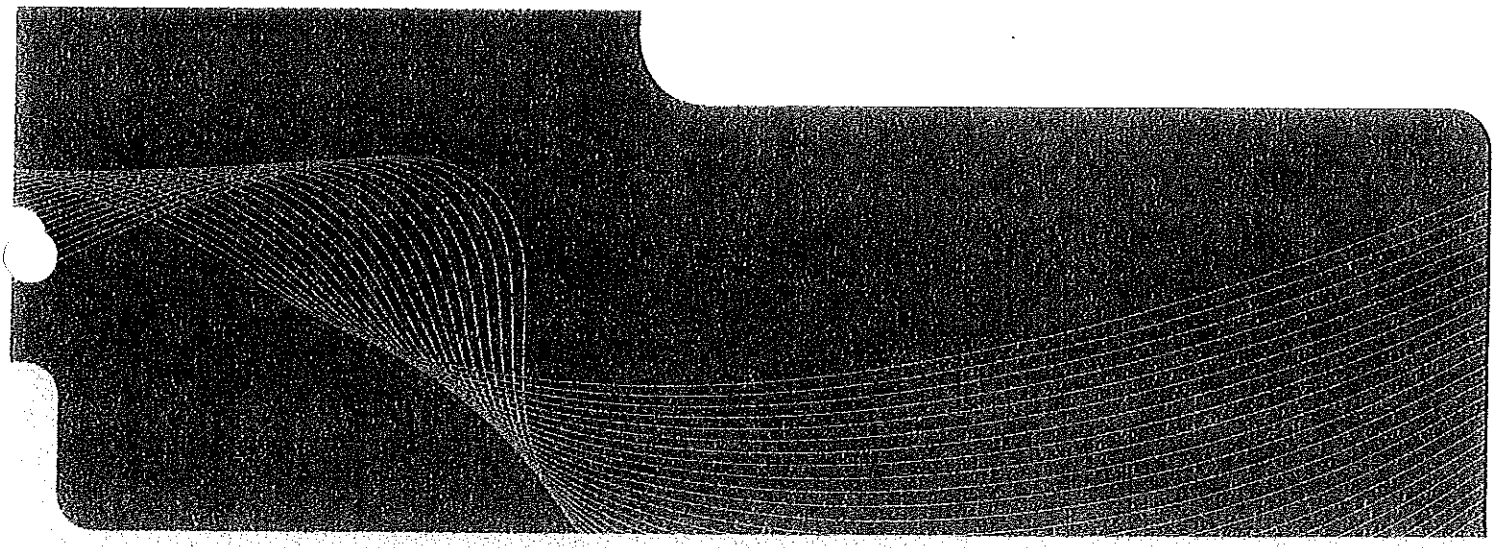
CLIENTS PEOPLE PERFORMANCE

Wide Bay Water

Lenthalls Dam Flooding

December 2010 Event

June 2011



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Contents

1. Introduction

1.1 Background

This flood investigation was commissioned by Wide Bay Water in response to a storm event that occurred in December 2010. It builds on the work of an earlier 2009 study, which investigated the flood levels at Lenthalls dam during the February 2008 floods (Lenthalls Dam Flooding, GHD, February 2009).

In February 2008, during a moderate rainfall event, a flood incident occurred at Lenthalls Dam. This was attributed to the failure of the crest gates, which malfunctioned and did not open to release the floodwaters during the peak of the storm. The rising water levels at the dam backed up along an upstream tributary, and resulted in some residents near the watercourse being stranded at their farmhouse.

In December 2010, after several days of continuous rainfall, another flood event occurred. Water levels at the dam rose and reached trigger levels, and the residents in the area were subsequently notified and evacuated in accordance with the Lenthalls Dam Emergency Action Plan. The water levels at the dam eventually exceeded February 2008 dam levels.

1.2 Objectives

The primary objective of this study is to review and update the February 2009 work, where applicable, on the basis of the December 2010 storm event. The scope of work includes the following:

- Obtain and review available rainfall and dam water level information for the December 2010 storm event;
- Review and update hydrology and hydraulics models developed for February 2009 Lenthalls Dam Flood Report, where applicable;
- Recalibrate hydrology and hydraulic models if necessary; and
- Update findings of February 2009 study report, where applicable.

2. Available Data

A description of the Lenthalls Dam catchment has previously been provided in the February 2009 report (Lenthalls Dam Flooding, GHD, February 2009)). The reader is referred to that report for additional details on the catchment, watercourses, and other drainage characteristics relating to the site.

Data obtained and reviewed for this study included the following:

- Lenthalls Dam Flooding Report, GHD, February 2009;
- Digital Terrain Model of site (from aerial photogrammetry) at 2m contour intervals supplemented by field survey of creek at selected locations;
- RORB hydrology model (February GHD 2009);
- HEC-RAS hydraulics model (GHD, February 2009);
- Spillway rating curves with all gates operational and all gates not-operational (GHD, December 2008);
- Lenthalls Dam water level records, from 21 December 2010 to 30 December 2010, (provided by Wide Bay Water);
- Rainfall records at Lenthalls Dam Alert (Station No. 040906), Howard Post Office. 040098), Musket Flat (Station No. 040902), 1 December 2010 to 20 January 2011 (irregular rainfall time series data, provided by Wide Bay Water and Bureau of Meteorology);
- Water level records at Howard Alert (Station No. 040907), 1 December 2010 to 18 January 2011 (provided by Wide Bay Water); and
- Event log for the December 2010 flood event, 22 December 2010 to 29 December 2010 (provided by Wide Bay Water).

It is noted that the December 2010 event log was recorded manually by a field operator manning the dam operations during the flood event. While this was not included in the data originally provided for the study, it was later requested to assist in validating the hydrology model adopted for the dam.

3. Study Methodology

3.1 Hydrology (RORB Model)

RORB is a networked rainfall and runoff model that is widely used in Australia for flood estimation (Australian Rainfall and Runoff, ARR 1998).

The RORB rainfall-runoff model developed for the February 2009 Flood Study was adopted and used to simulate the hydrological behaviour of the catchment for the December 2010 event.

It is noted that the 2009 RORB model was configured using data from an earlier version of RORB (DNRW 1999). The 2009 model updated the 1999 model and was calibrated using the February 2008 flood event. Additional details of the RORB model and calibration work undertaken are documented in the February 2009 report.

Based on the results of the February 2009 study, the Lenthalls Dam catchment was found to have RORB model parameters of 30 and 0.8, for kc and m, respectively. An initial loss of 8 mm and a continuing loss of 2 mm/hr were also derived for the February 2008 event.

In this present study, the above RORB model parameters established from the 2009 Flood Study were reviewed and used as the basis for calibration and validation of the December 2010 storm event.

3.2 Historical Rainfall Data

Historical rainfall information provided by the Bureau of Meterology included the following:

- Lenthalls Dam Alert (Station No. 040906);
- Howard Post Office (Station No. 040098); and
- Musket Flat (Station No. 040902);

It is noted that Lenthalls Dam Alert (Station 040906) is located within the dam itself, while Musket Flat (Station 040902) is located mid-catchment approximately 17 km upstream of the dam. Howard Post Office (Station 040098) is located 10 km to the north and downstream of Lenthalls Dam.

The rainfall data was provided as raw irregular time series data. This was processed and converted to regular time series, at time steps of 30 mins, for the purposes of this study. The processed rainfall data are plotted in Figure 3-1 for Lenthalls Dam and Figure 3-2 for Musket Flat.

In calibrating the December 2010 event, both the rainfall at Lenthalls Dam Alert and Musket Flat were initially weighted and used. However, it was later found that the rainfall data at Lenthalls Dam Alert had better correlation with the water levels in the dam and was adopted for the study.

The rainfall data at Howard Post Office was used for consistency checks but was not used for this study, as the rainfall data at Lenthalls Dam Alert was considered to be appropriate.

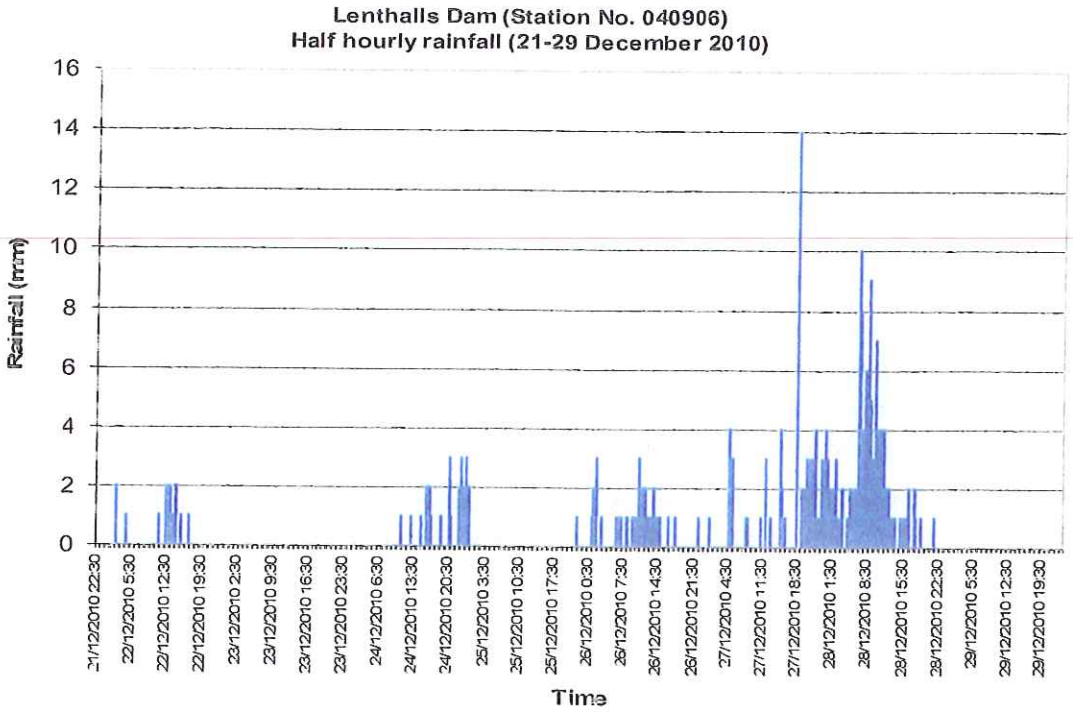

Figure 3-1 : Half-hourly Rainfall Data at Lenthalls Dam Alert (21-29 December 2010)

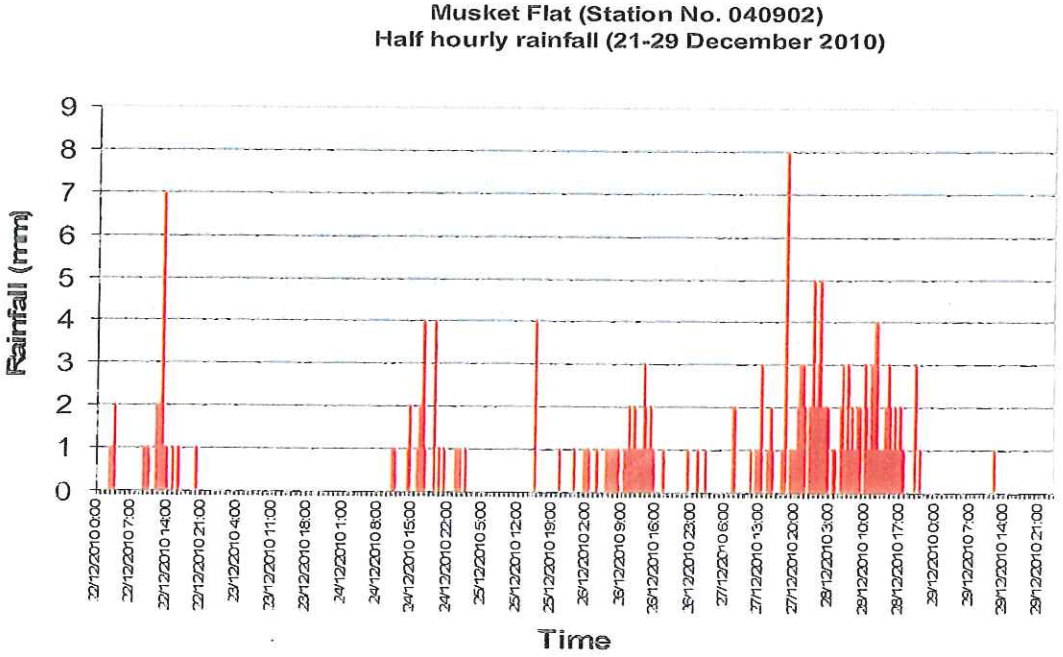

Figure 3-2: Half-hourly Rainfall Data at Musket Flat (21-29 December 2010)

3.3 Lenthalls Lanthalls Dam Discharge Characteristics

Dam storage characteristics and rating curves for the spillway Crest Gates were obtained from the 2009 report. The discharge curves, for scenarios with all the crest gates opened, and all the crest gates closed, are shown in Figure 3-3.

The scenario with all the crest gates opened represents the design dam operational rule as per the Lenthalls Dam Operation Manual, whereby Gate 3, Gate 2, Gate 4, Gate 5, and Gate 1 are progressively opened to release the floodwaters as the water level in Lenthalls Dam rises.

The scenario with all crest gates closed shows the behaviour of the dam in the event that the floodwaters are not released through the gates but discharged only over the spillway. In this case, the dam water levels are seen to rise steeply. This scenario occurred during the February 2008 storm event, when all the gates were jammed and could not be opened.

For the December 2010 storm event, the data log provided by Wide Bay Water indicated that some of the gates were opened, closed, and reopened at various times leading to the peak of the storm. There were problems with some of the equipment, including the SCADA and Lenthalls Dam radar level sensor. Gate 5 was also reported to have failed to open throughout the storm event. However the log indicated that Gates 1, 2, 3 and 4 were opened at 4.23 am (dam water level at 26.379) on the 27 December 2010. After that, no additional information on the status of the gates was recorded up to the time the dam water level peaked at 28.12 m (7.30 pm on 28 December 2010) and thereafter. It is noted that the recorded peak water level derived from the time series (Figure 3-5) is slightly higher at 28.183 m. This may be because the water level had not yet reached its peak at the time the entry was made in the event log. It is assumed that the actual peak water level was 28.183 m AHD.

The event log indicated that the crest gates did not function as designed or intended, and that only four of the five gates were operable. This meant that neither of the design discharge curves presented in Figure 3-3 was applicable during the December 2010 event.

In other to simulate the operation of the dam during the December 2010 event, a new discharge curve was derived to reflect the event log and sequence of gate opening, closure and re-opening adopted during that event. In doing so, the same discharge relationships used to model the original discharge curves in Figure 3-3 were adopted. The results are shown in Figure 3-4.

Figure 3-4 effectively shows a new discharge curve with only four of the five gates working (Gate 5 reportedly did not function). As expected, the new discharge curve lies between that for all five of the gates closed and all five of the gates opened.

The corresponding stage-storage and stage-discharge relationships established for the above 3 operational scenarios (all five gates closed, all five gates opened, four of five gates opened) are presented in Table 3-1 and Table 3-2.

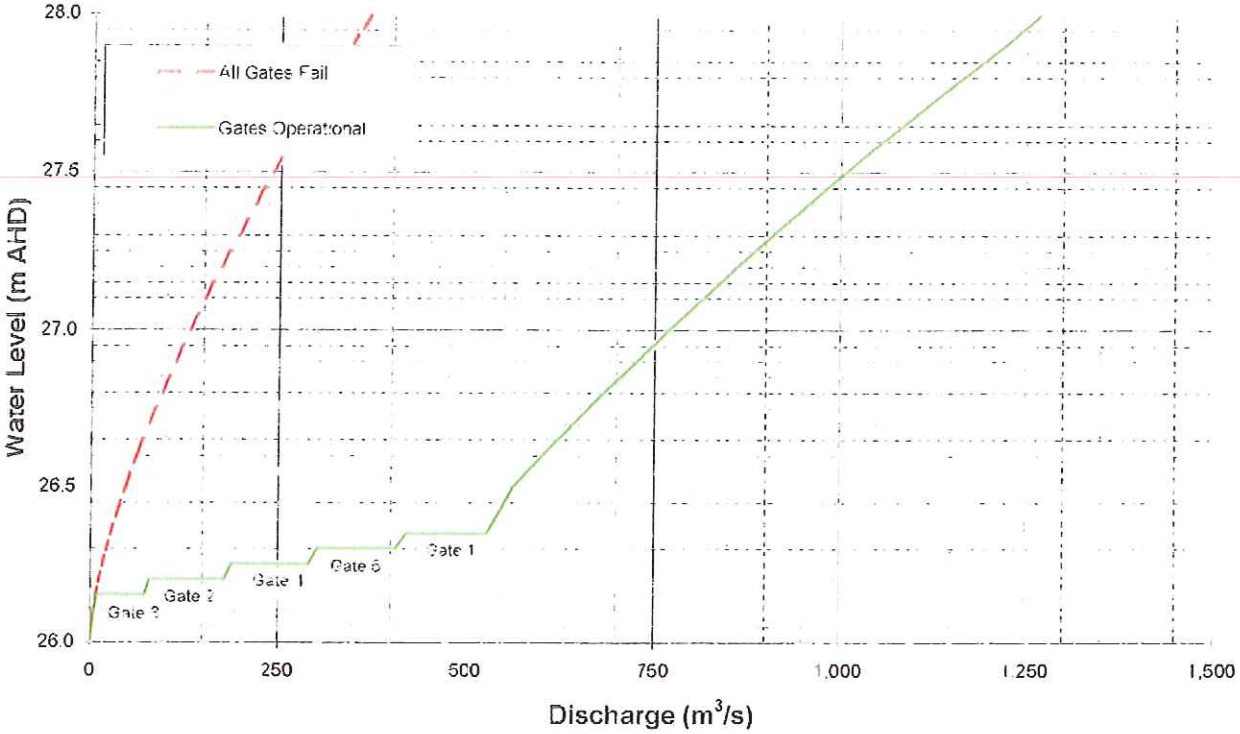

Figure 3-3: Discharge Data for Lenthalls Dam with Crest Gates Fully Operational and Fully Non-Operational

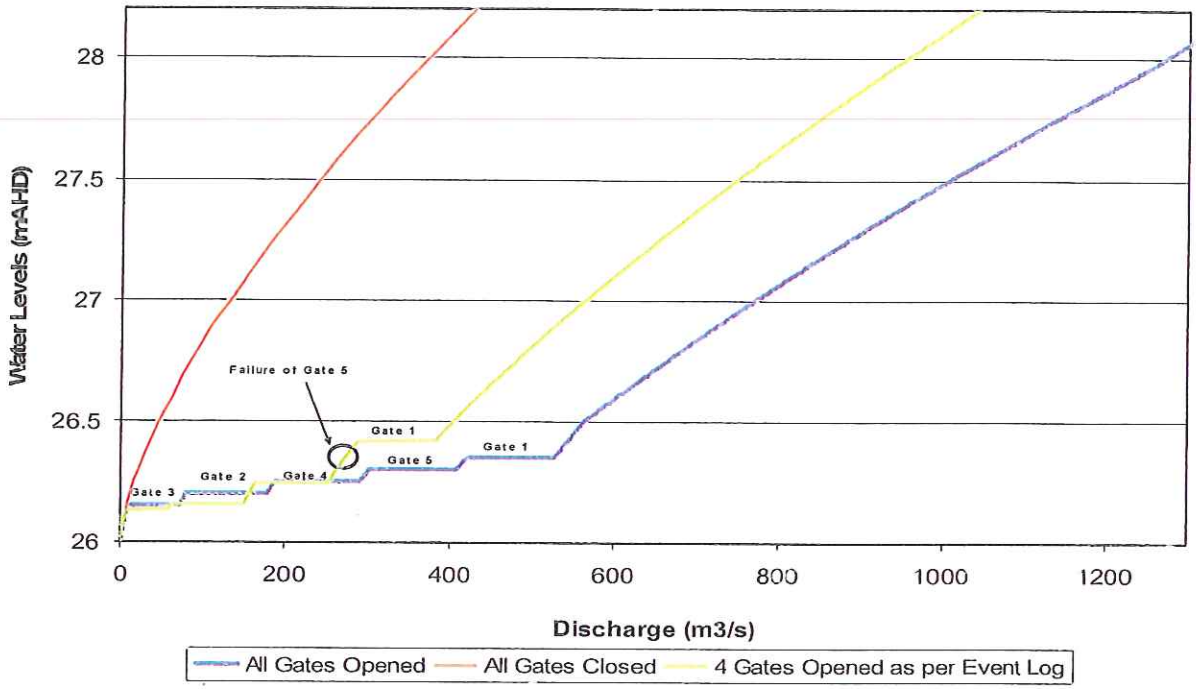

Figure 3-4: Discharge Curves for Lenthalls Dam with 5 Crest Gates Fully Opened, 5 Gates Fully Closed, and 4 of 5 Gates Opened

Table 3-1: Lenthalls Dam Stage Storage Discharge Data (All Gates Closed and All opened)

Elevation Storage	
Elevation (m)	Storage (ML)
12.00	0
12.20	0.67
14.00	512.7
16.00	1650
18.00	3801
20.00	6951
21.00	8938
21.40	9823
21.80	11,260
23.00	13,990
24.00	17,260
24.20	18,030
24.80	20,770
25.00	21,840
26.00 FSL	28,630
26.30	30,910
26.31	31,000
26.35	31,370
26.36	31,460
26.40	31,820
26.41	31,920
26.45	32,280
26.46	32,370
26.50	32,740
26.51	32,830
27.00	37,330
27.50	43,210
28.00	49,090
29.00	63,720
30.00	81,380
31.00	102,400
32.00	127,100
33.00	155,700
34.00	188,300
35.00	225,300

Storage Discharge		
Storage (ML)	Discharge m3/s	
	5 Gates Fully Opened	5 Gates Fully Closed
28,631	0	0
29,768	8.82	8
29,768	72.55	8
30,148	78.84	12
30,148	179.02	12
30,527	188.18	16
30,527	290.66	16
30,906	302.46	21
30,906	407.15	21
31,365	421.4	27
31,365	528.23	27
32,741	563.28	46
33,659	602.13	61
34,576	642.19	76
35,493	683.47	93
36,411	725.96	111
37,328	769.68	131
38,504	814.62	151
39,681	860.8	172
40,857	908.2	193
42,034	956.85	216
43,210	1006.7	240
44,386	1057.9	264
45,563	1110.3	289
46,739	1163.9	315
47,916	1218.8	342
54,943	1470.9	485
62,257	1740.9	644
70,782	2028.2	818
79,610	2332.4	1005
89,783	2653.3	1204
100,292	2990.6	1415
112,267	3321.5	1638
124,608	3663.7	1870
138,508	4017	2113
152,799	4381	2365
168,712	4755.3	2627
185,030	5139.7	2898
203,115	5533.9	3177

Table 3-2: Lenthalls Dam Stage Storage Discharge (Gates 1, 2, 3, 4 Opened, Gate 5 Closed)

Elevation Storage	
Elevation (m)	Storage (ML)
12.00	0
12.20	0.67
14.00	512.7
16.00	1650
18.00	3801
20.00	6951
21.00	8938
21.40	9823
21.80	11,260
23.00	13,990
24.00	17,260
24.20	18,030
24.80	20,770
25.00	21,840
26.00 FSL	28,630
26.30	30,910
26.31	31,000
26.35	31,370
26.36	31,460
26.40	31,820
26.41	31,920
26.45	32,280
26.46	32,370
26.50	32,740
26.51	32,830
27.00	37,330
27.50	43,210
28.00	49,090
29.00	63,720
30.00	81,380
31.00	102,400
32.00	127,100
33.00	155,700
34.00	188,300
35.00	225,300

Storage Discharge	
Storage (ML)	Discharge (m3/s)
	Gates 1, 2, 3, 4 Opened (Gate 5 closed)
28,631	0
29,010	1.7
29,389	4.8
29,617	7.1
29,617	55
29,768	64
29,806	64
29,806	149
30,148	156
30,474	163
30,474	251
30,527	252
30,906	263
31,365	274
31,824	285
32,007	289
32,007	383
32,282	391
32,741	404
33,200	418
33,659	433
34,117	448
34,576	464
35,035	479
35,493	496
35,952	512
36,411	528
36,869	545
37,328	562
37,916	579
38,504	598
39,093	615
39,681	634
40,269	652
40,857	670
41,445	689
42,034	708
42,622	728
43,210	747
43,798	767
44,386	787
44,975	807
45,563	828
46,151	848
46,739	869
47,327	890
47,916	912

3.4 Water Level Data

Water level records were obtained at Lenthalls Dam Alert (Station No. 040906) and Howard Alert (Station No. 040907). Howard Alert is located approximately 8 km downstream of Lenthalls Dam Alert.

The water levels recorded at Lenthalls Dam are presented in Figure 3-5, while those at Howard Alert are presented in Figure 3-6. It is noted that the discharge from Lenthalls Dam (catchment area 511 km^2) provides most of the discharge into Howard Alert (catchment area 610 km^2). There is, however, approximately 100 km^2 of catchment area downstream of Lenthalls Dam which also discharges into Howard Alert.

Based on Figures 3-5 and 3-6, the recorded peak water level at Lenthalls Dam was 28.183 m AHD (6 pm, 28 December), while that at Howard Alert was 7.42 m AHD (2 pm, 28 December).

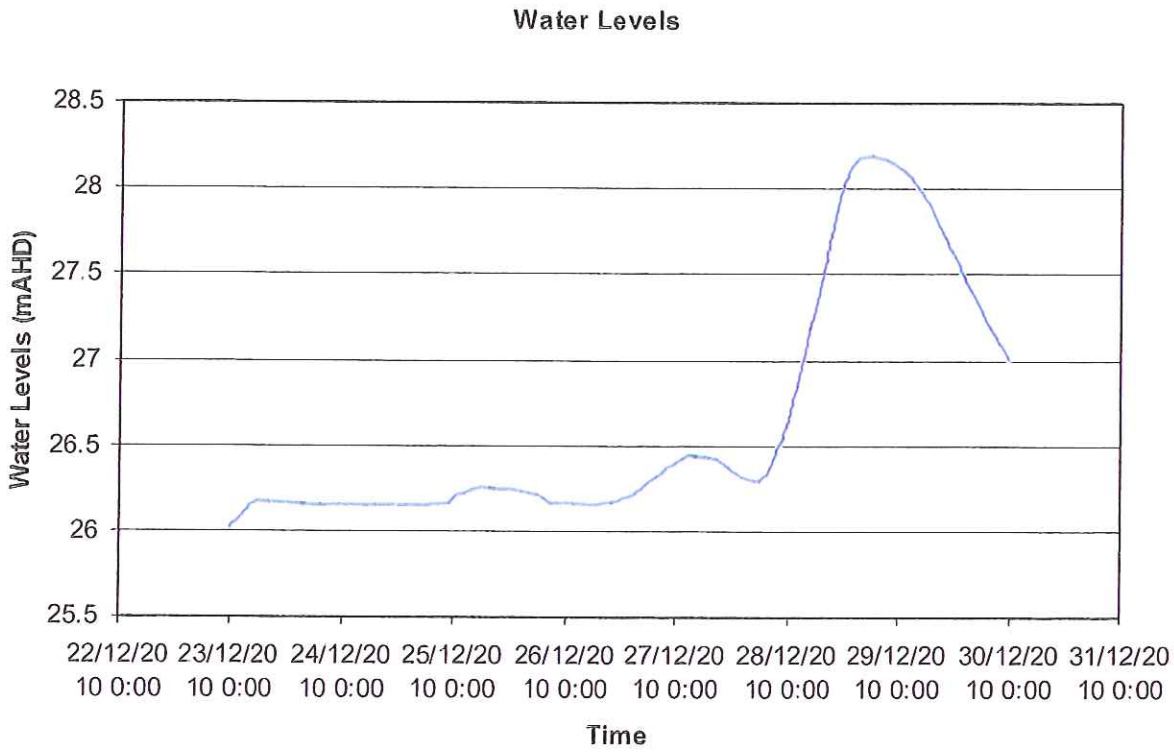

Figure 3-5: Water Level Data Recorded at Lenthalls Dam for December 2010 Storm Event

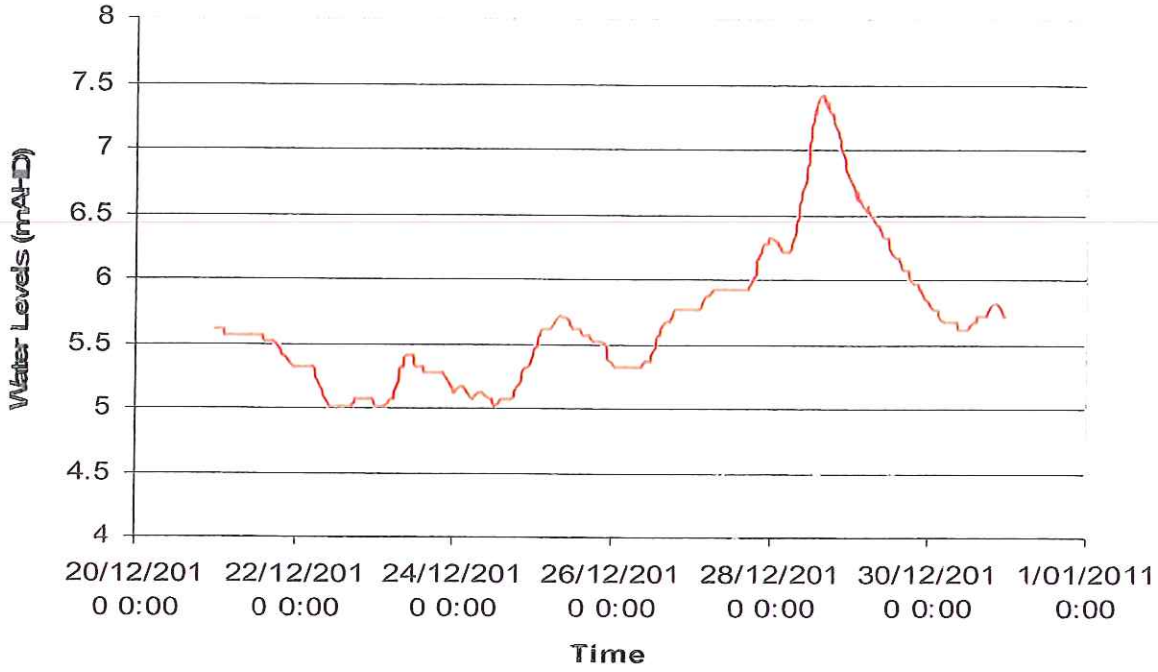

Figure 3-6: Water Level Data Recorded at Howard Alert for December 2010 Event

3.4.1 Calibration of RORB Model

The same model used to simulate the February 2008 event was used to assess the December 2010 event. As noted earlier, the original calibration parameters were initially adopted (Table 3-3). These parameters were later varied to test the robustness of the previous calibration in assessing the December 2010 storm event.

Table 3-3: RORB Parameters (February 2009 model)

Parameter	Adopted Value
Catchment kc	30
Catchment m	0.8
Initial Loss (mm)	8
Continuing Loss (mm/hr)	2

4. Findings

4.1 RORB Model Results

A range of calibration parameters were trialled in the RORB model in assessing the robustness of the model and in examining the December 2010 storm event. The results are presented in Table 4-1 for 3 gate operation scenarios as follows:

- Scenario 1 – All 5 gates opened and operational;
- Scenario 2 – All 5 gates closed and non-operational; and
- Scenario 3 – 4 gates opened (Gates 1, 2, 3, and 4), and 1 gate closed (Gate 5) as per Event Log for December 2010 Event.

For Scenario 1, the results for 15 runs are presented, while for Scenarios 2 and 3, the results for 4 runs and 7 runs are presented, respectively. The RORB model hydrographs for some of these model runs are also plotted in Figures 4-1 to 4-6. It is noted that in Figures 4-1 to 4.6, the recorded hydrographs were derived using the Lenthalls Dam water levels recorded by Wide Bay Water and the Bureau of Meteorology.

Scenario 1 (All Gates Opened)

In Table 4-1 , the results for Scenario 1 indicate that the peak water level at the dam could not possibly have reached the recorded peak of 28.18 m AHD, with all the 5 gates opened and operational. This was the case for the full range of model parameters tested. Example plots, for RUN 1A, RUN 1I and RUN 1J, are shown in Figure 4-1, Figure 4-2 and Figure 4-3,

It is noted that the model parameters k_c and m represent the intrinsic characteristics of the catchment, which were previously determined, and it was not expected that these parameters would have to be altered in validating the model. Nevertheless, the results confirmed that Scenario 1 does not apply and that in fact the gates were not all operational during the December 2010 storm event.

The results for Scenario 1 also indicate that the model, when applied to the December 2010 event, was not particularly sensitive to initial loss but more sensitive to continuing loss. This was due to the long duration storm for the December 2010 event, as expected.

Scenario 2 (All Gates Closed)

In Table 4-1, the results for Scenario 2 indicate that the peak water level in the dam would reach the recorded peak of 28.18 m AHD if the 5 gates had been closed and non-functional. In addition to the peak discharge, the timing and shape of the modelled hydrograph also matched the recorded data (Figure 4-4).

These results were not expected if the gates had been functioning. However, it is interesting to note in Figure 4-4 that there was a rapid drop in the recorded dam water level at the falling limb after passage of the dam peak water level. While this cannot be confirmed, one possibility is that the gates somehow closed and opened again after the peak of the storm had passed.

Table 4-1: Results of Calibration Tests

Scenario	Kc	m	Initial Loss (mm)	Continuing Loss (mm/hr)	Peak Q in (m^3/s)	Peak Q out (m^3/s)	Modelled Dam Water Levels (m AHD)		Recorded Peak (m AHD)
							Starting	Peak	
Original Model (2008 storm)	30	0.8	8	2					
Scenario 1 Gates All Operational									
1A	30	0.8	8	2	734.73	609.66	25.98	26.62	28.183
1B	30	0.8	7	2	734.73	609.66	25.98	26.62	28.183
1C	30	0.8	5	2	734.73	609.66	25.98	26.62	28.183
1D	30	0.8	3	2	734.73	609.66	25.98	26.62	28.183
1E	30	0.8	0	2	734.73	609.66	25.98	26.62	28.183
1F	30	0.8	8	1.5	805.96	659.42	25.98	26.74	28.183
1G	30	0.8	8	1	876.89	713.91	25.98	26.87	28.183
1H	30	0.8	8	0.5	947.59	770.46	25.98	27.00	28.183
1I	30	0.8	8	0	1018.17	819	25.98	27.11	28.183
1J*	30	0.8	8	2	448.12	413.07	25.98	26.32	28.183
1K*	30	0.8	8	1	577.81	535.51	25.98	26.38	28.183
1L*	30	0.8	8	0	721.42	629.49	25.98	26.67	28.183
1M	20	0.8	8	2	891.103	694.01	25.98	26.82	28.183
1N	10	0.8	8	2	1227.36	824.95	25.98	27.12	28.183
1O	0	0.8	8	2	3699.36	942.72	25.98	27.37	28.183
Scenario 2 All Gates Closed									
2A	30	0.8	8	2	734.73	433.2	25.98	28.215	28.183
2B	30	0.8	8	2.1	722.76	425.38	25.98	28.188	28.183
2C	30	0.8	8	2.11	721.57	424.59	25.98	28.185	28.183
2D	30	0.8	8	2.12	720.38	423.81	25.98	28.182	28.183
Scenario 3 4 Gates Opened as per Event Log									
3A	30	0.8	8	2	734.73	557.87	25.98	26.99	28.183
3B	30	0.8	8	1.5	805.96	603.46	25.98	27.12	28.183
3C	30	0.8	8	1	876.89	655.08	25.98	27.26	28.183
3D	30	0.8	8	0.5	947.59	711.54	25.98	27.41	28.183
3E	30	0.8	8	0	1018.17	770.04	25.98	27.56	28.183
3F	12	0.8	0	0	1440.51	945.18	25.98	27.98	28.183
3G	<12	0.8	0	0	critical model error				

*Using weighted rainfall at Lenthalls Dam and Musket Flat. Other runs use rainfall at Lenthalls Dam only.

Scenario 3 (4 Gates Opened, 1 Gate Failed as per Event Log)

In this Scenario, the exact sequence of gate opening, closure and re-opening was followed as per the Event Log, and 4 gates were assumed to have opened, with the 5th gate failing to open, as noted earlier.

The results, presented in Table 4-1, are rather surprising. Essentially, they showed that the recorded peak water level in the dam of 28.18 m AHD could not possibly be reached using the Event Log. This was the case for the full range of model parameters tested, including the use of impractical parameters. Example plots for RUN 3A and RUN 3E are shown in Figure 4-5 and Figure 4-6. In these two runs, the peak RORB model levels are between 0.6 to 1.2m lower than the recorded peak dam level.

This raises the possibility that all the gates had somehow failed to open during the peak of the storm, which would be consistent with the results for Scenario 2.

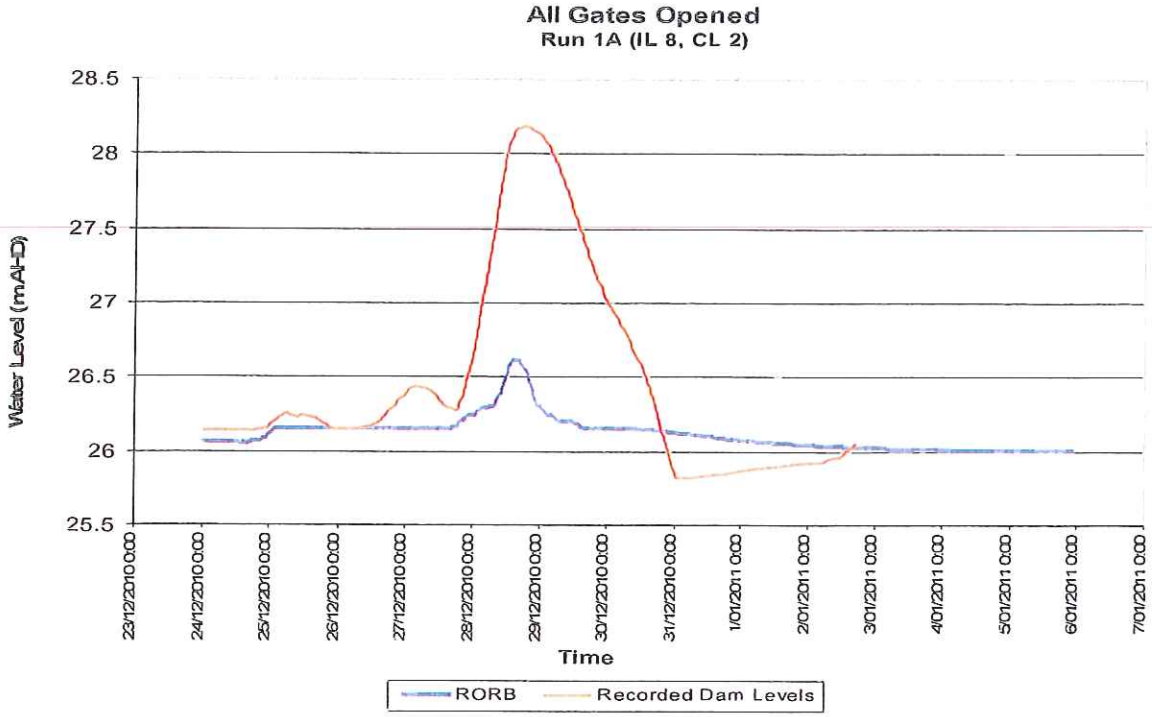

Figure 4-1: Scenario 1A (All Gates Opened) Dam Outflow Hydrographs

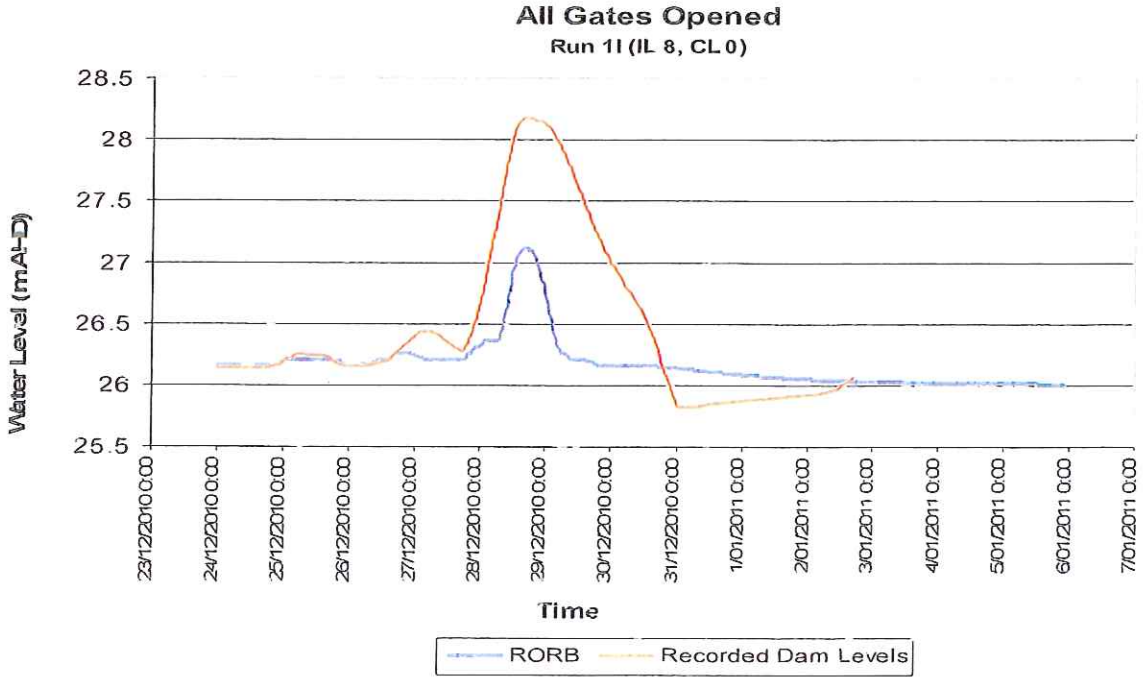

Figure 4-2: Scenario 1I (All Gates Opened) Dam Outflow Hydrographs

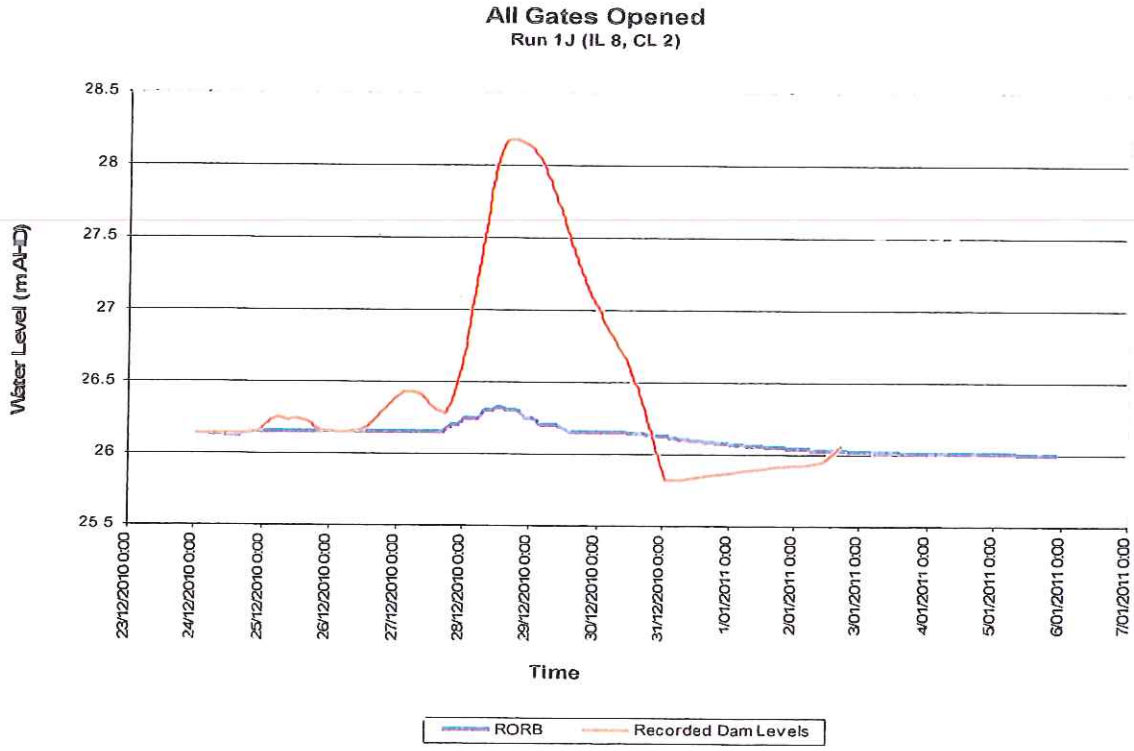

Figure 4-3: Scenario 1J (All Gates Opened) Dam Outflow Hydrographs

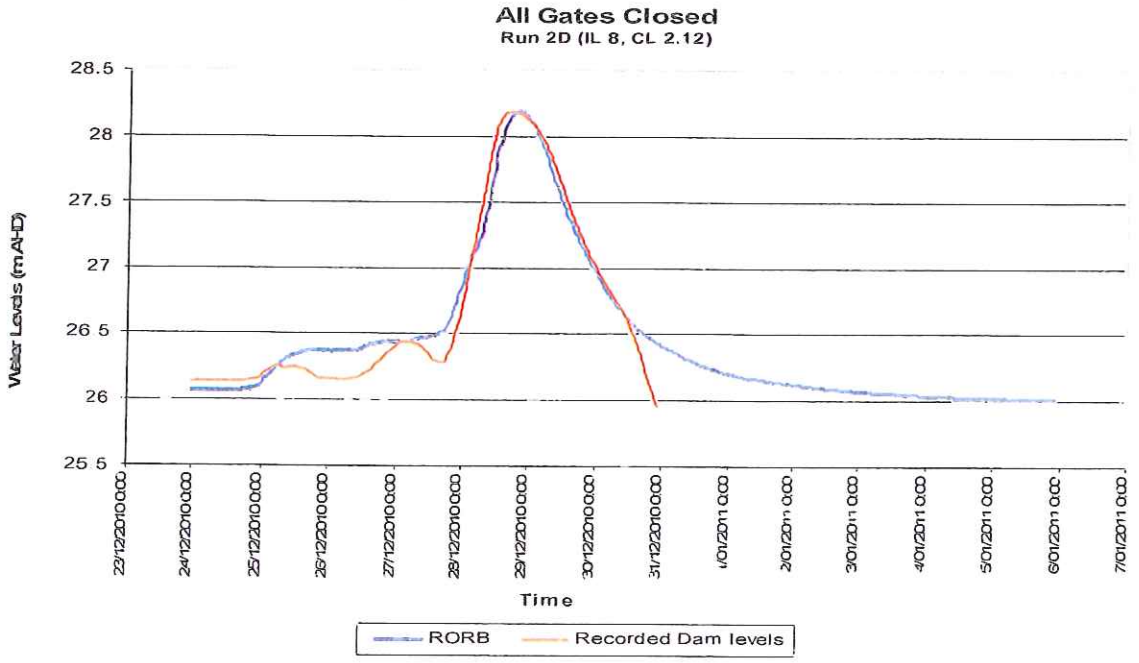

Figure 4-4: Scenario 2D (All Gates Closed) Dam Outflow Hydrographs

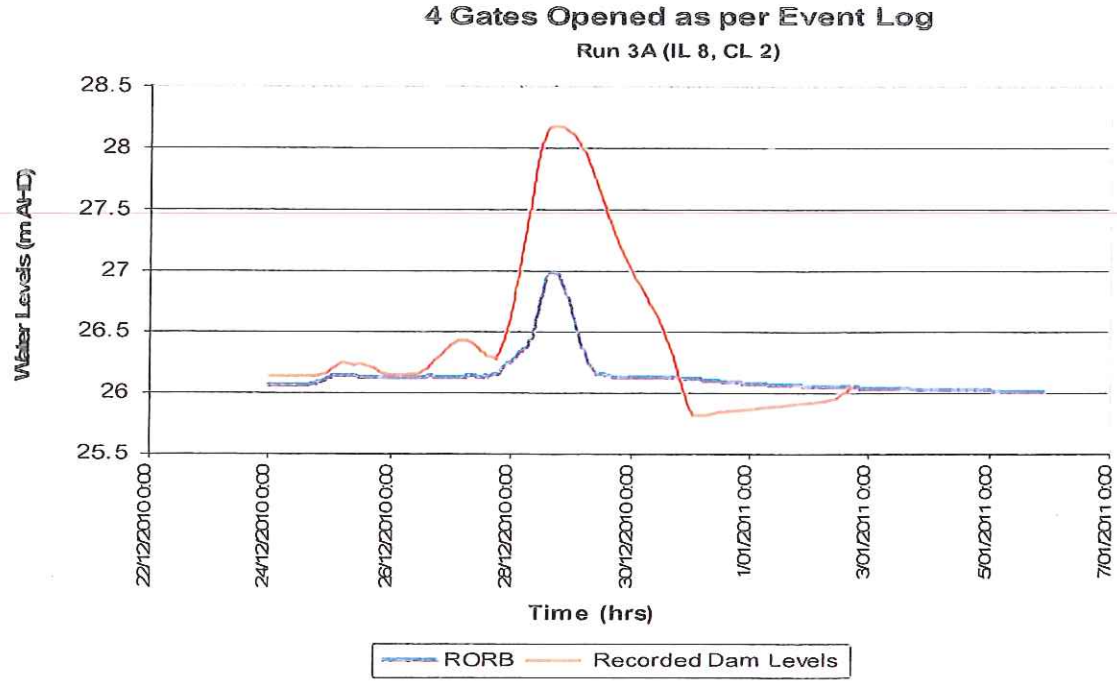

Figure 4-5: Scenario 3A (Event Log) Dam Outflow Hydrographs

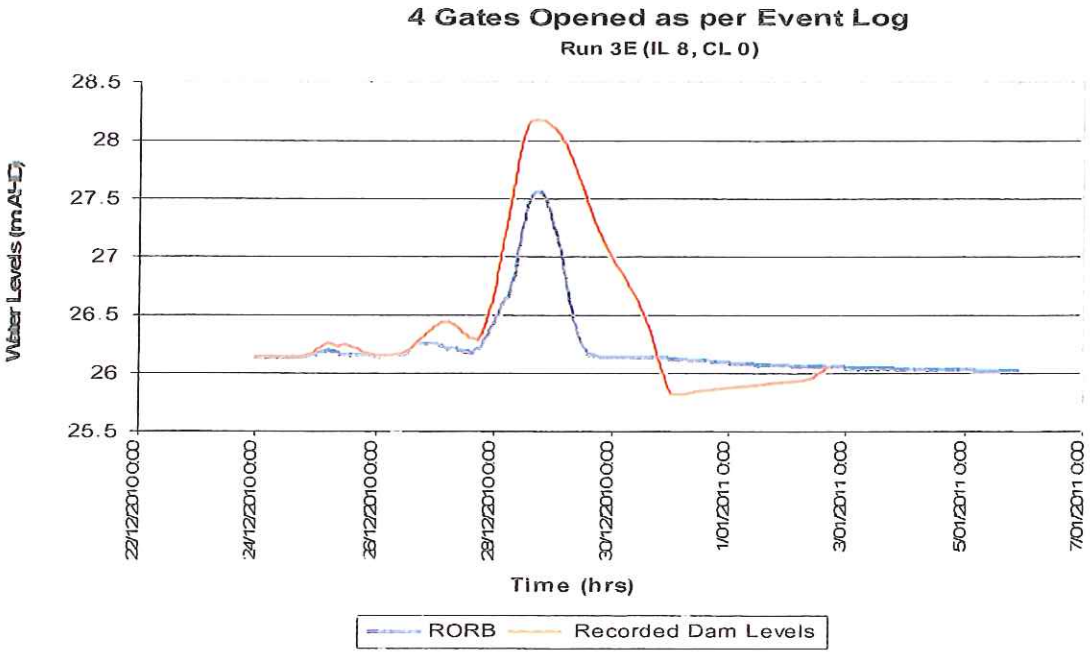

Figure 4-6: Scenario 3E (Event Log) Dam Outflow Hydrographs

4.2 Magnitude of December 2010 Event

In order to assess the magnitude of the December 2010 storm event, the recorded rainfall depths were compared with design rainfall depths for the full range of durations from 1 hour to 120 hours (5 days). In Table 4-2, the comparison suggests that the December 2010 event was a relatively small event, with a magnitude significantly less than that for a 1 in 5 year ARI event. This was the case for all the durations checked. It is noted that in Table 4-2, the 1 in 2 year ARI design rainfall depths were not available and therefore not shown.

In Table 4-3, design water levels for the dam are extracted from the Lenthalls Dam Flooding Report (2009) and examined. These design levels are based on the stage-storage-discharge relationships for the dam and form the basis for the design and operation of the dam. Accordingly, with all the gates opened, the peak water level in the dam is not expected to exceed 28 m AHD, up to the 1 in 50 year ARI event. However, a dam water level of 28 m AHD would be exceeded at the 1 in 5 year ARI event if the gates are closed.

Considering that the rainfall intensities for the December 2010 event were rather small and less than that for the 1 in 5 year ARI event, it does not appear consistent or plausible that the peak water level in the dam could have risen to that of the 1 in 50 year design dam level with all the gates opened. This is notwithstanding a scenario with 4 instead of 5 gates opened.

By contrast, the results are consistent with the design case with all the gates closed. It can be seen from Table 4-2 and Table 4-3, that the magnitude of the December 2010 storm (rainfall intensities and dam water level less than 1 in 5 year ARI) matches that of the design condition for a 1 in 5 year ARI event with all the gates closed.

Overall, the above results are consistent with the likelihood that the gates had somehow shut closed during the peak of the December 2010 event.

Table 4-2: Comparison of Recorded Rainfall Depths for December 2010 Event with Design Depths

Duration	Peak Recorded Rainfall Depth for December 2010 Event	Design Rainfall Depth (CRC Forge)[1]		
		1 in 5 year ARI	1 in 10 year ARI	1 in 20 year ARI
1 hr	15	61	69	79
3 hrs	39	87	99	114
6 hrs	66	109	123	142
12 hrs	82	135	154	178
18 hrs	123	161	185	217
24 hrs	143	182	211	248
120 hrs	238	269	311	366

1. Lenthalls Dam Flooding Report, GHD 2009

Table 4-3: Design Dam Water Levels

Design Condition	Recorded Level (m AHD)	Design Peak Water Level at Lenthalls Dam (m AHD)[1]					
		1 in 2 year ARI	1 in 5 year ARI	1 in 10 year ARI	1 in 20 year ARI	1 in 50 year ARI	1 in 100 year ARI
All Gates Closed		27.81	28.52	28.88	29.3	29.86	30.26
All Gates Opened		26.39	26.94	27.23	27.63	28.15	28.52
February 2008	27.45						
December 2010	28.18						

1: Lenthalls Dam Flooding Report. GHD 2009

4.3 Howard Alert Water Level Records (Burrum No. 1 Dam)

The water level data available at Howard Alert (Station No 040907) were obtained and analysed to assist in understanding the flow behaviour and what may have happened at Lenthalls Dam. As noted earlier, Howard Alert is located downstream of Lenthalls Dam, with approximately 100 km^2 of catchment area in-between.

It is noted that Lenthalls Dam reached a peak water level of 28.18 m AHD at 6 pm on the 28 December 2010 (Figure 3-5). By comparison, Howard Alert reached a peak water level of 7.42 m AHD at 2 pm on the 28 December 2010 (Figure 3-6). At Howard Alert, the water level was at about 7.1 m AHD between 6 to 7 pm on the same day. Based on the rating curve for Howard Alert, a water level of about 7.1 m AHD corresponds to a discharge of approximately 650 m^3/s (Figure 4-7).

In Table 4-4, the discharge at Howard Alert is estimated using the stage-storage-discharge data for Lenthalls Dam, coupled with the intervening catchment area flow between Lenthalls Dam and Howard Alert, and then compared with the recorded discharge at Howard Alert. The purpose of this comparison is to establish the order of magnitude of flow that would be expected at Howard Alert if the gates at Lenthalls Dam had either been fully opened, fully closed, or partially opened.

Based on a catchment area of 511 km^2 at Lenthalls Dam and a peak inflow of 735 m^3/s, the 100 km^2 intervening catchment area downstream of Lenthalls Dam was estimated to have a peak contributing flow of approximately 142 m^3/s into Howard Alert.

With the Lenthalls Dam gates all opened, a peak water level of 28.18m is estimated to yield a peak discharge of 1362 m^3/s. With 4 of the 5 gates opened (Gate 5 closed), the peak discharge would reduce to 1034 m^3/s. This would further reduce to 424 m^3/s if all the gates are closed.

In Table 4-4, taking into account the discharge from Lenthalls dam and that from the contributing catchment downstream of Lenthalls Dam, it is clear that the recorded discharge at Howard Alert could not possibly have been only of the order 650 m^3/s if 4 of the 5 Lenthalls Dam gates were opened. This is

because the corresponding discharge from Lenthalls Dam alone would have exceeded that flow. However, the results are entirely consistent if the gates were all closed. In this case, the estimated total discharge of 566 m^3/s at Howard Alert compare favourably with the recorded discharge of 650 m^3/s.

On the basis of the above results, it is concluded that the Lenthalls Dam gates were most probably closed during the peak of the December 2010 event.

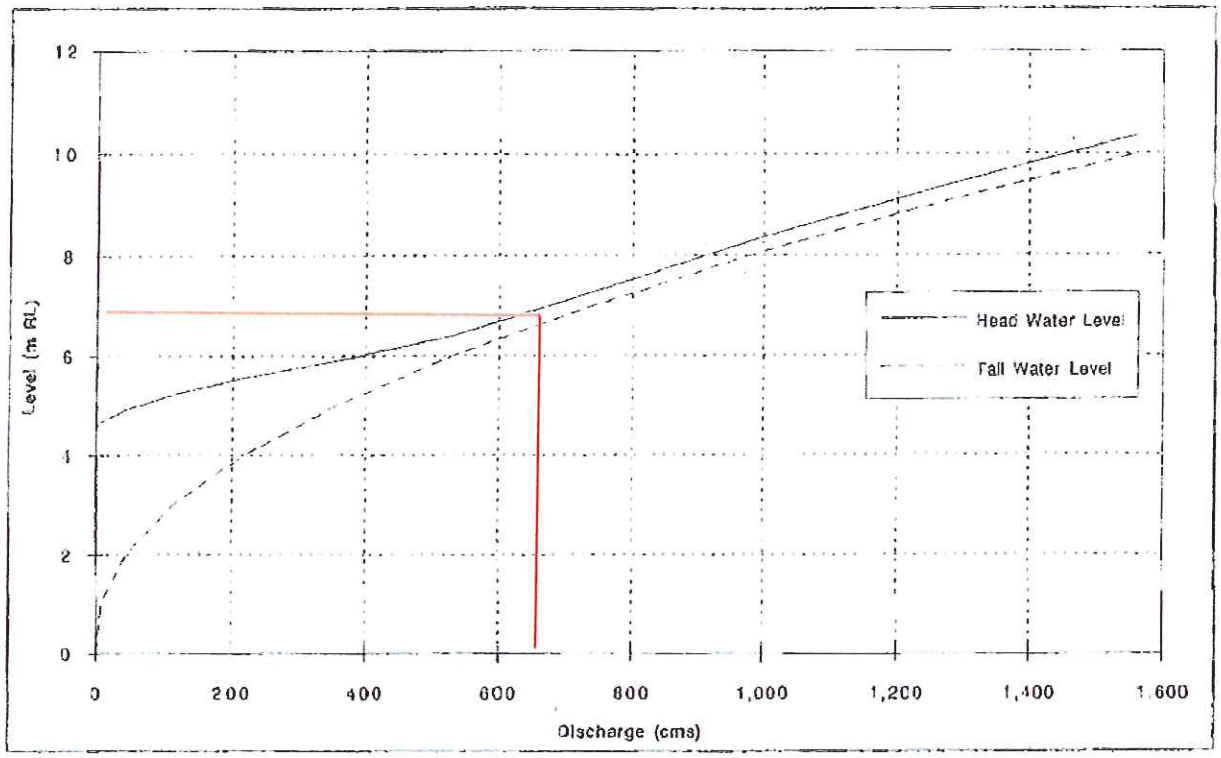

Figure 4-7: Rating Curve for Howard Alert (Burrum No 1 Dam)

Table 4-4: Estimated and Recorded Discharge at Howard Alert

Scenario	Lenthalls Dam		Downstream Catchment Flow (100 km^2)[1] (m^3/s)	Estimated Discharge at Howard Alert (m^3/s)	Recorded Discharge at Howard Alert (m^3/s)
	Peak Level (m AHD)	Peak Discharge (m^3/s)			
All Gates Opened	28.18	1362	142	1504	650
All Gates Closed	28.18	423.9	142	566	650
4 Gates Opened (Gate 5 Closed)	28.18	1034.3	142	1176	650

1: This catchment area exists between Lenthalls Dam and Howard Alert

4.4 Analysis of Gate Malfunction

In order to identify the period during which the gates may have malfunctioned, the recorded flows at Howard Alert and Lenthalls Dam were plotted and compared. As the flow at Howard Alert is made up of the flow from Lenthalls Dam and the 100 km^2 intervening catchment between these gauges, any period of time where the recorded flow at Lenthalls Dam is greater than that at Howard Alert would therefore be erroneous.

The results are plotted in Figure 4-8. It is noted that the recorded flows at Lenthalls Dam and Howard Alert were derived from the recorded water levels and their respective rating curves. For comparison, the flows with all the Lenthalls Dam crest gates hypothetically closed, with 4 of the gates hypothetically opened, as well as the modelled inflow at Lenthalls Dam, are also included.

In Figure 4-8, it is evident, based on the recorded flow at Howard Alert, that flow regulation at the Lenthalls crest gates did occur. This is characterised by the distinct regulated flow pattern at Howard Alert for extended periods of time on the 22 December, 23 December, 25 December and 27 December. In other words, the opening and closure of the crest gates at Lenthalls Dam did work up to that time.

However, it is evident that the Lenthalls crest gates malfunctioned at around 17:36 hours on the 27 December (WSL = 26.284 m) to 04:07 hours on the 28 December (WSL = 27.1 m). At around this time, it is seen that the Lenthalls Dam discharge, with 4 gates hypothetically opened, begins to exceed that at Howard Alert, which is erroneous and not possible.

Another indicator of the malfunction is the shape of the Howard Alert hydrograph at around the above times (17:36 hours 27 December to 04:07 hours 28 December). During this time period, it can be seen that the Howard Alert hydrograph shape is markedly similar to the Lenthalls Dam inflow shape. While not definitive, this suggests that there was no discharge from the Lenthalls Gates, and the inflow into Lenthalls Dam was essentially spilling over the spillway.

Interestingly, the recorded flow pattern at Howard Alert suggests that flow regulation kicked in again after around 17:50 hours on the 29 December (WSL = 27.28 m). This means that the gates functioned during the early hours of the storm event, malfunctioned as the dam water levels rose, but somehow functioned again after the water levels dropped.

Overall, the above findings support the notion that the Lenthalls Dam crest gates malfunctioned and somehow shut closed during the peak of the December 2010 storm event. This resulted in the dam water levels rising to a peak of 28.183 m AHD, which would not have occurred if the gates had operated as intended.

4.5 Design Flood Levels Upstream of Lenthalls Dam

The design flood levels upstream of Lenthalls Dam have previously been determined in the Lenthalls Dam Flood Study Report (GHD 2009). This covers the full range of flood events from the 1 in 2 year AR event to the 1 in 100 year ARI event, and includes Doongul Creek, Logbridge Creek, and several un-named tributaries. The reader is referred to the 2009 report for full details of the design flood levels along those watercourses.

Taking into account the December 2010 storm event, it is considered that the design flood levels established in the 2009 Report for the watercourses upstream of Lenthalls Dam are still relevant, appropriate and would remain unchanged. In essence, the December 2010 event was a relatively small event, and the unexpected high water levels in the dam was attributed to the failure of the crest gates.

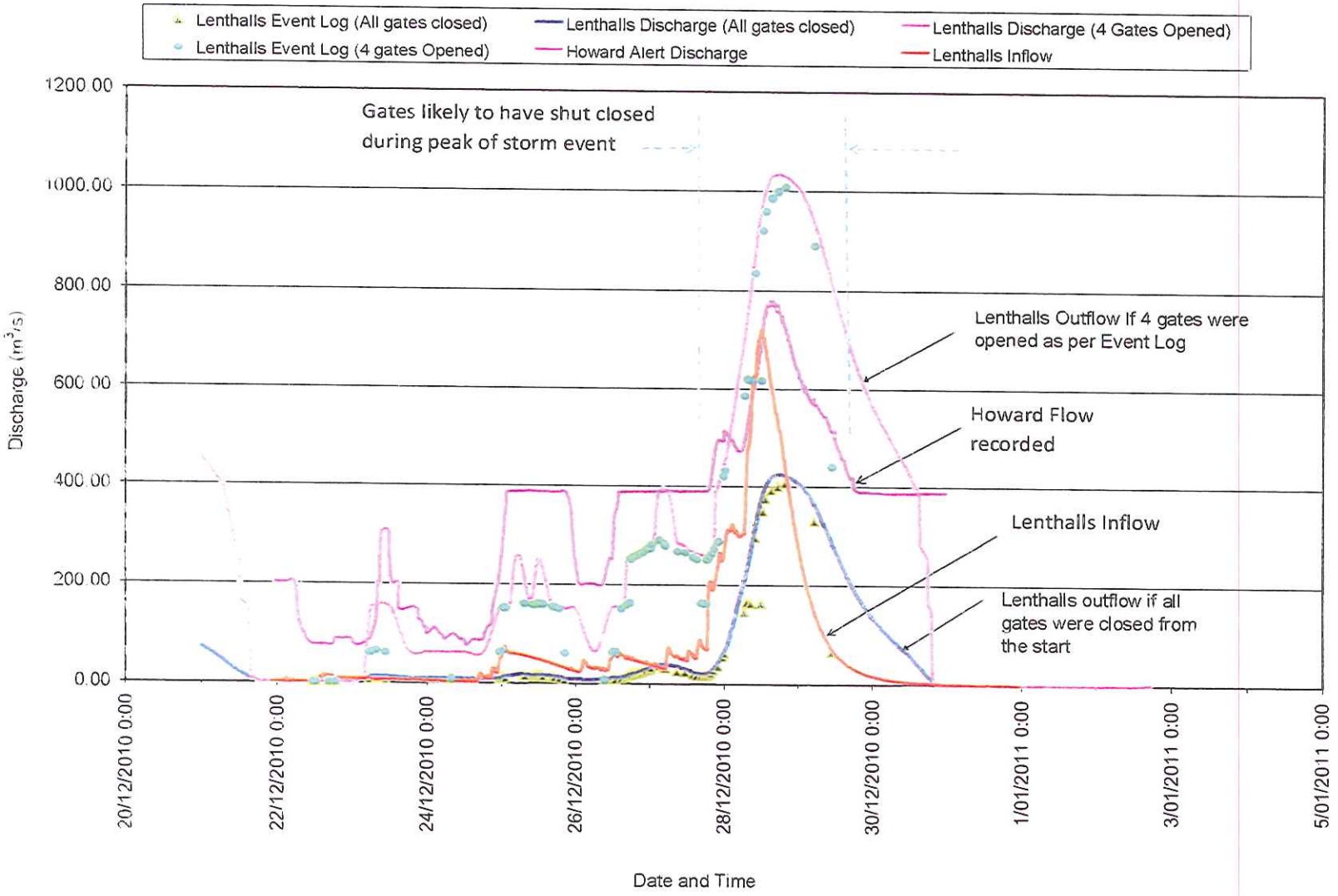

Figure 4-8: Analysis of Lenthalls Dam Gate Malfunction

5. Conclusions

The December 2010 storm event was assessed using the hydrological model RORB previously developed and calibrated for the Lenthalls Dam catchment. The results indicated that calibration of the December 2010 event was only possible if the Lenthalls Dam gates had been fully closed rather than opened during the peak of the storm.

The magnitude of the rainfall intensities for the December 2010 event was found to be relatively small and less than that for the 1 in 5 year ARI event. On this basis it was found that the peak water level of 28.18 m AHD recorded at the dam would occur only if all the crest gates were closed during the storm event.

It was found that the relatively small December 2010 event would have had to behave as a 1 in 50 year ARI event for it to reach a peak water level of 28.18 m AHD. This was not considered to be plausible.

Comparison of the peak flow recorded at Howard Alert (Burrum No. 1 Dam) with that estimated using the Lenthalls Dam data and RORB model, indicated that the recorded flows are consistent with the Lenthalls Dam gates being all closed.

Further analysis of the recorded flows at Howard Alert and Lenthalls Dam indicated that the Lenthalls Dam gates did operate, and opened and closed, during the early stages of the December 2010 event. However, as the water levels in the dam rose, the gates malfunctioned and shut closed. The gates then appeared to work again after passage of the storm peak.

It is concluded that the Lenthalls Dam gates were faulty and did not function as intended during the peak of the December 2010 storm event. This led to the dam water levels rising to higher than expected levels for a storm the size of the December 2010 event. In terms of design flood levels in the watercourses upstream of Lenthalls Dam, it is considered that the flood levels established in the 2009 report, for the full range of events up to the 1 in 100 year ARI flood, are still appropriate and remain unchanged.

Considering that malfunction of the gates for a relatively small event could lead to a significant rise in water level at the dam, a major storm event could potentially result in major consequences. It is recommended that the dam design as well as the operation of the crest gates be reviewed, with the view of rectifying any faults to mitigate against any potentially adverse impacts.

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