Wivenhoe:

A Dam Designed to Fail

and

Decimate Brisbane

With a Solution

So That Won't Happen

by

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Introduction

Wivenhoe is a dangerous dam which is designed to fail. We hope that it won't, but we know that it will. The question is: when?

Wivenhoe has a clay core and an earth wall. It has no structure which could survive overtopping which would collapse the wall leading to tsunami like flooding downstream.

Wivenhoe is built in an earthquake zone. There was an earthquake of magnitude 4.4 near Mt Glorious in 1960, and of magnitude 4.0 near Gatton in 1988. The Wivenhoe wall is in a direct line between Mt Glorious and Gatton, closer to Mt Glorious than to Gatton. Earthquakes of magnitude 6.0 are predicted in South East Queensland on a 120 year cycle.

The Hume Weir, built on the Murray River, has dimensions of a similar order to Wivenhoe's. Monitoring of the Hume Dam wall in the early 1990s revealed that the water pressure and leakage had caused the dam to move on its foundations slightly, leading to concerns that the dam was heading for collapse, threatening Albury-Wodonga and the entire Murray basin with it. Traffic was banned from the spillway, and a large repair job commenced.

In January 2011, a deluge at Toowoomba and near Grantham caused torrential runoff with loss of life.

The deluge followed persistent rain over a considerable period, with several results. Firstly, almost 100% of the rainfall was converted to runoff. Secondly, the runoff was at a very high rate. Thirdly, the fast runoff of water gathered the water already running off ahead of it in an avalanche with a snowball effect that accelerated the runoff in front of it creating torrential runoff vastly in excess of the runoff from the deluge itself.

This Accelerator/Avalanche/Snowball Effect is a very dangerous phenomenon as we saw at Toowoomba and Grantham. It is a particularly dangerous effect if the possibility of its occurrence is not allowed for in the management of Wivenhoe.

On the Tuesday 11th January, there were of the order of a million megalitres of water in the catchment, but not yet in Wivenhoe. If a short sharp deluge accelerated that water into Wivenhoe in an avalanche with a snowball effect, then the Wivenhoe outlets would not have been able to cope with the inflow. The dam, already nearly full, would have quickly overflowed.

So what can we do? Some catchments like Moggill Creek lend themselves to the construction of levee banks with flood gates and flood pumps.

But the most significant thing we can do is to make Wivenhoe safe by concreting the outer skin of the wall.

Wivenhoe is a dangerous dam

Wivenhoe is a dangerous dam.

It is designed to fail.

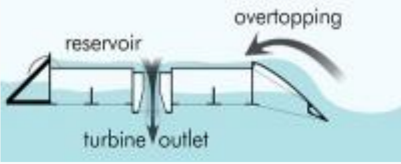
The consequences of its failure would be catastrophic for all downstream communities.

Wivenhoe is designed to be over-topped by runoff when that runoff exceeds the Flood Capacity of the dam. When that happens, the earthen dam wall will fail, and a tsunami like wave of water of gigantic proportions will destroy Brisbane as we know it in an epic disaster which will put hundreds of thousands of lives at risk.

Wikipedia refers to over-topping dam failures as follows.

http://www.engpedia.com/index.php/Causes_of_Earth_Dam_Failure

1. Over-topping Failures



Over Topping of Dams

Over topping failures result from the erosive action of water on the embankment. Erosion is due to un-controlled flow of water over, around, and adjacent to the dam. Earth embankments are not designed to be over-topped and therefore are particularly susceptible to erosion. Once erosion has begun during over-topping, it is almost impossible to stop.

It is because of the knowledge of the danger of over-topping and collapse that there was the massive release of water from Wivenhoe in January 2011, causing extensive flooding to Brisbane and other downstream communities. But that flooding would be minor compared with that which would follow a failure of the wall.

Wivenhoe has a clay core and an earthen wall which is lined on the outside with rocks. Unlike Somerset Dam which has a concrete wall, Wivenhoe has no structure which could withstand the force of water flowing over its wall. The wall would quickly erode and fail, releasing the contents of a full Wivenhoe to flow down the Brisbane River at torrential speed.

There would be a Toowoomba-Grantham style of flood on a massively greater scale.

That event is due to happen infrequently; once in thousands of years.

When will it fail? No-one knows. But it could happen next year, or the year after, or the year after that. No-one knows when it will happen. But everyone knowledgeable about the design of Wivenhoe knows that it is due to happen eventually. Wivenhoe was built with a design that ensures it will eventually fail.

In an attempt to reduce the likelihood of the failure of Wivenhoe, a few years ago, three fuse plugs were installed. But the fuse plugs won't prevent the failure of Wivenhoe; they will merely make it less likely.

One of the main criteria in relation to the selection of the fuse plug solution was cost. But the risk to the people who live downstream from Wivenhoe is too great to settle for second rate solutions just because they are cheap. They are cheap and very nasty.

We have already seen how difficult it was to manage Wivenhoe in January 2011. Matters for judgement and human error by over-worked and stressed out people have been retained as main elements in the management of Wivenhoe.

In January 2011, much of the theoretical flood capacity could not be used. Much of the Wivenhoe flood capacity was used to save the wall from overtopping, thereby rendering that flood capacity useless to save downstream communities from the flooding which ensued as a result. We are still learning about the management of Wivenhoe, and it is not an easy task. It is based on estimates of weather conditions and of rates of runoff: sciences which are still developing their skills and learning from recent events by trial and error.

The management of Wivenhoe relies on communications which may fail during tempestuous cyclonic weather. It also relies on power and mechanical operation of the gates, which may also fail in the extreme conditions which may apply. What backup do we have if there is a power or mechanical failure; if communications towers and power towers are down; or if there is a failure of leadership under crisis conditions?

The management of Wivenhoe also relies on human operations from a control room located in the Wivenhoe wall; a control room manned by brave people who may panic in an event which may seem to become life-threatening.

I suspect that the overtopping of the wall of Wivenhoe would be emotionally similar to the sinking of the Titanic to those in the control room. Would you want to be there? How would you react? People do under pressure what they have done under practice; and they need realistic practice which is very difficult to simulate following year after year of fine days during droughts.

Elsewhere in this report, I argue that a short sharp deluge like that which hit Toowoomba and Grantham would have overwhelmed the wall in January 2011. That is because there was so much water in the catchment on its way to Wivenhoe; and that water would have been accelerated into Wivenhoe by a deluge. The acceleration would have produced a volume of inflow far greater than the combined outflow capacity of the gates and the fuse plugs. The wall would have overtopped and collapsed.

Wivenhoe Dam dangerously full on Monday 10 January 2011

Vital questions must be answered

For more analysis about the lives at risk and the property damage anticipated by an overtopping and collapse of the Wivenhoe wall, please refer to the analysis by Messrs Crichton, Grant, Williams, & Ford in a paper entitled "***Flood Passing Capacity Upgrade Considerations for Wivenhoe Dam***" to be found at http://www.ancold.org.au/papers/2001-14.pdf

Please note that the abovementioned paper preceded the construction of the fuse plugs.

Hedley Thomas, writing in the ***Australian*** on February 11, 2011 stated in relation to the abovementioned report:

A decade ago, with Queensland in an El Nino-caused drought, a handful of dam engineers produced an expert report on Brisbane's Wivenhoe Dam and the potential peril for those living downriver in the event of a catastrophic collapse.

"The population at risk within a distance that would result in less than three hours' warning of a dam failure is between 57,000 and 244,000, depending on the time of day and nature of the breach," *said the paper, entitled* ***Flood Passing Capacity Upgrade Considerations for Wivenhoe Dam****.*

Today, with Queensland at the mercy of La Nina-caused floods, there are vitally important matters requiring scrutiny by the Floods Commission of Inquiry, which is led by Supreme Court judge Cate Holmes.

The tragic deaths in the Lockyer Valley and Toowoomba will be exhaustively and sensitively examined, along with land-use planning, the Bureau of Meteorology's capacity to give timely warning of flash flooding, and the devastation caused across vast regions of the state.

However, the "population at risk" from a dam that is a flood-mitigation tool, a great reservoir for urban water supply and a key piece of Queensland's political furniture needs to be reassured that those responsible for the dam have the policies and competence to operate it safely.

This may be one of the reasons an international expert on dams, Phil Cummins, was selected by the Queensland government to assist Holmes and her senior counsel, Peter Callaghan SC, in an inquiry they pledge will be immune from political interference.

Already, thanks to the openness of Premier Anna Bligh, we know the dam "came very close to an uncontrolled release" during the peak of the run-off of the extreme levels of rain that fell across 7000 square kilometres of catchment, which does not include the Lockyer Valley.

As Bligh said gravely on the evening of January 14 after Brisbane was heavily flooded: "Of course we were worried . . . you would much rather be in control of the dam than it being in control of itself."

Now that the city and its flooded low-lying suburbs are dry again, fundamental questions for the inquiry revolve on investigating why control of this massive and potentially deadly infrastructure was almost lost.

Residents need to understand why the dam's operator, SEQWater, permitted it to lose its critical storage capacity in the days and hours before they were overtaken by crisis, necessitating a sudden, extreme and enormous release of water that caused much of the Brisbane River flood.

And why the Queensland government preferred to save funds by keeping the dam at full supply level even as the weather bureau issued increasingly serious warnings about extreme rain, as the Lord Mayor of Brisbane was cancelling his annual leave because he foresaw a major flood.

And why the pleas and warnings from people living below the dam went unheeded.

Reassuringly, Callaghan gives the impression he will brook no bureaucratic or political stonewalling in the quest for answers.

This is good news for the "population at risk".

The Failure of Wivenhoe

Wivenhoe is now rated as having a failure rate of once in many thousands of years. Rare events are particularly dangerous because their rarity leads to complacency. The fact that they are not likely to happen allows us to ignore them. We are lulled into taking the risk.

The Wivenhoe rating means that over a period of thousands of years, we can expect Wivenhoe to fail. That is, despite releasing water at the maximum rate, and the operation of the fuse plugs, we can expect Wivenhoe to fail. The earthen wall will quickly cut back under the force of the over-topping water, and collapse, releasing the Lake uncontrollably in a Tsunami like surge which will dwarf the Grantham flood. When Wivenhoe does fail, it will flood Brisbane cataclysmically with unacceptable loss of life.

As we now realise, Wivenhoe is a two edged sword: A Damocles' sword hanging over Brisbane.

The larger question for the Inquiry is not what to do about floods like that which has just happened to Brisbane, and how to prevent them. The larger question is how to protect Brisbane from looking like Grantham as a result of a cataclysmic flood following the failure of Wivenhoe.

The failure of Wivenhoe is not something which will never happen. As Wivenhoe is currently designed, it will happen.

The question is not if, but when?

What are we going to do to prevent that?

There's Always a Bigger Flood Coming

For a history of flooding in the Brisbane and Bremer Rivers, please refer to http://www.bom.gov.au/hydro/flood/qld/fld_history/brisbane_history.shtml

This history only goes back 170 years, and commences with the following reference:

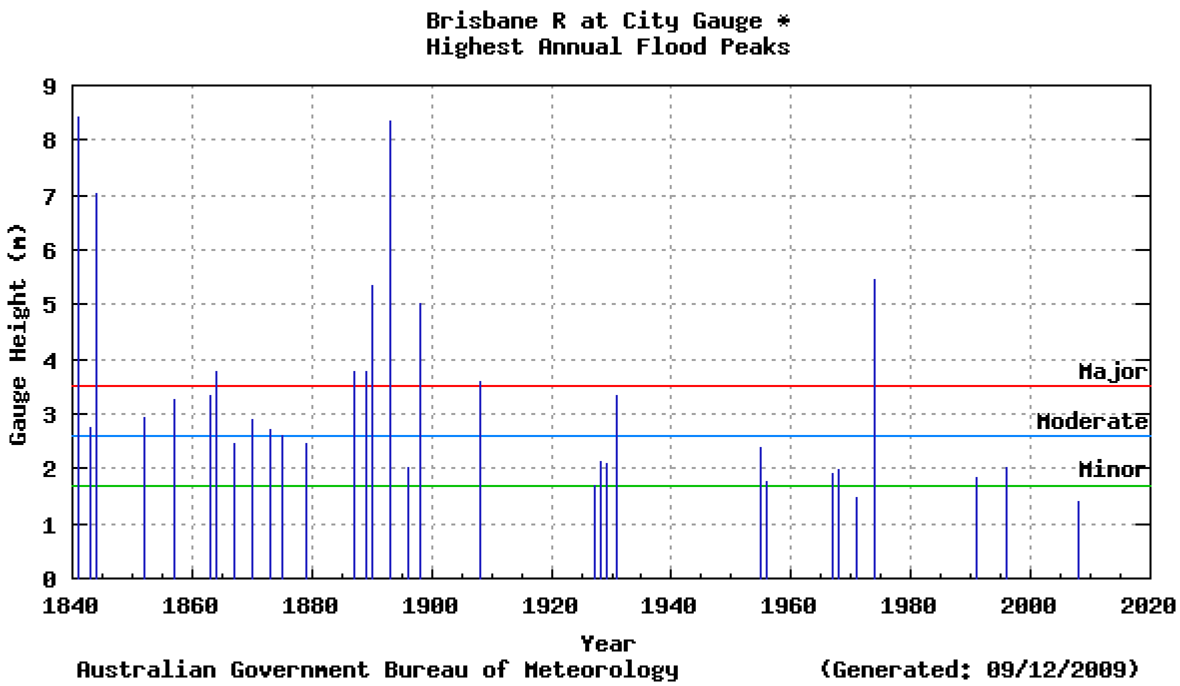
1824	***John Oxley, early explorer, mentioned evidence of an inundation which he discovered on 19 September 1824 in an area north of the junction of the Bremer with the Brisbane : "the starboard bank an elevated flat of rich land, declining to a point where had evidently by its sandy shore and pebbly surface, been at some time washed by an inundation; a flood would be too weak an expression to use for a collection of water rising to the full height (full fifty feet) which the appearance of the shore here renders possible." (Ref 2)***

As we have seen in the Global Warming debates, we don't yet understand the cycles of climate change, or how long or large those cycles are.

We can see from the graph below that Brisbane River floods vary in severity and frequency, and that flood years seem to follow drought years with some sort of cycles.

No one knows how large the largest flood may be. We know that the 1840s and 1890s floods dwarfed what anyone now alive has seen.

Will "Climate change" lead to larger floods? How big a flood could occur? What will that do? No one knows. So abundant caution is the responsible course.



Study the future by studying the past

That expectation of larger floods than the one just experienced is borne out by studying the many large floods of which we are aware (see the chart above) including two in the 1840s (1 over 8 metres the other over 7 metres), three in the 1890s (1 over 8 metres, the other 2 over 5 metres) and 1974 (over 5 metres).

There is anecdotal evidence of the aborigines showing Oxley debris in trees from a 12 metre flood prior to 1825.

We have only been collecting records for 170 years. We can anticipate that there will be larger floods than any of which we have evidence, given enough time.

How does SEQWater plan to manage an 8 metre flood? How does SEQWater plan to manage a 12 metre flood?

How much of Wivenhoe's flood compartment will be available to protect downstream communities in such large floods? I doubt if there would be any capacity for downstream flood mitigation at the peak of the flood, because the focus would be on Dam safety.

Wivenhoe is Built in an Earthquake Zone

I wonder if the designers of the Wivenhoe Dam factored in the impact of an earthquake on the wall which has a clay core and is a rock lined earthen embankment.

There was a magnitude 4.0 earthquake near Gatton in 1988, a magnitude 4.4 near Mt Glorious (not far from the Wivenhoe wall) on 17 November 1960, a magnitude 4.4 near Monto on 16 January 2004, a magnitude 5.4 near Bundaberg in 1935, a magnitude of at least 6 near Lady Elliot Island on 7 June 1918.

It may be the case that an earthquake of magnitude 6 would threaten the Wivenhoe wall.

Qld earthquake risk real reports Daniel Hurst

in the Brisbane Times on April 24, 2009

- http://www.brisbanetimes.com.au/queensland/qld-earthquake-risk-real-20090424-ahbe.html

Central Queensland University seismologist Mike Turnbull.

A Queensland seismologist has warned the state should prepare for damaging earthquakes as strong as magnitude 6 in the future, despite widespread public perceptions the risk is low.

Central Queensland Seismology Research Group leader Mike Turnbull said his pleas for greater funding to help his ground monitoring work had fallen on deaf ears - even though Central Queensland had experienced strong earthquakes in the past including a magnitude 6 quake in 1918.

The scale of this earthquake - which caused property damage in Rockhampton, Bundaberg and Gladstone - is nearly as high as the devastating 6.3 quake that struck in Italy early this month, killing hundreds of people and leaving thousands homeless.

Diagram: Implied fault lines in the area west of Bundaberg

Brisbane is considered to have a lower earthquake risk, but the region has experienced earthquakes in the past.

The Emergency Management Australia disaster database shows a 4.4 magnitude quake hit Mount Glorious, 20 kilometres north-west of Brisbane, on November 17, 1960, causing some damage in the Lockyer Valley region.

Houses sustained damage when a magnitude 4 earthquake struck near Gatton in 1988.

Mr Turnbull told brisbanetimes.com.au the state's greatest earthquake risk was in Central Queensland. He said he was particularly worried about potential earthquakes along a fault line just 30 kilometres west of Bundaberg - the origin of a quake at least 5.4 in magnitude in 1935.

The Central Queensland University researcher has operated a monitoring station at his home in the Gin Gin area since 2004. Mr Turnbull said he had detected more than 100 earthquakes in this time, including a magnitude 4.4 quake that struck 30km east of Monto on January 16, 2004.

"It was felt quite strongly over a radius of 70 kilometres," he said.

"We can expect to have a magnitude four earthquake in this region every two years ... and we can expect to have at least one magnitude six earthquake in any 120 year period.

"We've had them in the past, we're going to have them again, we just don't know when exactly."

James Cook University School of Earth Sciences associate professor Tom Blenkinsop said the predictions sounded reasonable, based on the limited data available.

Dr Blenkinsop said earthquakes occurred in Australia even though the nation did not sit on a tectonic plate boundary. The nearest boundary passed through Papua New Guinea to the north, into the Pacific Ocean and south to New Zealand.

Australia experienced "intraplate earthquakes" along fault lines dating back millions of years when parts of the country were on or near plate boundaries, Dr Blenkinsop said.

"These earthquakes go off and they catch people by surprise because they're unanticipated," he said.

Mr Turnbull said he had received barely any funding for his monitoring work, even though the smaller quakes could provide a better picture of fault lines and potential earthquake locations.

Mr Turnbull said a three-year experiment to identify active faults west of Bundaberg would cost about $300,000.

He claimed scientists, engineers, state and local governments and insurers "would be falling over themselves" to identify active earthquake faults if South East Queensland - rather than Central Queensland - had experienced two major earthquakes in the last 100 years.

Mr Turnbull said the "Great Queensland Earthquake" that struck on June 7, 1918, originated near Lady Elliot Island and was felt as far west as Charleville, as far north as Mackay and as far south as Lismore.

He said the 1918 quake, which was now listed in the Emergency Management Australia database as a magnitude 6, had often been identified in literature as a magnitude 6.2 and even as 6.3 in University of Queensland literature in 2006.

"It caused minor structural damage in Rockhampton and Bunbaberg, toppling chimneys for example, and caused mild panic in Rockhampton where people were reported to have run into the streets screaming," he said.

Geoscience Australia says the nation experiences about 200 earthquakes of magnitude 3.0 or more every year. It says on its website that a potentially disastrous earthquake of magnitude 6 or more occurs every five years in Australia.

Thirteen people died when a 5.6 magnitude earthquake struck Newcastle, in New South Wales, on December 28, 1989.

The quake damaged more than 35,000 homes, leaving an estimated damage bill of $4 billion

There have been a number of significant earthquakes in Australia. We have recently witnessed the results of earthquakes in Christchurch and Japan.

The following list of major Australian earthquakes includes three earthquakes in South-east Queensland.

http://en.wikipedia.org/wiki/List_of_earthquakes_in_Australia

Location	Date	Magnitude	Damage
Gayndah,Queensland	1883 28 August	5.9	Caused major damage in the Gayndah region.
Bundaberg - Rockhampton,Queensland	1918 7 June	6	Caused "serious damage" to Rockhampton, Bundaberg and Gladstone.
Gayndah,Queensland	1935 12 April	5.4	Caused considerable damage to the town of Gayndah. One fatality[13]

Internet searches of earthquake induced dam failures include:

Earthquakes can certainly cause damage to dams but complete failure of a large dam due to earthquake damage appears to be very rare. The Lower San Fernando Dam in California, USA did fail during a (magnitude 6.6) earthquake in 1971 which caused the fill in the dam wall to liquefy resulting in the collapse of the upstream part of the dam. A disastrous flood was only prevented because the reservoir level happened to be low at the time of the earthquake and no water escaped downstream.

Santa Barbara, California
1925 June 29 14:42 UTC
Magnitude 6.8

This destructive earthquake caused property damage estimated at $8 million and killed 13 people. Most of the damage occurred at Santa Barbara and nearby towns along the coast, but the earthquake caused moderate damage at many points north of the Santa Ynez mountains, in the Santa Ynez and Santa Maria River valleys. North of Santa Barbara, the earth dam of the Sheffield Reservoir was destroyed, but the water released caused little damage.

The Hume Weir started moving down river

Lake Hume is an artificial lake in Australia formed by the Hume Weir east of Albury-Wodonga on the Murray River just downstream of its junction with the Mitta River. The small towns of Tallangatta, Bonegilla and Bellbridge are located on the shores of Lake Hume. It is often referred to as the Hume Weir, only named Lake Hume in the mid 1980s.

History

Monitoring of the dam in the early 1990s revealed that the water pressure and leakage had caused the dam to move on its foundations slightly, leading to concerns that the dam was heading for collapse, threatening Albury-Wodonga and the entire Murray basin with it. Authorities denied any short-term threat. Traffic was banned from the spillway, and a large repair job commenced involving, in part, the construction of a secondary earth wall behind the original to take the strain.

Facilities

The Hume Weir dam wall

The dam wall is constructed of rock covered with clay and other earth, with a concrete spillway. Designed to carry vehicular traffic, the dam wall is 51 metres high and 1,616 metres long, and at 100% capacity can hold 3,000,000 megalitres of water. Water is retained nearly 40 kilometres up both river valleys. Lake Hume holds approximately 5 times the volume of Sydney Harbour.

The Wivenhoe wall

Those familiar with the specifications of Wivenhoe will notice the similarities between the Hume Weir and Wivenhoe. Wivenhoe Dam consists of an earth and rock embankment 2.3 kilometres (1.4 mi) long and 50 metres (160 ft) high. It has a concrete spillway section on which five steel crest gates are installed. The dam's reservoir has a total storage capacity of 2.61 cubic kilometres (0.63 cu mi), of which 1.16 cubic kilometres (0.28 cu mi) is used for urban water storage.

Let's hope that the Wivenhoe wall is more stable than the Hume Weir.

Accelerator/Avalanche/Snowball Effect

We've all heard of the snowball effect. A snowball rolling down hill gathers snow and pace exponentially.

And we've all heard of avalanches which are large examples of an effect similar to the snowball effect.

Something similar happens with runoff. When water is flooding in from Peachester (at the very north-east of the Wivenhoe catchment), towards Wivenhoe, it starts trickling off trees and through grass and over soil and around rocks and sticks, and slowly makes its way to Wivenhoe via gullies then creeks then the Stanley River, then it flows out of Somerset Dam into the Brisbane River at the top of Wivenhoe. Its speed gradually increases as it goes further down the catchment, because it gets deeper. The more it concentrates, the deeper it gets, and the faster it flows.

For a certain rate of rainfall, water reaches an equilibrium rate of flow. We can find that a catchment which receives X mm of rain per hour will generate Y cubic metres per second of runoff.

However, if rainfall dramatically increases for a short period, the depth of the runoff also dramatically increases, and the rate of flow dramatically increases.

For example, let's assume in **Scenario A** that rain is falling at the rate of 1 mm per minute, which is 60 mm per hour.

Then let's assume in **Scenario B** that the rain falls at the rate of 8 mm per minute for 5 minutes (the Deluge) and then drops back to .3636 mm per minute for 55 minutes (the Trickle). That's also 60 mm per hour.

However, in Scenario B, the rate of rainfall during the Deluge is 8 times that of Scenario A, and the velocity of the runoff during the Deluge is of the order of 4 times that of Scenario A. The Deluge runoff not only runs off faster than in Scenario A, but the Deluge runoff accelerates all the water already moving in the landscape, and moves that water at the rate of the Deluge runoff.

This is of enormous consequence in saturated extensive catchments such as Wivenhoe's in January 2011. Perhaps conventional runoff modelling of 60 mm per hour would allow for steady state runoff. But Deluges would produce immensely faster runoff, not just from the Deluge, but from all the runoff water speeded up by the Deluge.

This torrential flow then catches up with all of the slow moving water ahead of it from previous rainfall and pushes the total body of water faster and faster and faster as the water gets deeper and deeper and deeper. The previously slow moving water in the system is all hurried-up and delivered together with the water from the Deluge.

There is resistance in the landscape to the flow of water: by grass, trees, rocks, soil, sticks, stones etc; but as the amount of water increases, the resistance becomes less important. The resistance of grass to a trickle is very significant, and slows water flow down appreciably. But at torrential rates, the resistance of cars and houses is negligible. Resistance drops inversely proportionally to rates of flow as water is flowing smoothly over water instead of being slowed by grass, and other landscape elements, and flow velocity increases dramatically.

It's a bit like an out-of-control semi-trailer hitting a line of cars in a traffic jam going down the Toowoomba Range: there is a cataclysmic snowball towards the bottom of the hill, not just of the semi-trailer, but of everything in its path.

Another analogy is that It's a bit like a home run in baseball. If you're the first batter, you only get one home run. But if the bases are loaded, you get 4 home runs. There's an avalanche during which the 4 runners arrive in quick succession. With runoff, instead of the runners arriving in succession, it's different. It's like a fast runner catching up to a runner in front; whereupon the combination causes both runners to go even faster than the faster runner of the two (deeper water flows faster). When the first two runners catch up on the next runner, the impact is exacerbated, and the three runners go even faster than before, etc.

At Toowoomba and Grantham, water moved very fast because there was a lot of it. The more there was, the faster it travelled, and the easier it was to overwhelm and destroy obstacles without slowing down. I believe that the **Accelerator/Avalanche/Snowball Effect** was on display in Toowoomba and Grantham.

The Toowoomba and Grantham floods occurred on Monday 10 January 2011. It is interesting to look up the rainfalls for the 24 hours to 9:00 am on Tuesday 11th:

Toowoomba: 117 mm

Helidon: 29 mm

These are not exceptional levels of rainfall compared to the average in the Wivenhoe catchment which was of the order of 110 mm that day and 153 mm the day before. So why was the Toowoomba rainfall so destructive? Why was the Helidon/Grantham rainfall so destructive? Because it fell quickly. The Toowoomba downpour was reported at 60 mm in an hour whereas the Wivenhoe catchment rainfall averaged of the order of 6.4 mm per hour to 9:00 am on Monday 10th and 4.5 mm per hour to 9:00 am on Tuesday 11th.

On Tuesday 11 January 2011, on my calculations, there was in excess of 1 million ML (perhaps up to 1.5 million ML: I have not had time to reconcile the final detailed figures) in the Wivenhoe/Somerset catchment, not yet in the Lakes.

If a catchment-wide Scenario B Deluge had accelerated that 1 million ML, plus the water from the Deluge of 280,000 ML (5 minutes @ 8 mm = 40mm x 7,000 hectares), then 1.28million ML would all arrive in Wivenhoe in a relatively short period and overwhelm the wall. If the 1.28 million ML of water arrived at Wivenhoe in 6 hours, that would be far too much for the release capacity of the gates and the fuse plugs. And because there was very little flood capacity at that stage, the Wivenhoe wall would quickly be over-topped and destroyed.

It is very important to managing Wivenhoe that the **Accelerator/Avalanche/Snowball Effect** is understood and taken into account. Without proper allowance of that **Effect, and of the amount of**

water in the catchment but not yet in the Lake, Wivenhoe may be kept so full that a short sharp Deluge across the catchment could quickly overfill Wivenhoe leading to wall failure.

I believe that we were only a Deluge away from the Wivenhoe wall collapsing during the Flood in January 2011.

I suspect from reading section 8.9 of the SEQWater Flood Report, particularly page 147, that SEQWater may not have factored in the **Accelerator/Avalanche/Snowball Effect** which would produce an alternative explanation instead of the 1/2,000 year rainfall imputed to solve the problems explained on pages 146 and 147 of SEQWater's Report. The SEQWater comments suggest that there may be problems with their modelling. Perhaps SEQWater hasn't allowed for the **Accelerator/Avalanche/Snowball Effect.** That effect is of massive importance in managing Wivenhoe.

Please refer particularly to the excerpt from SEQWater's report highlighted in gold hereunder to appreciate the difficulty SEQWater are having with their modelling:

"It was then ***necessary to scale this rainfall up by a factor of two to match the rapid lake level rises****. This factored Mt Glorious rainfall data had an average intensity of 68mm/hr, which exceeds an annual recurrence interval of 1 in 2,000 years and may be well into the extreme category"*

SEQWater state in Section 8.9 (I have removed the graphs):

8.9 Impact of intense rainfall occurring on Tuesday 11 January 2011

As discussed in Section 6, heavy, localised, intense rainfall around the Wivenhoe lake area commenced in the early hours of Tuesday 11 January 2011 and continued into the afternoon.

This rainfall was recorded in the rain gauges to the east and south of Lake Wivenhoe (around Mt Glorious and Lowood), however, it was not recorded in gauges to the north and west of Wivenhoe Dam. There is a large, unmonitored area between these gauges, which covers a large component of the Lake area. For modelling purposes, this area is treated as impervious and generates 100% runoff. Radar images at the time indicated rain was falling continuously in this area over the period. Rainfall totals in the 12 hours to 15:00 ranged from 410mm at Mt Glorious on the eastern side of the lake, to only 32mm at Rosentretters on the western side of Lake Wivenhoe.

The real time modelling undertaken with the available recorded rainfall data did not reproduce the rapid rise in Lake level recorded that afternoon. This inferred very heavy rain fell within and around the Wivenhoe Dam Lake area immediately upstream of the Dam. This suggestion was tested using the Seqwater Unified River Basin Simulator (URBS) model using the following methodology.

The recorded Mt Glorious rainfall was transposed to a dummy station at the centre of the Lake and, for the period of heavy rainfall, scaled up the URBS model re-run, and the resultant flows imported into the gate operations spreadsheet. The modelled water levels were then compared with the recorded water levels. Figure 8.9.1 below shows the impact of the scaled rainfall on the modelled upper Brisbane River inflow to Wivenhoe Dam. The peak of the inflow is both much higher and earlier with the transposed dummy rainfall station than without.

In order to reproduce the recorded Wivenhoe Dam levels, it was necessary to scale the rainfall of the transposed Mt Glorious data by a factor of two for the period between 03:00 to and 15:00 on Tuesday 11 January 2011, indicating the significance of the heavy rainfall in the ungauged area immediately upstream of the Dam.

IFD analysis of the rainfall record at Mt Glorious shows the 12 hours to 15:00 on Tuesday 11 January 2011 had an average intensity of 33.9mm/hr and was in the range 1 in 500 to 1 in 1,000 AEP, between the large and rare categories.

To model the rapid rise of the recorded Wivenhoe Dam levels between 03:00 to 15:00 on Tuesday 11 January 2011, the Mt Glorious rainfall data was repositioned to the ungauged area immediately upstream of the Dam, where the BoM radar indicated was the centre of the heavy rainfall during that period. It was then necessary to scale this rainfall up by a factor of two to match the rapid lake level rises. This factored Mt Glorious rainfall data had an average intensity of 68mm/hr, which exceeds an annual recurrence interval of 1 in 2,000 years and may be well into the extreme category. Rainfall of this intensity and duration over the Wivenhoe Dam lake area at such a critical stage of a Flood Event was unprecedented. The resulting runoff could not be contained without transition to Strategy W4, as discussed in Section 2 and Section 10.

Michael O'Brien comments on SEQWater's report as follows in his report "***Brisbane Flooding January 2011: An Avoidable Disaster***", found at:

http://resources.news.com.au/files/2011/03/22/1226025/997481-aus-news-file-obrien-report-replace.pdf

There are two possible explanations: -

- *That this period of 8 hours was the period of highest rainfall in the Wivenhoe catchment, or*

- *The manual gauge board was reading high and the dam level was not increasing at the rate shown by the gauge board. In this case the calculated inflow rates would then be lower than the currently estimated values.*

Further detailed analysis of this period is essential because: -

- *This is a critical period for gaining a proper understanding of the impact of the releases from Wivenhoe on the flood in Brisbane.*
- *If correct, the elevated rainfall over this period would represent the most severe inflows to the dam and would be expected to significantly impact on future event forecasting. As noted by SEQWater this would require a rainfall event with an ARI of 2000 years.*

I suspect that the anomaly referred to by both SEQWater and Michael O'Brien may be solved by further analysis of the **Accelerator/Avalanche/Snowball Effect.**

It is very important to managing Wivenhoe that the **Accelerator/Avalanche/Snowball Effect** is understood and taken into account. Without proper allowance of that **Effect, and of the amount of water in the catchment but not yet in the Lake,** Wivenhoe may be kept so full that a short sharp Deluge across the catchment could quickly overfill Wivenhoe leading to wall failure.

It seems to me to be vital to factor into the Wivenhoe Management Manual the possibility of a Deluge which could very quickly change the water levels in the Lake. Such a Deluge could trigger a Strategy w4 almost instantaneously, and therefore the possibility of that event should be taken into account in the Manual of Operational Procedures. The possibility of such an event would trigger a W4 Strategy much earlier than otherwise.

I believe that we were only a Deluge away from the Wivenhoe wall collapsing during the Flood Event in January 2011.

I believe that if on the afternoon of Tuesday 11th the Wivenhoe catchment had received the 60 mm cloudburst that hit Toowoomba the day before, the Wivenhoe dam wall would have failed. Wivenhoe was nearly full then, and couldn't cope with much more.

"How likely were we to get rainfall of 60 mm in an hour in the Wivenhoe catchment?"

A relevant question pursuant to this analysis is: "How likely were we to get rainfall of 60 mm in an hour in the Wivenhoe catchment?"

That question is addressed by the BoM at an Intensity-Frequency-Duration rainfall site (the IFD site) at http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml

The results of inputs to that site of the coordinates of Kilcoy (26/59/00 South & 152/30/00 East) are copied below.

Kilcoy is due north of the Wivenhoe wall and is close to the rainfall weighted epicentre of the Wivenhoe catchment.

The IFD site shows that a rainfall of 60 mm in an hour at Toowoomba has an average frequency of about 40 years; and at Kilcoy, of about 10 years (for 58.8 mm in an hour). I dare say that during the rainfall events that we were experiencing, the chance of such a rainfall event was higher than on any "normal" day.

More alarmingly, for Kilcoy, we can see from the IFD Table that rainfall at that intensity of 58.8 mm per hour for 20 minutes occurs every year on average. The relevance of the intensity relates to the mobilization of the water already ahead of the Deluge through the **Accelerator/Avalanche/Snowball Effect** so that a relatively short sharp Deluge can mobilize a far greater quantity of water.

This is the first major flood we've had since Wivenhoe was built, and it is clear that we are still learning how the Wivenhoe catchment behaves, and learning how to manage the Dam.

When we have high rainfall, all of the Wivenhoe flood compartment may need to be used merely to save the dam wall from collapse, with none available to mitigate the type of flooding which Brisbane recently experienced which may be necessary to prevent far worse cataclysmic Grantham tsunami type flooding of Brisbane if the Dam wall fails.

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Intensity-Frequency-Duration Table

Location: 26.975S 152.500E NEAR.. Kilcoy Issued: 16/2/2011

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	104	134	170	192	223	264	296
6Mins	97.0	125	159	179	208	246	276
10Mins	79.4	102	130	147	170	201	226
20Mins	58.8	75.7	95.7	108	125	148	166
30Mins	47.9	61.7	78.0	88.0	102	120	135
1Hr	31.8	41.0	52.0	58.8	68.0	80.6	90.5
2Hrs	19.7	25.4	32.6	37.0	43.0	51.1	57.6
3Hrs	14.5	18.8	24.3	27.7	32.3	38.6	43.6
6Hrs	8.53	11.1	14.5	16.7	19.6	23.6	26.9
12Hrs	5.12	6.71	8.85	10.2	12.1	14.7	16.7
24Hrs	3.20	4.18	5.56	6.44	7.62	9.26	10.6
48Hrs	2.00	2.61	3.47	4.02	4.76	5.78	6.61
72Hrs	1.44	1.89	2.51	2.92	3.46	4.21	4.83

(Raw data: 42.46, 6.8, 1.93, 77.76, 13.84, 3.99, skew=0.26, F2=4.38, F50=17.26)

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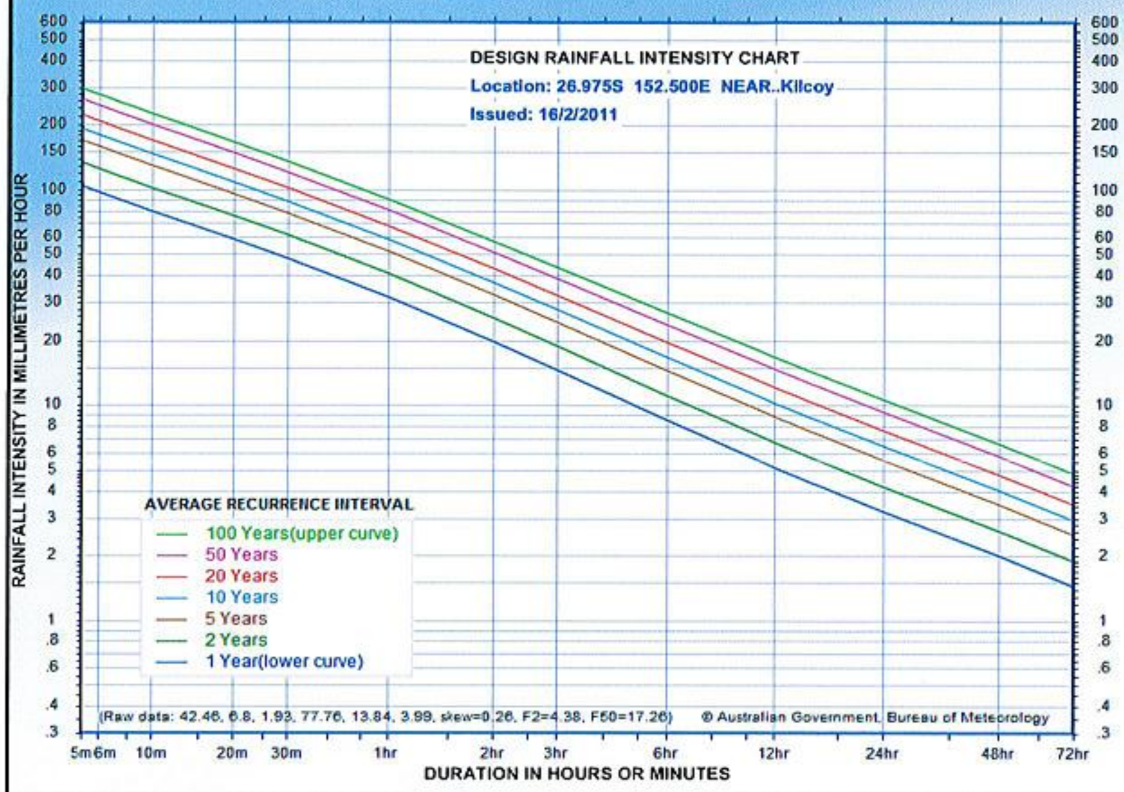
DESIGN RAINFALL INTENSITY CHART
Location: 26.975S 152.500E NEAR..Kilcoy
Issued: 16/2/2011
RAINFALL INTENSITY IN MILLIMETRES PER HOUR
600 500 400 300 200 150 100 80 60 50 40 30 20 10 8 6 5 4 3 2 1 .8 .6 .4 .3
AVERAGE RECURRENCE INTERVAL
100 Years(upper curve)
50 Years
20 Years
10 Years
5 Years
2 Years
1 Year(lower curve)
(Raw data: 42.46, 6.8, 1.93, 77.76, 13.84, 3.99, skew=0.26, F2=4.38, F50=17.26)
© Australian Government, Bureau of Meteorology
5m 6m 10m 20m 30m 1hr 2hr 3hr 6hr 12hr 24hr 48hr 72hr
DURATION IN HOURS OR MINUTES

Levees & Flood Gates: Moggill Creek

There are many creeks in Brisbane with a wide variety of geography.

Moggill Creek lends itself to the construction of levee banks between two knolls near the river bank. Flood gates (of steel seated in waterproof gaskets housed in concrete) can be installed in these gates to allow the gates to swing outwards to allow outbound water to flow to the river, but not vice versa. In the event that the Creek and the River are running simultaneously, a battery of diesel powered high volume flood pumps can provide a backup when the gates are closed.

Thereby, Moggill Creek can be flood proofed, at least against a 12,000 cubic metre per second (cumec) river flood in accordance with the flood map as published by the Bureau of Meteorology.

As a result of those Flood Control Levee Bank Works, "Valuer-General's" property values of affected property would increase considerably, perhaps doubling for some properties, thereby raising Rate revenue and Land Tax. These sources of revenue can assist with the financing of the works.

Most of Brisbane's creeks lend themselves to this approach, but not all to the same extent.

For example, it would be easy to protect Oxley Creek and the Rocklea Markets from a 2011 level flood, but not so easy in respect of a 12,000 cumec flood.

It is then a difficult decision as to what to do. The cost for minor works provides reasonable protection against minor floods, but not major ones. Yet the expectation arising from the works is that the land will be invulnerable to flooding, and that would not be the case.

Concrete the outer skin of the Wivenhoe wall

We deserve a safe solution to the Wivenhoe problem.

That solution is to concrete the outer skin of the Wivenhoe wall.

In Table 1, to make a start on cost estimates, I have set out some parameters which estimate the cost of concreting the Wivenhoe wall at between $300 million and $700 million.

In Table 2, I list some of the advantages flowing from the concreting of the outer skin of the Wivenhoe wall.

Wivenhoe is built above rock which provides a base into which a concrete wall can be anchored. That concrete wall would allow the dam to be safely overtopped.

That situation would allow the fuse plugs to be closed up, thereby increasing the flood capacity. In addition, because the wall could be safely overtopped, the entire flood capacity could be used to mitigate downstream flooding.

Earthen dam walls usually fail from the outside bottom upwards. They progressively cut back and up from turbulence at the outside bottom of the wall until the cutting reaches the top whereupon the breach quickly widens and the wall collapses.

The solution is to create a massive concrete anchor in bedrock near the outside bottom of the wall, and concrete the road and the outside skin of the wall (the inside is irrelevant) fully anchored into rock along the length of the wall, supported by piles, and strengthened by horizontal and vertical beams. This then allows the dam to be safely overtopped.

There is then no danger of overtopping, or from movement or pressure of the water inside.

There are real issues in that respect with all earthen walls particularly relating to how well they are keyed into bedrock at the heart of the wall.

See the Wikipedia article about the Hume Weir "***Monitoring of the dam in the early 1990s revealed that the water pressure and leakage had caused the dam to move on its foundations slightly, leading to concerns that the dam was heading for collapse, threatening Albury-Wodonga and the entire Murray basin with it. Authorities denied any short-term threat. Traffic was banned from the spillway, and a large repair job commenced involving, in part, the construction of a secondary earth wall behind the original to take the strain***."

The cost of concreting the outside skin of the Wivenhoe wall is petty cash compared with the cost of the failure of Wivenhoe.

The extent of the rock can be seen near the Wivenhoe gates.

The height of the wall can be estimated

Table 1: Cost of concreting the outer wall of Wivenhoe (plus the road & an apron at the foot of the wall; plus beams & piles)

The cost range is estimated at between $300 million & $700 million as follows.

Average Wall Height metres	Average Road Width metres	Average Apron Width metres	Height plus Road plus Apron metres	Total Length in metres	Average Thickness of concrete metres	Concrete Volume in Cubic Metres	Cost per Cubic Metre	External Skin Cost $ millions	Surcharge for beams at 20% $ millions	Surcharge for piles 20% $ millions	Total Cost in $ millions	Total Cost rounded up $ millions	Cost Range in $ millions
25	10	10	45	2,300	2	207,000	$1,000	$207	$41	$41	$290	$300	low
30	10	15	55	2,300	2.5	316,250	$1,500	$474	$95	$95	$664	$700	high

Table 2: Benefits of concreting the outer wall of Wivenhoe (plus the road & an apron at the foot of the wall; plus beams & piles)

1	Allows the wall to be safely overtopped without causing the dam to collapse
2	Safety to downstream people
3	Safety to downstream property
4	Enables abandonment of fuse plugs, thereby increasing Flood Capacity
5	Allows full Flood capacity to be used, thereby increasing Flood capacity
6	Simplifies Dam management
7	Reduces the likelihood of 2011 type panic releases and damage to downstream properties
8	Insures against collapse or partial collapse from overtopping, thereby saving on repairs
9	Stabilizes against Hume Weir type downstream movement which may lead to collapse
10	Stabilizes against earthquake which may lead to collapse (Mt Glorious magnitude 4.4 in 19; Gatton 4.0 in 1988; up to 6.0 forecast)
11	Because of the above, improves downstream property values
12	Because property values increase, rate revenue and land tax increase
13	Rate and Land Tax revenue can help to amortise cost

Conclusion:

Concrete the outer skin of the Wivenhoe Wall as a result of which most of the following matters are not as important.

Move the Wivenhoe control room from the Wivenhoe Wall.

Ensure redundant methods of securing all communications, power, gate operation, etc., so that the operation of Wivenhoe is fail-safe.

Liaise with flight simulators to attempt to create realistic operator training.

Practice every scenario until operators know what to do without having to think out what to do under stressful conditions.

Ensure redundancy of personnel so that if one person falls ill, the operation continues uninterrupted during a crisis.

Build Levee Banks at the mouth of Moggill Creek and on such other creeks as designs are found for.

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