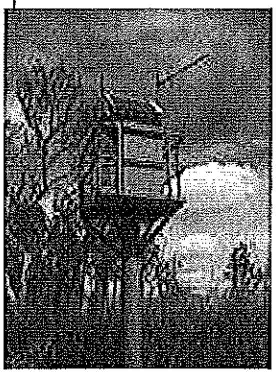




Water Level Monitoring Station



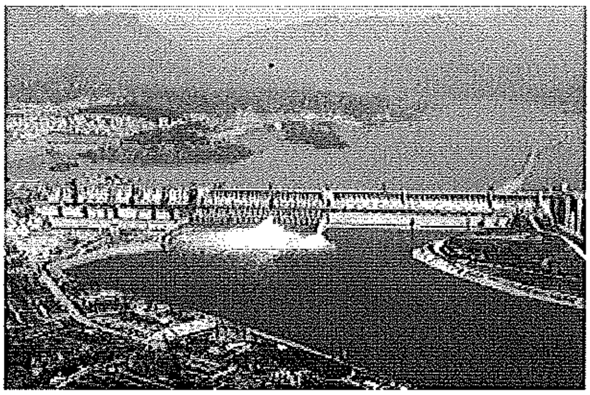
Warning Sign



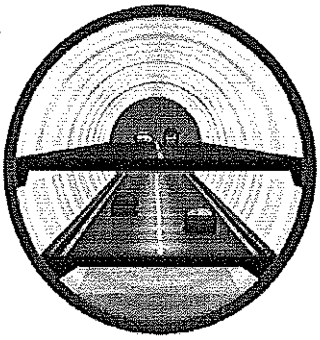
Control Station

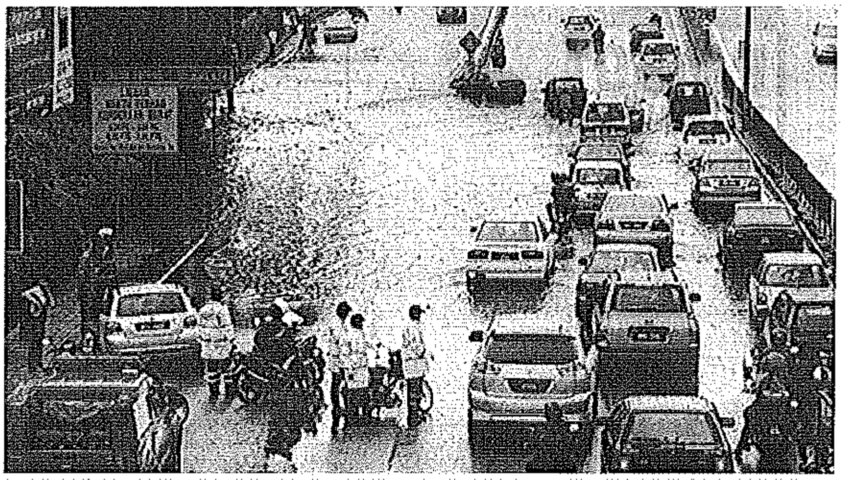
Images on this page: QMR Flood Warning – Bruce Highway Proserpine

The *Yangtze Three Gorges Dam System* was designed by Greenspan in 2001 with work completed in 2003. The system reportedly helping to save more than 1 million lives just 1 week after commissioning and involving the design of monitoring and communication systems for more than 300 locations along more than 2000km of the Yangtze River.



The *Kuala Lumpur SMART Flood Forecasting, Warning and Stormwater Diversion System* was designed by Greenspan in 2005 and is considered to be the most advanced system of its type in the world (*). The Greenspan designed system is critical for the operation of the SMART Tunnel (as seen on Discovery Channel and National Geographic) which protects Kuala Lumpur from flash flooding. The SMART Project secured the prestigious British Construction Industry Award for Best International Project (2008) (*Attachment 3*) amongst many other awards.





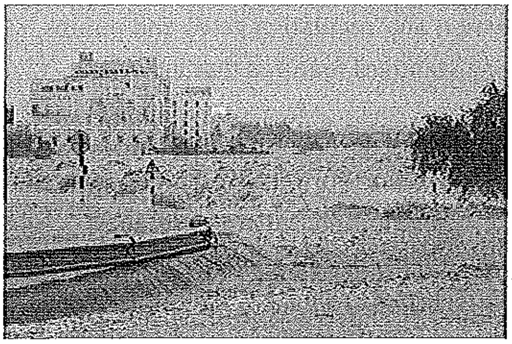
SMART Tunnel helped divert flood

(*): http://www.youtube.com/watch?v=XfdTcyP6WLE&feature=related)

The design of the SMART Flood Forecasting and Warning System was undertaken by a Technical Committee comprising of Mark Wolf and his Greenspan Engineers, Senior Engineers from the Department of Irrigation and Drainage - Malaysia, Consultants (SSP and DNA of Malaysia) and representatives of the Tunnel Builder: Mott McDonald-Gamuda.

In order to ensure that the system would not fail and would provide accurate and reliable forecasts the world's best technology was chosen for each and every component of the scheme. Greenspan drew on its many years of expertise and experience designing flood warning systems in remote and hazardous locations including: the Sumatran jungles of Indonesia, the Zagros Mountains of Iran, the Wadi's of Oman and the Yangtze River in China.

Yangtze River in Flood



Flooding in Muscat - Oman

The SMART system was completed in June 2007 and since that time has successfully forecast more than 100 floods and saved the city from major flooding on a number of occasions. It has never failed despite experiencing all of the extreme weather conditions typical of a tropical location. The cost of close to A$1b being easily justified when taking into consideration that a major flood costs the community close to A$300m (the impact on GDP, damage to property and infrastructure and clean-up costs). The Government of Malaysia is more than satisfied with Greenspan's design (*Attachment 4*).

More recently Coffs Harbour City Council engaged Greenspan to develop a concept design for the Coffs Harbour Flash Flood Forecasting and Warning System. The concept design is closely based on the Kuala Lumpur SMART system (minus the tunnel!!).

2. Successful Flood Forecasting and Warning Systems

Local and international press releases regularly report on the failure of Flood Forecasting and Warning Systems throughout the world (but of course do not report when a system has functioned as intended)!

Before we examine why, first let's ensure there is an understanding of the systems used within Australia and specifically Queensland.

2.1 Australian Flood Forecasting and Warning Systems

Flood Forecasting and Warning Systems within Australia are either:

ALERT based and to a much lesser extent SCADA based.

ALERT based systems are installed by the Bureau of Meteorology for the purpose of obtaining near real time rainfall and water level data. The ALERT system is a simplex event reporting system (using VHF radio communications). It has been the BoM standard since the early 1990's.

SCADA based systems are used when control is required. Control means that base station software not only collects data from the remote field devices (as opposed to the remote field station in an ALERT system sending in its data) but can also control equipment such as warning sirens, stormwater diversion and regulating gates and pumps. SCADA systems utilise software that is industrial strength having standard features that include:

- Data security via encryption
- Support for triple redundant servers
- Distributed Network Protocols
- Highly developed historians
- Trending of every measured and derived variables
- Alarm options
- Error detection
- Auto remote field device clock synchronisation
- Auto database backfilling

SCADA based Flood Forecasting and Warning Systems are few and far between in Australia while throughout Asia, the Middle East and Europe they are the preferred technology.

Greenspan installed a SCADA based system at Tenterfield NSW in 2001. There are also other similar systems installed for the purpose of warning inhabitants downstream of dams which are required as part of dam safety operations.

2.2 Why do Flood Forecasting and Warning Systems Fail?

We have two functions here:

i) Forecasting
ii) Warning

2.2.1 Flood Forecasting Systems

The flood forecast is generally derived from a computer model or algorithm developed for a catchment or sub catchment and will either provide a classified warning for a river system (in the case of the BoM forecasts) or if a purpose built system (such as KL SMART) the computer models will forecast levels at critical locations throughout the catchment focusing on hot spots within populated areas.

For the forecast to be accurate and reliable sufficient data of high quality must be regularly received from the remote monitoring stations to the base station in near real time.

In addition there must be sufficient data collecting points (rainfall and water level recording and reporting stations throughout the catchment). If there are hydraulic structures within the catchment (such as a storage dam, detention or retention basins) the operating rules relating to these must be included in the model(s) and there must be sufficient monitoring stations upstream of the structure to accurately forecast the inflow, rate of rise, monitoring of spillway gate positions for discharge calculations and of course accurate measurement of water levels within the ponding areas.

So why do Flood Forecasting Systems Fail (that is they do not accurately forecast the inflow to a dam (if applicable) and the level and extent of flooding in the flood prone areas).

i) The remote monitoring stations fail
   a. Power supply inadequate
   b. Damage to instrumentation
   c. Vandalism
   d. Not properly maintained
   e. Damage as a result of flood debri

ii) The communication systems fail
   a. Power supply inadequate
   b. Lightning or transience damage
   c. Poorly maintained equipment
   d. Overload due to too many transmissions

iii) The base station fails
   a. Loss of power and UPS inadequate
   b. Damage due to flood, earthquake, Act of God
   c. Cyber terrorism
   d. Staff negligence – virus brought in via a USB stick etc
   e. Equipment not upgraded as required
   f. Server fails and no redundancy
   g. Other equipment fails and no redundancy

iv) The number of monitoring stations is inadequate
   a. Reported accumulated rainfalls within the catchment are not a true representation of average catchment rainfall
   b. River monitoring stations (level and velocity) are insufficient in the upper catchment and therefore do not provide the quantity of quality data required to provide early warning
   c. Velocity monitoring stations are not installed and therefore the river flow data is purely based on the rating curves (which rarely take into account hysteresis effects)

v) Operating rules are not obeyed by Dam Operators
   a. Perhaps more common in developing nations where operators take on their own set of rules based on the actual rate of rise in the pond but not taking into account the catchment conditions

vi) The data is poor quality
   a. Monitoring stations are not correctly located or site conditions have changed since the station was first installed
   b. Sensors have not been properly maintained and are no longer in calibration

c. Communication paths have deteriorated and not all data is being received or is corrupted
d. Rating curves are not up to date and the conversion of water level to a discharge produces an over or under derived flow rate

vii) Systematic and Random Errors reduce the quality and accuracy of the incoming data
a. Systematic errors can relate to clock drift at the remote station (this occurs when the data logger clocks are not synchronised to a master clock
b. Instruments have drifted out of calibration
c. Instruments have not been maintained

viii) Calculated river flows are inaccurate due to poorly maintained rating curves
a. In many cases it is not possible to obtain high flow measurements and therefore rating curves are extrapolated in the mid to high range flows

ix) Computer models not recalibrated as catchment or hydraulic structure characteristics/operating rules change

2.2.2 Warning Systems

Public Warning is currently provided using the following mechanisms:

i) Audible public warnings – sirens, loudspeaker system
ii) Audible and visual alert enunciators within a home or building triggered by SCADA
iii) SMS
iv) Email
v) Telephone
vi) Door knocking

Causes of failure include:

i) Audible public warnings – sirens, loudspeaker system
a) Power supply failure
b) Component failure
c) Vandalism/theft
d) Communications system failure

ii) Audible and visual alert enunciators within a home or building triggered by SCADA
a) Power supply failure
b) Component failure

iii) SMS
a) System overloaded
b) Communications tower failure

iv) Email

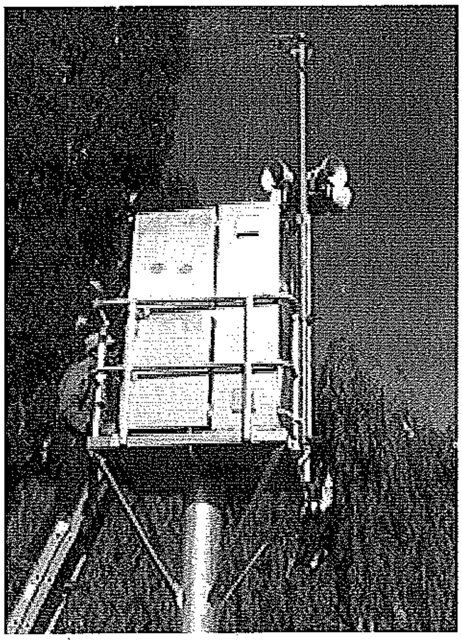
a) IT system failure

v) Telephone

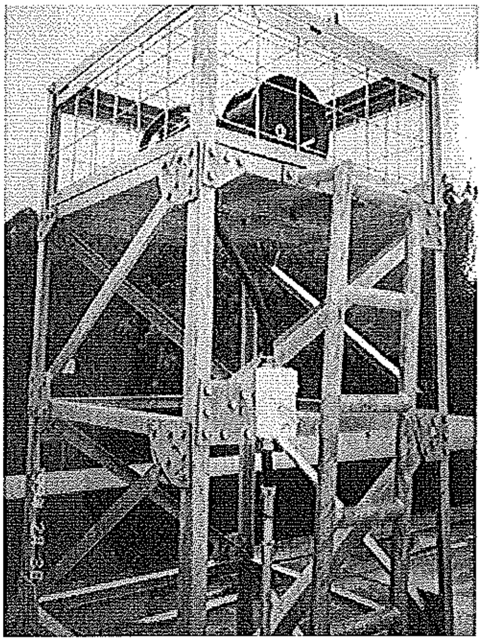
a) Damaged exchange or phone lines

vi) Door knocking

a) Unable to access the sites

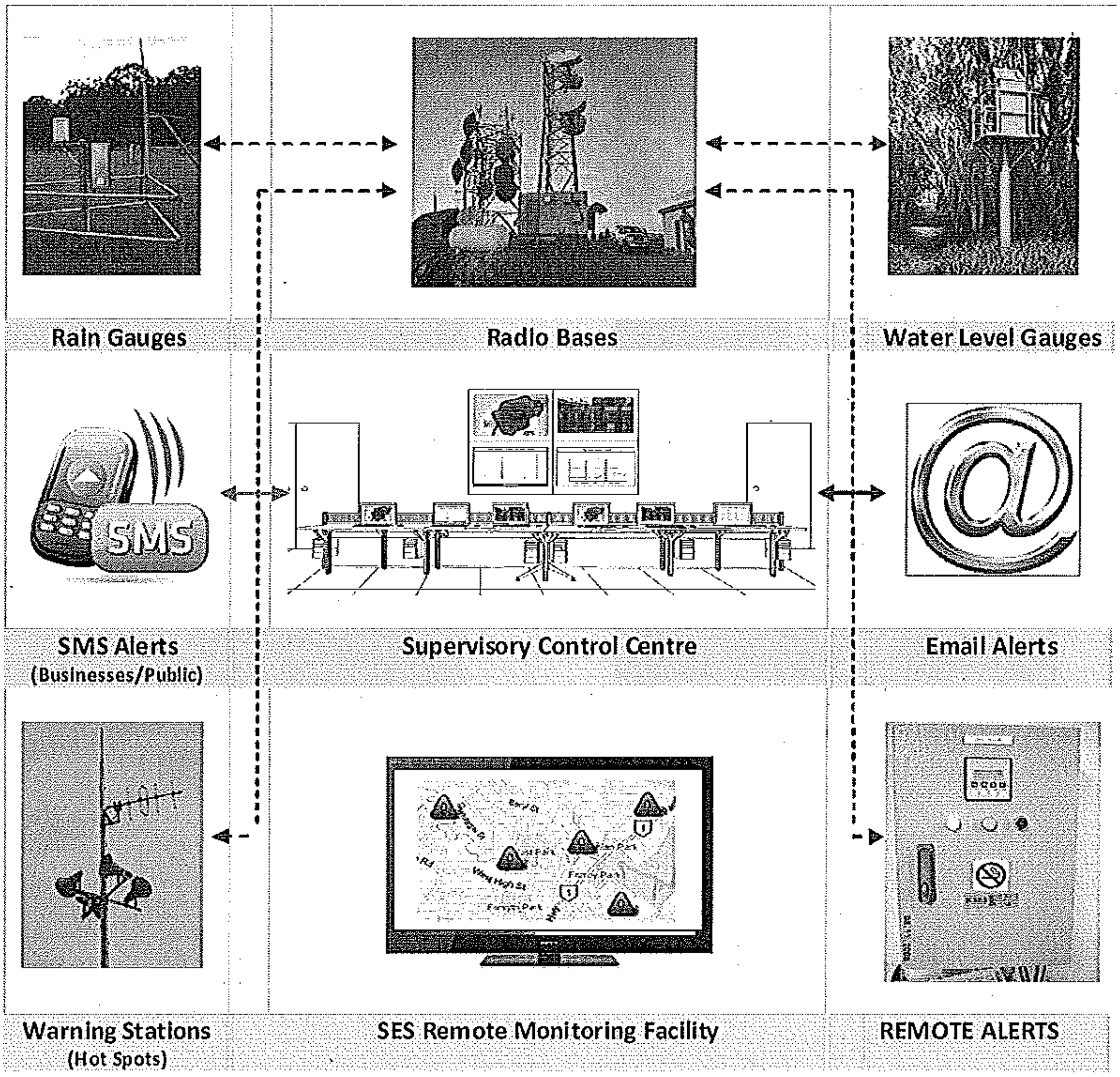


Loudspeaker based Warning Station (Tenterfield, NSW)



Siren based Warning Station (Kuala Lumpur, Malaysia)

2.3 Essential Elements of a Highly Reliable and Robust Flood Forecasting and Warning System



Experience has taught us that the essential elements for an effective flood forecasting and warning system that will operate with uptime of better than 99.9% will be as follows:

2.3.1 Remote Monitoring Stations

The remote monitoring stations must be designed fit for purpose with:

i) High quality instrumentation
ii) Robust signal processing and data logging equipment
iii) At least 2 means of communications (primary and backup)
iv) Incoming signal lines fitted with transient barriers

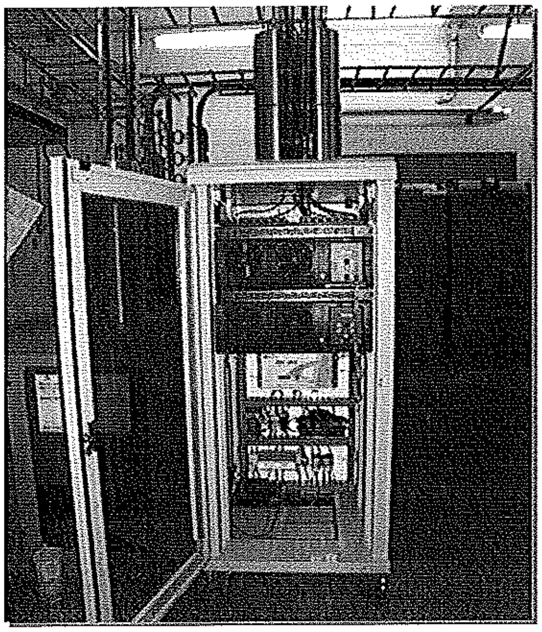
v) Rainfall gauges having 0.5mm bucket size
vi) Water level gauges being gas purge (compressor or nitrogen gas type) or shaft encoder and float system for existing sites
vii) 30 sunless days battery capacity (solar only powered sites otherwise 10 days)
viii) Security switch on the cabinet door
ix) For flash flood systems 1 minute data logging interval
x) For other systems 5, 10 or 15 minute data logging intervals
xi) Secure building or structure to house the equipment (must be vandal proof)
xii) Grounding system impedance of <10 Ohm
xiii) Security fence
xiv) Structures must be in suited to local conditions including ensuring that the floor or base is well above the PMF level
xv) Regular routine maintenance including cleaning of rain gauges, check of the calibration of all instrumentation, adjustments as necessary, survey of river cross sections, flow gauging, rating curve maintenance, cleaning of solar panels, gauge plates, if radio is used annual check of radio fade margin and adjustment replacement of parts as necessary
xvi) Refurbishment of stations as required (instrumentation etc)

At key water level gauging stations the installation of Doppler current meter devices (in-stream) or alternatively radar velocity devices (attached to a bridge or structure) should be considered.

2.3.2 Communications Systems

Flood warning systems must be built not to fail. Reliance on public infrastructure for communications should be avoided. Wherever possible the use of radio communications or satellite communications should be used with backup provided by Telco's (if available).

VHF radio is best for flood warning, repeater stations however are required and they must of course be well maintained.



Redundant Radio Repeater Station featuring full diagnostics, signal filtering and redundant power supplies

Radio repeaters should be able to output up to 25Watts and have a main and standby transceiver (a redundant pair), in more advanced systems a third radio is used to confirm station operations. Power supplies must be such that the station can operate for 30 sunless days if AC power and a back-up generator are not installed on site. A local RTU monitors the status of the radio transceivers and automatically manages the duty cycles of the transceivers and advises the SCADA of any alarm conditions at the site and with the equipment.

The communications protocol should be robust and reliable, modern systems now operate using protocols that comply with IEEE standards. One such protocol is DNP3. DNP3 has excellent features well suited for flood forecasting systems:

- Auto backfilling of the database in the event of a communications glitch
- Auto clock synchronisation
- Supports distributed networks
- Has a high level of security for the data
- Is supported by all reputable suppliers of measurement and control equipment

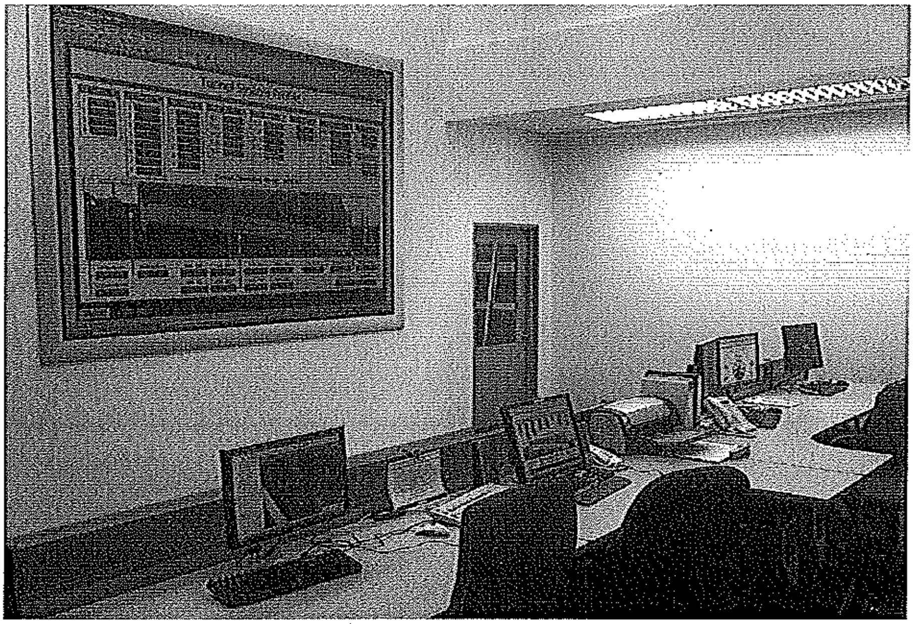
2.3.3 Supervisory Control Centre

The Supervisory Control Centre (SCC) should be purpose built and manned 24/7. All communication devices should be redundant, the servers at least redundant and as required triple redundant. A Disaster Recovery Centre is a necessity for larger systems and be connected to the Main Control Centre by a least 2 means of communications (fibre, leased line, microwave etc).

2.3.3.1 Control Centre Hardware

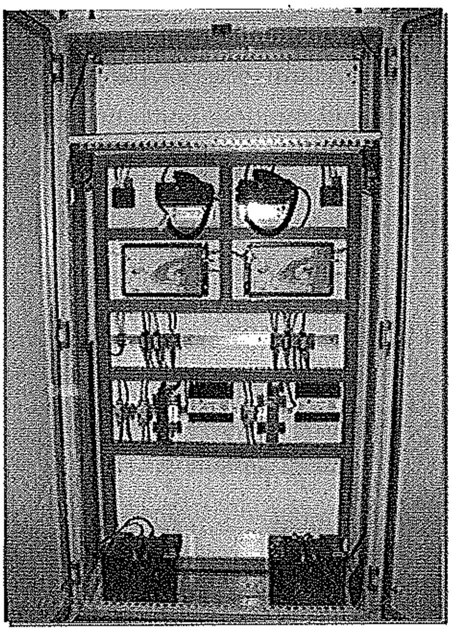
A video wall (2 x 2 x 67" panels) should be standard for larger systems.

All equipment in the field and the SCC should be managed by the one organisation to ensure that there is no blaming between organisations for failure of components.

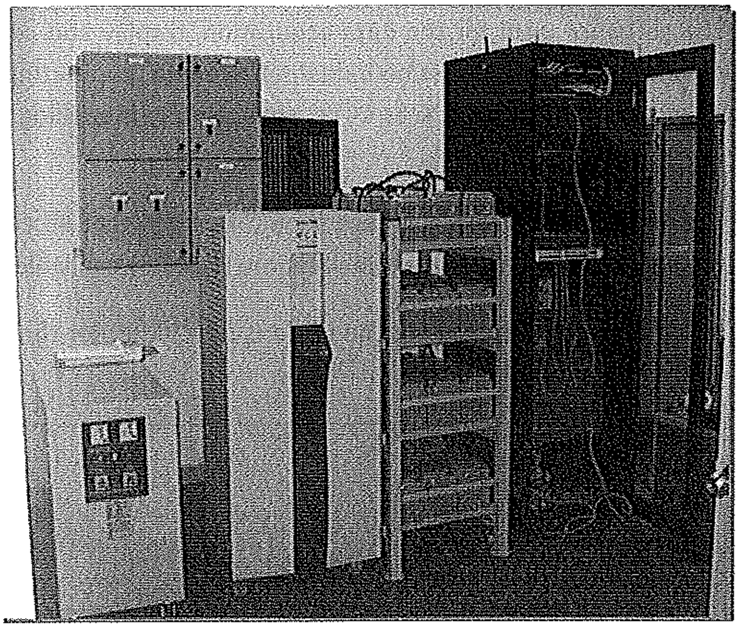


A modern Control Centre

Redundant Communications and back-up power supply systems are essential.

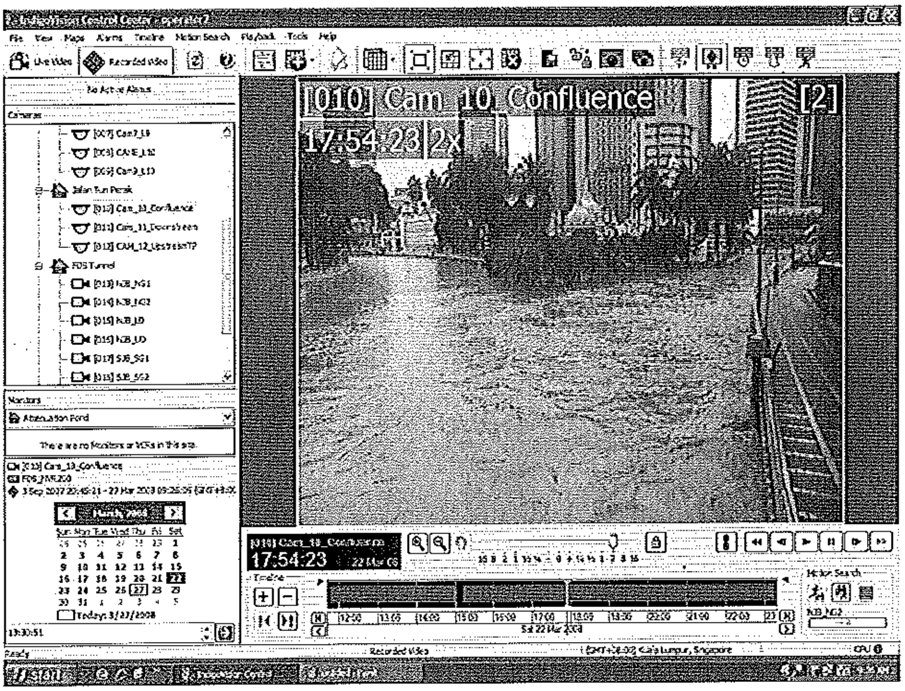


Redundant Base Station Communications Equipment (VHF radio and GSM)



Power supply, UPS

For larger systems the use of CCTV cameras to observe spillway gates, critical locations in towns and cities, causeways, flood gauges etc are recommended.

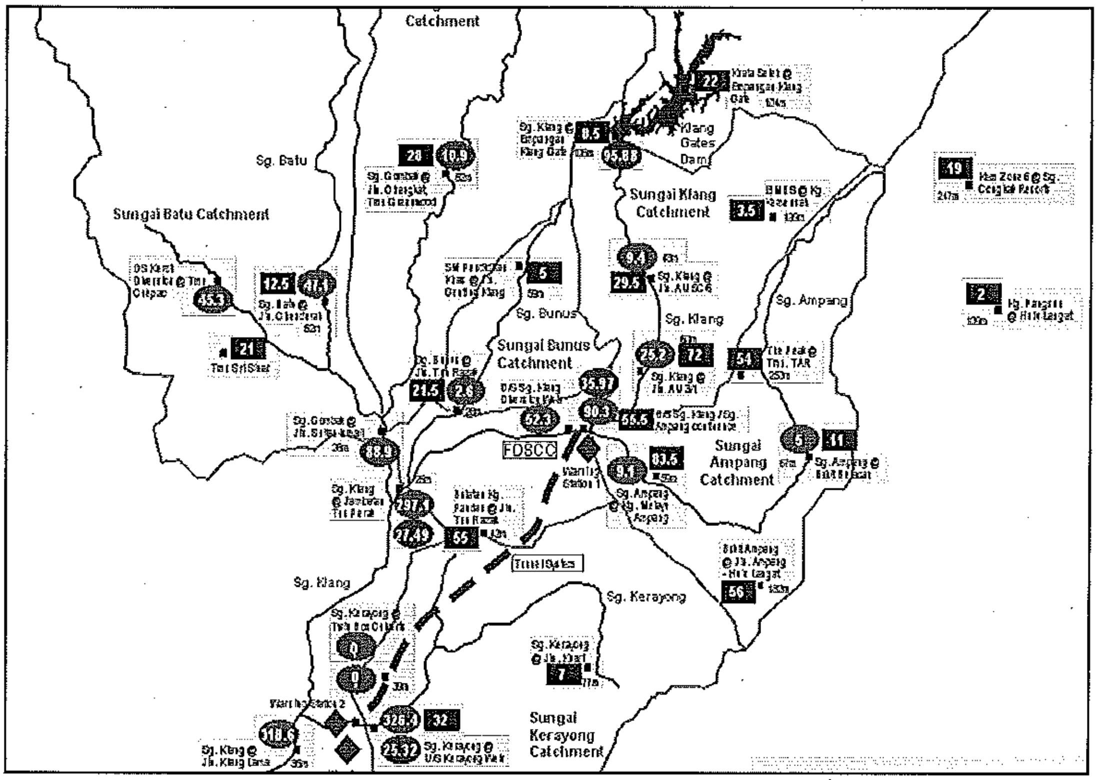


2.3.3.2 Software

The software used for the data acquisition, display and control of warning stations and gates and pumps (if included) must be industrial strength, supporting triple redundant servers, able to easily interface to databases, GIS, CCTV applications, modelling packages and multiple communications systems.

The graphical user environment should be such that all information that will enable strategic and tactical decisions to be made in real time is readily available.

Just a very small number of the screens developed for the Kuala Lumpur SMART system are shown below:

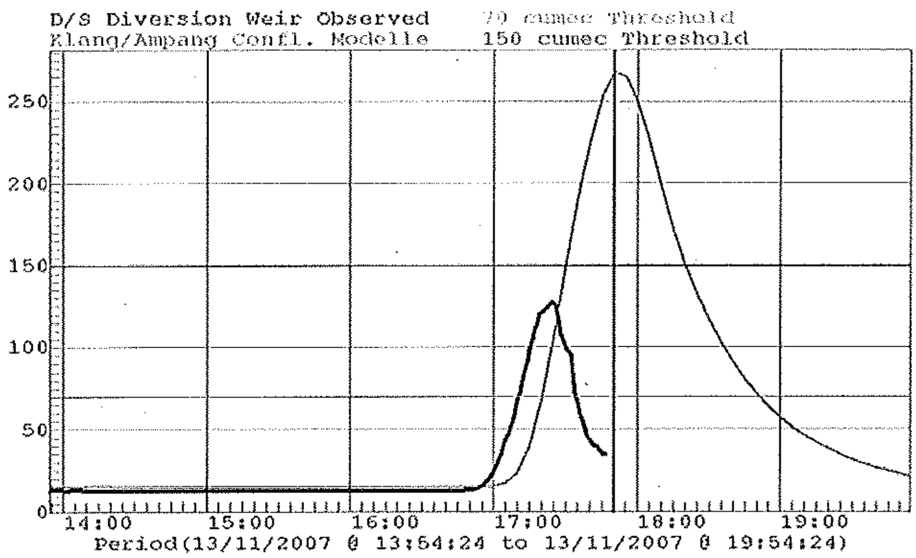


Legend:
Green background: Stormwater flow rates (m3/s)
Blue background: Rainfall totals (last 30 minutes)
Magenta background: Critical Water Levels (m)

The outline above is of the Klang Basin in Malaysia

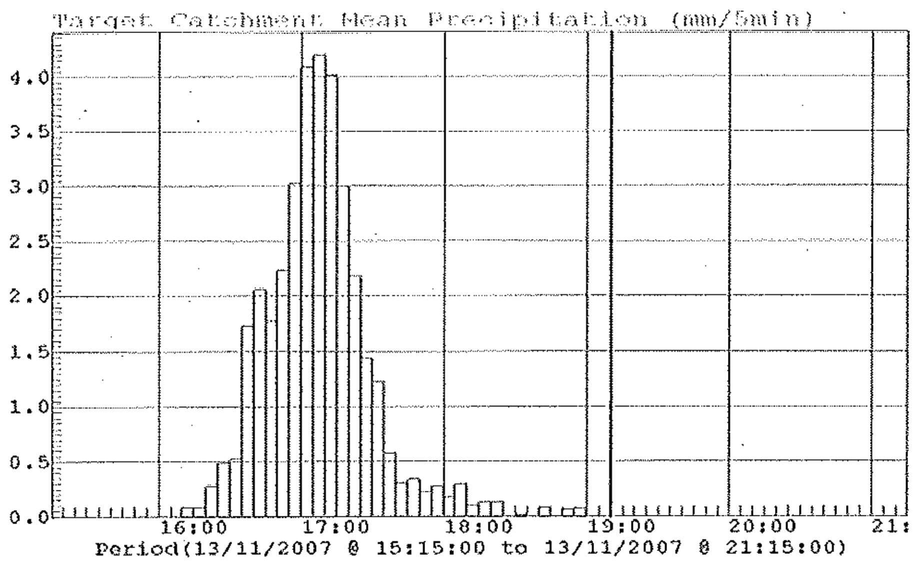
The screen shots below (Flow Forecast, Average Catchment Rainfall and Level Forecast - p15 & 16) are produced by hydrological rainfall routing and hydraulic computer models.

D/S Diversion Weir Flow Forecast

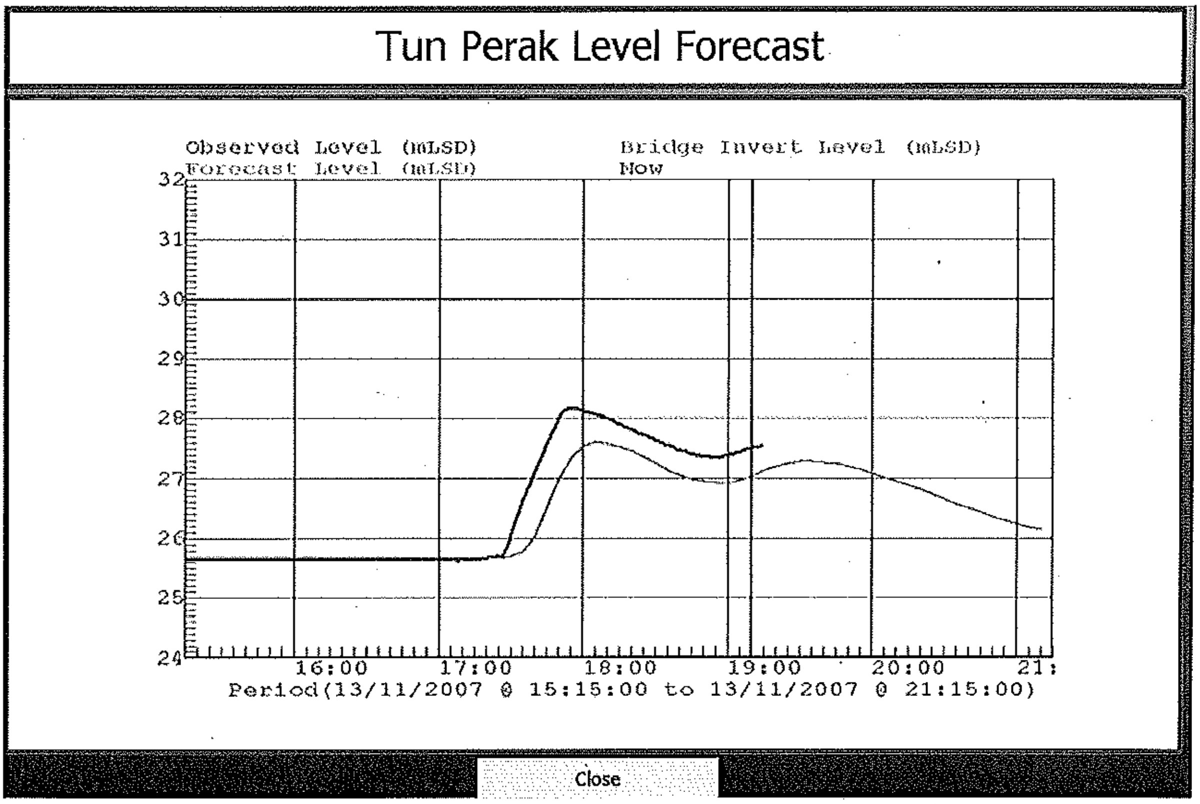


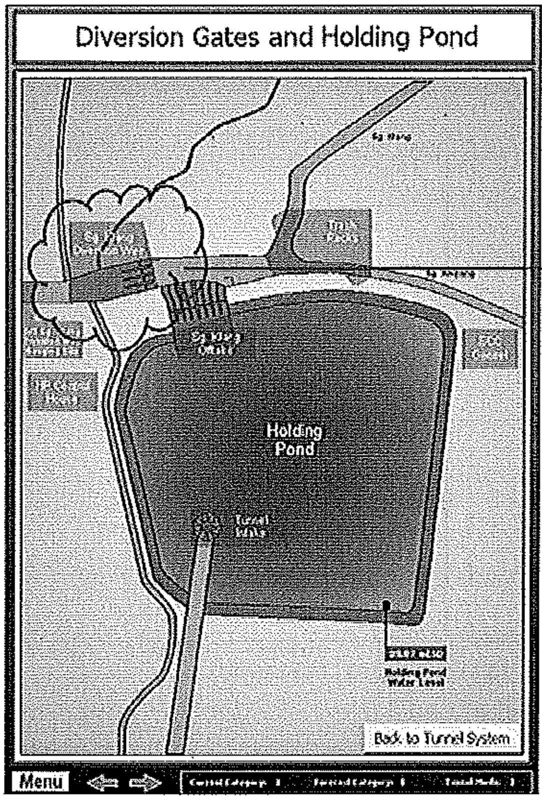
Close

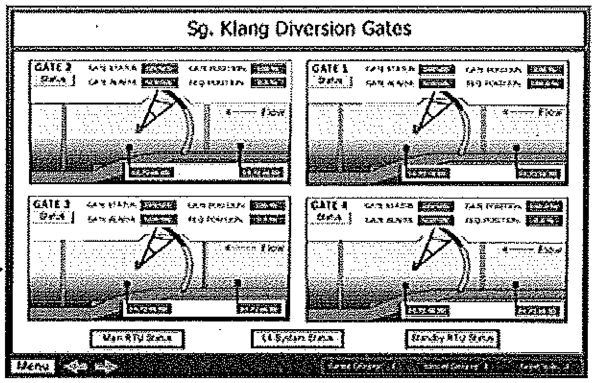
Klang-Ampang Average Catchment Rainfall

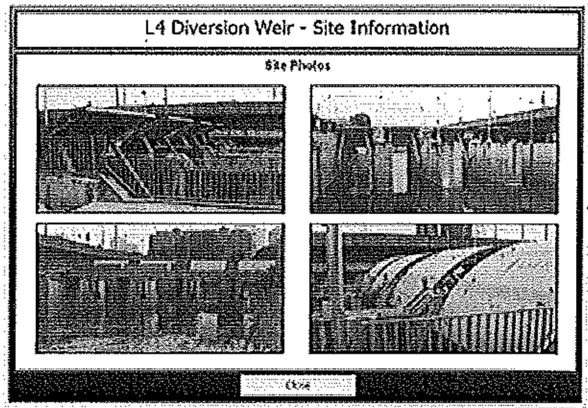


Close





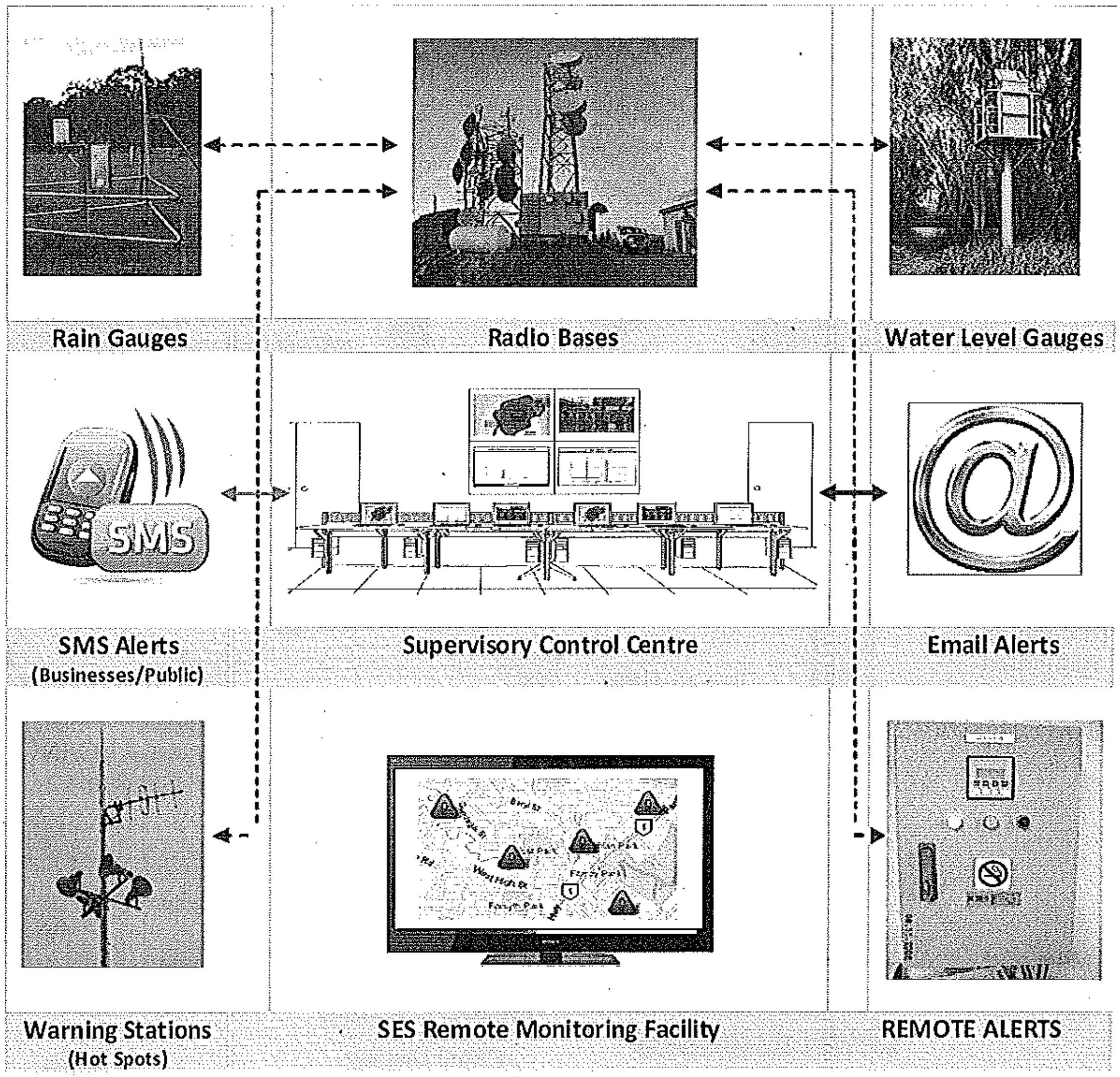




The SCADA System allows for monitoring and control of gate systems critical for the protection of Kuala Lumpur, the Operators can easily confirm via the CCTV system that the gates have closed!

The software must also support the issuing of alerts via SMS and email plus be able to operate Warning Stations in both Automatic and Manual Modes.

Access to data by agencies including the SES should be possible with communication secure (fibre, leased line, radio) and with backup.

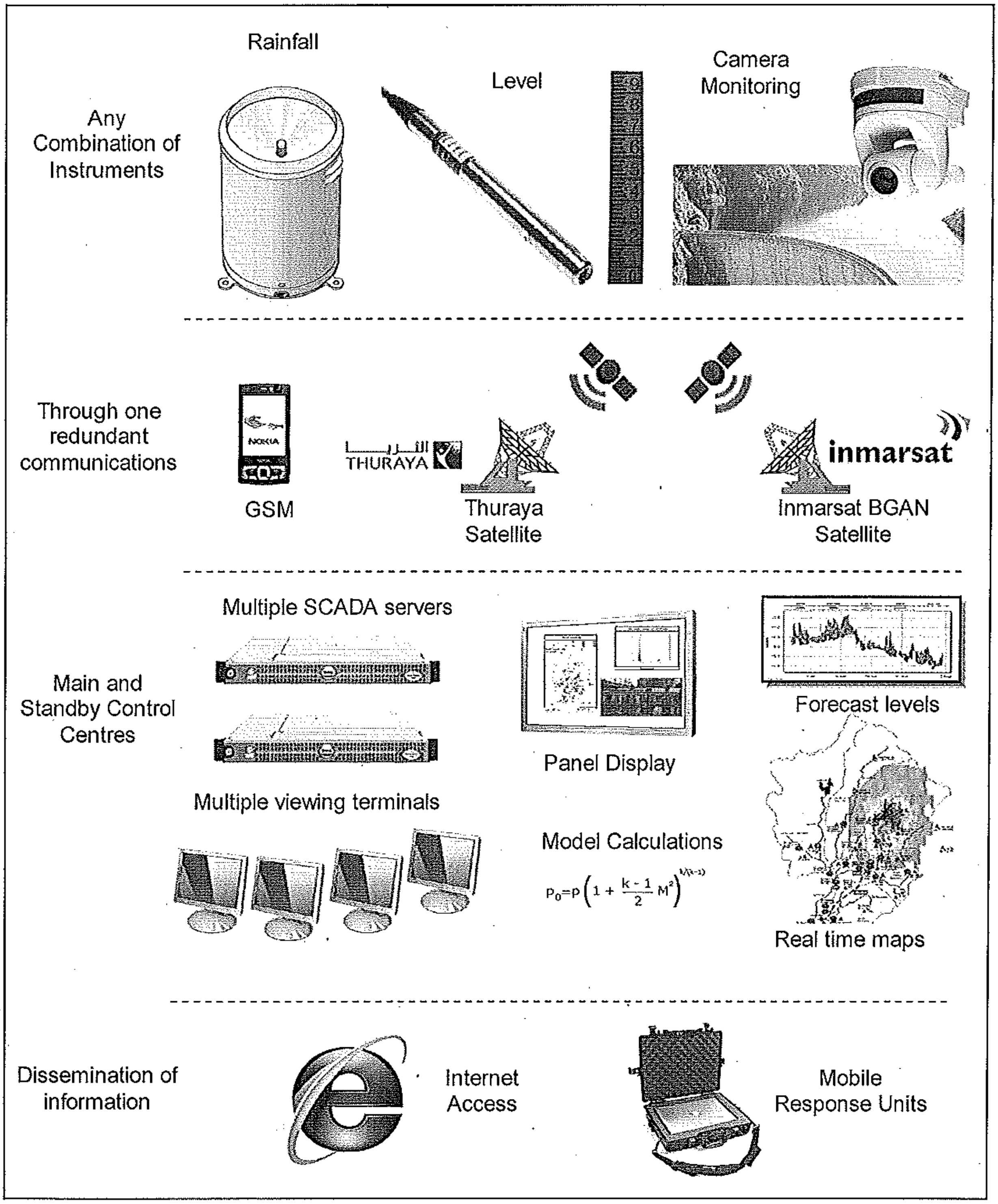


Remote alert systems (not to be confused with the BoM ALERT) should also be made available to organisations responsible for the welfare of the elderly, the sick, and the general public where facilities are located in flood prone areas and loss of life is a real concern. These systems provide visual and audible alerts to building security personnel including if permitted critical water levels and forecast flood heights.

Greenspan has also provided self contained warning systems for shopping malls (Brookvale Sydney, Chatswood Chase) and for monitoring city drainage systems to prevent localised flooding (1000 sites in Singapore) – these should not be forgotten in Flood Warning System design.

2.4 Advanced Systems

Greenspan has recently designed a flood forecasting and warning system for the Government of Oman, the schematic details the concept from measurement to dissemination of data using satellite and GSM communications.



3.0 Summary

Flooding is a reality, communities need to be prepared. Lack of adequate lead time re the impending arrival of floodwaters can lead to death.

As flooding is not an everyday occurrence the impacts are soon forgotten about as people resume their normal lives once again.

Capital and recurrent funding for Flood Warning Systems is generally meagre compared to the cost of flooding excluding the loss of life for which a cost cannot be assigned.

Hopefully those assigned the task of examining the 2011 floods of QLD will be able to make a difference!

Whilst we would have liked to be able to refer to Flood Warning Systems that we have designed and built in Australia, system such as the Yangtze or Kuala Lumpur's SMART are not common place.

Greenspan and in particular Mark Wolf hope that the information provided in this document is of some use.

If we can be of further assistance please do not hesitate to contact Mark Wolf.

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Mark Wolf

Principal Consultant
Greenspan Technology
[redacted]

April 6, 2011

Attachments removed here