# APPENDIX E: EXAMPLE OF RAPID IMPACT ANALYSIS

# APPENDIX E : EXAMPLE OF RAPID IMPACT ASSESSMENT

**RAPID IMPACT ASSESSMENT**
**for reservoirs owned by Xenon plc on**
**Rivers Anduin, Aries and Kappa**

**Preface**

1. This example Impact assessment, although based on a real cascade, has been edited in respect of key features of the cascade and downstream valley to preserve the anonymity of the dam, including names.
2. This example plan is completed in respect of the impact assessment for the River Anduin, but excludes the detailed results for Rivers Aries and Kappa, in the interests of brevity.
3. For the reservoirs covered by this plan a rapid method would not normally be appropriate, as it should be evident by inspection that the dams are high consequence such that a standard impact assessment is warranted. Nevertheless this rapid assessment has been carried out on the same set of dams to
    - contrast the accuracy and content of the two methods
    - provide an example of a raid analysis that may be appropriate for low consequence dams

**Change log for plan**

| Rev | Date | Details of nature of change | By | Ckd | Approved | | Accepted by EA |
|---|---|---|---|---|---|---|---|
| | | | | | Owner | Panel AR[1] | |
| A01.01 | 17/06/2005 | Issued to Environment Agency for examination and acceptance | FJBS | AJB | EHG | JDG | Na |
| A01.02 | 15/08/2005 | Accepted by Environment Agency | - | - | - | - | ABC |
| A02.01 | 2/3/20012 | Add new housing estate to consequence tables | RTS | SEG | EHG | JDG | GTF |
| | | | | | | | |

Notes
1. Documented in signed off separate statement by Qualified Civil Engineer

## Contents



**Tables**



**Figures**

# 1 OBJECTIVES, SCOPE AND ADMINISTRATION OF THE IMPACT ASSESSMENT

## 1.1 Objectives

This plan forms part of the risk management of the reservoirs listed in Table 1, comprising an assessment of the potential consequences in the event of dam failure. It also satisfies the requirements for Element I of a Flood Plan under Section 12A of the Reservoirs Act 1975 (added through Section 77 of the Water Act 2003).

## 1.2 Scope

This assessment covers some of the reservoirs and dams in the lower cascade above the Rivers Anduin, Aries and Kappa as listed in Tables 1 and 2 and shown on Figure 1.1.

There is an upper cascade comprising one reservoir upstream of Beta reservoir, but separated by a community (the village of Bree).

The analysis has been carried out by JACOBS, Leatherhead under contract to Xenon plc.

**Table 1 : Reservoirs and dams covered by this Impact assessment (owned by Xenon plc)**

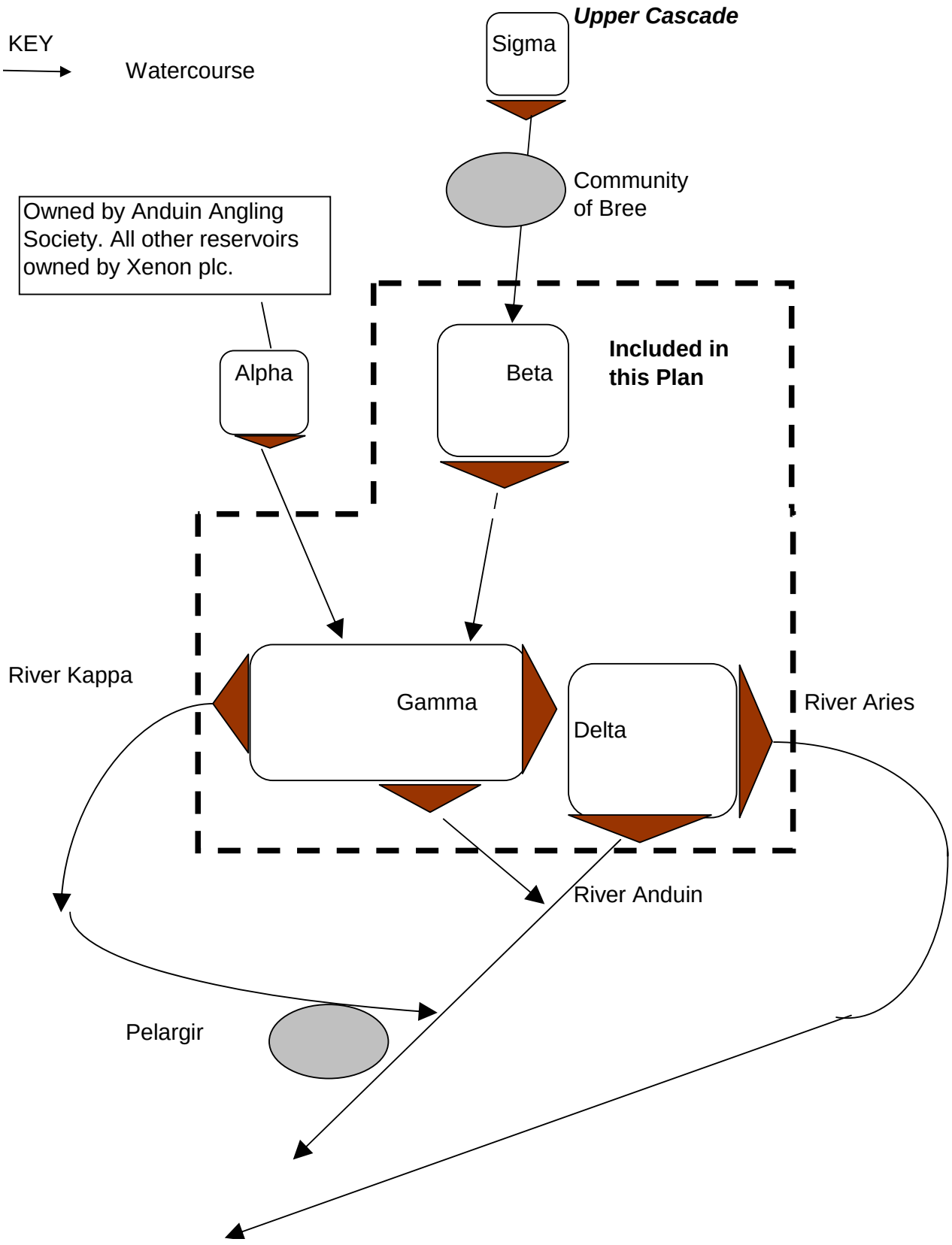
| Reservoir | | Dams | | | | Reservoir or watercourse that would receive breach |
|---|---|---|---|---|---|---|
| Name | Capacity ($m^3$) | No. | Name | Grid Ref | Consq. Class | |
| Beta | 3,500,000 | 1 | Beta South | Xxxxx xxxx | A1 | Gamma Reservoir |
| Gamma | 4,200,000 | 3 | Gamma East | Xxxxx xxxx | A1 | Delta Reservoir |
| | | | Gamma South | Xxxxx xxxx | A1 | River Anduin |
| | | | Gamma West | Xxxxx xxxx | A1 | Kappa Brook 5.5km to confluence with Anduin. |
| Delta | 1,100,000 | 2 | Delta South | Xxxxx xxxx | A1 | River Anduin |
| | | | Delta East | Xxxxx xxxx | A1 | River Aries approx 38km to confluence with Anduin |

Notes
1. Shown on Landranger (1:50,000 scale) Map No xxx and Explorer (1:25,000 scale) Map No xxx

**Table 2 : Reservoirs and dams upstream of reservoir's not covered by this Impact assessment**

| Reservoir | | Dams | | | Reservoir or watercourse that would receive breach |
|---|---|---|---|---|---|
| Name | Capacity ($m^3$) | No. | Name | Grid Ref | |
| Alpha | 250,000 | 1 | Alpha South | Xxxxx xxxx | Gamma Reservoir |
| Sigma | 55,000 | 1 | Sigma south | Xxxxx xxxx | River Anduin through Bree; then Beta reservoir |

**Figure 1.1 : Schematic of reservoirs and dams in cascade**



## 1.3 Administration of the Impact assessment

The status of this document is as shown in the table on the cover and it is issued to those shown in Table 3. The electronic copy is password protected, with the password issued by the Reservoir Safety Manager.

**Table 3 : Distribution list for copies of this document**

| Role | Name | Postal Address | Phone (working hours) | Format |
|---|---|---|---|---|
| **Internal – Water Company** | | | | |
| Reservoir Safety Manager | xxxxx | xxxxx | xxxx | Electronic notification of changes; Impact assessment on company intranet |
| Emergency Planning Officer | xxxxx | xxxxx | xxxx | |
| Supervising Engineer (s) | xxxxx | xxxxx | xxxx | |
| Operations Manager | xxxxx | xxxxx | xxxx | |
| **Enforcement Authority -Environment Agency:** | | | | |
| a) Technical Manager-Reservoir Safety | xxxxx | Reservoir Safety - Technical Manager, The Environment Agency, Manley House, Kestrel Way, Sowton Industrial Estate, EXETER, EX2 7LQ | | Hard + Electronic |
| b) Regional office Operations Manager | xxxxx | xxxxx | xxxx | Hard + Electronic |
| **Category 1 Responders** | | | | |
| Local authority Emergency Planning Officer | | | | Electronic |
| Environment Agency Area office. Operations Manager | xxxxx | xxxxx | xxxx | Hard copy |
| **Other External** | | | | |
| Local Authority – Development Control Officer | | | | Hard copy |

# 2 SCENARIOS MODELLED IN ANALYSIS

The Guide to Emergency Planning for UK Reservoirs defines a Standard Analysis Scenario based on the identification of a critical flow route and failure of all the dams on that route following a 10,000 year flood.

It has been concluded that the Standard Analysis Scenario is a reasonable representation of the dam breach flood for all three watercourses and no alternative scenarios will be presented. The key points in this assessment are set out in Table 4 (note that all dams being considered are impounding).

**Table 4 : Assumptions in Impact assessment scenario**

| | **Issue** (Heading in Standard Analysis Scenario) | **Failure mode** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Rainy day, whole cascade, for watercourse** | | | **Sunny day, for watercourse** | | |
| | | Anduin | Aries | Kappa | Anduin | Aries | Kappa |
| 1 | Number of dams involved | All three significant dams on the critical flow route (e.g. Beta South/ Gamma East/ Delta South– see Table A.1) | Omitted for brevity. | | Delta South only | Omitted for brevity | |
| 2 | Mode of failure | 1:10000 year flood causing overtopping failure | | | Unexpected development of breach | | |
| 3 | Timing of failure at individual dam | Rapid method considers cumulative volume of all reservoirs | | | Not relevant (rapid method) | | |
| 4 | Initial reservoir level and reservoir volume (in all reservoirs) | Reservoir at top of crest wall | | | Reservoir at spillway crest | | |
| 5 | Steady state flow in the watercourse (prior to the dam failure) | Neglect (rapid method) | | | Neglect (rapid method) | | |
| 6 | Inflows into reservoir(s) | Neglect (rapid method) | | | Neglect (rapid method) | | |
| 7 | Outflows from reservoir | All outlets closed | | | All outlets closed | | |
| 8 | Inflow from tributaries downstream of reservoir | Neglect inflows downstream of Delta South: (1000 year flood at model downstream limit less than 10% of peak dambreak flood at Delta South) | | | Neglect (rapid method) | | |
| 9 | Downstream boundary for impact assessment | Confluence with larger river and entry into broad coastal flood plain. Flood impact reduced to inundation only and flood depth typically less than 0.5m. | | | As rainy day | | |
| 10 | Base Population at risk | It is considered that there would be insufficient time between the flood wave reaching the first community and subsequent communities, for any warning to be issued. | | | As rainy day | | |

# 3 DAM BREAK DISCHARGES AND CRITICAL FLOW PATHS

All the dams are conventional embankment structures. Breach discharges were estimated using the methodology in the Engineering Guide, namely peak flow as Froehlich (1995) and time to peak as CIRIA 2000 and are given in Table 5.

The critical flow routes for the Standard Analysis Scenarios has been identified as shown in Attachment A. Other assessments in identifying the critical flow routes are

a) Neglects failure of Alpha reservoir, as this has an insignificant volume compared to the other reservoirs on the critical flow route.
b) Neglects failure of Sigma reservoir, as this is upstream of the reservoirs covered by this plan.
c) Failure via Delta South gives a higher dam break flood than via Gamma South
d) The peak flow appears likely to be dominated by flows from Beta reservoir for all possible flow routes, due to the much greater reservoir volume and dam height.

The peak breach discharge from the top dam (beta south) gives a much higher discharge than those of the lower downstream dams. The peak breach discharge hydrograph has therefore been obtained as shown on Sheet 8.3 i.e.

- Peak discharge as maximum discharge from any dam in cascade
- Volume total for all reservoirs in cascade

## Table 5 : Estimation of dam breach flows and identification of critical flow route

| Reservoir | | | | | | | | Dam | | | | Rainy Breach discharge Q | | | | | | Sunny day breach discharge | | Flow route |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Level of | At Spillway crest | | Spillway | | Initial | Volume of | Name | Level of | | | Single (Note 2) | | Cascade failure | | | | (Note 4) | | |
| | Spillway crest | Volume | Area | Type | Minimum width of weir/ chute | water level | reservoir freeboard (lowest top of crest wall to spillway) | | Dam crest | Top crest wall | Original ground level under dam crest | Height | Discharge | Breach sequence | Height for dam break when reservoir overtopping | Cumulative volume (Note 3) | Discharge | Height | Discharge | |
| | mOD | m3 | m2 | | m | | | | mOD | mOD | mOD | m | $m^3/s$ | | m | | $m^3/s$ | m | $m^3/s$ | |
| Alpha | 161.96 | 250,000 | 30,000 | Chute | 5.5 | Spillway crest | 51,600 | Alpha South | 163.68 | None | 151.50 | 12.2 | 527 | Not app | | | | Not applicable | | |
| Beta | 169.52 | 3,300,000 | 250,000 | Chute | 18.5 | Spillway crest | 485,000 | Beta South | 171.46 | 172.66 | 143.72 | 25.8 | 2,861 | Not app | | | | Not applicable | | |
| Gamma | 142.38 | 4,000,000 | 740,000 | Chute | 21.2 | Spillway crest | 1,850,000 | Gamma West | 144.31 | 145.41 | 134.31 | 10.0 | 935 | Beta South/ Gamma West | 10.6 | 9,150,000 | 1,278 | 8.1 | 717 | Critical for R Kappa |
| | | | | | | | | Gamma South | 144.31 | 145.31 | 135.31 | 9.0 | 820 | Beta South/ Gamma South | 9.6 | 9,150,000 | 1,130 | 7.1 | 608 | Anduin (non-critical) |
| | | | | | | | | Gamma East | 143.78 | 144.88 | 134.03 | 9.8 | 906 | Beta South/ Gamma East | 10.9 | 9,150,000 | 1,321 | Not applicable | | Delta |
| Delta | 129.28 | 1,100,000 | 240,000 | Chute | 24.5 | Spillway crest | 760,800 | Delta South | 131.35 | 132.45 | 119.15 | 12.2 | 817 | Beta South/ Gamma East/ Delta South | 13.3 | 11,010,800 | 1,795 | 10.1 | 649 | **Critical for Anduin** |
| | | | | | | | | Delta East | 131.35 | 132.45 | 120.35 | 11.0 | 719 | Beta South/ Gamma East/ Delta East | 12.1 | 11,010,800 | 1,597 | 8.9 | 555 | **Critical for R Aries** |

Notes

1. From inspection (and rapid dambreak) reservoir volumes are sufficiently large not to require adjustment (reduction ) of Qp
2. Reservoir level as defined in Index Scenario
3. Reservoir volume at top of flood wall for all reservoirs below that at top of cascade. This volume represents volumes of flood inflows into upper dam and side catchments
4. For cascade sunny day scenario, only the bottom dam is considered

| This document is part of the following Inundation Analysis and Consequence Assessment: | |
|---|---|
| Watercourse | River Anduin |
| Reservoirs/Dams | Beta South<br>Gamma East<br>Delta South |

# 4 METHODOLOGY FOR HYDRAULIC ROUTING

## 4.1 Level of analysis, software and ground model

This plan is an example of a rapid analysis. The data and software used are shown in Table 6.

**Table 6 : Data and software**

| **Issue** | **Methodology used in preparation of this Impact assessment** |
|---|---|
| Software | Excel spreadsheet in Interim Guide QRA, with some amendments. In particular use of k of 2.5, as recommended in the CIRIA report, gives La of over 1000km which is considered unrealistic. K has therefore been reduced to 0.25 to give attenuation length la of between 20 and 80km. |
| Ground elevation data | Ordnance Survey 1;25,000 scale map<br>Sheet No XXX, Published 1998 |
| Channel cross-sections | Scaled from OS map |
| Structures and infrastructure embankments | Neglected |
| Urban areas across flow path | Only isolated buildings across the flow path; no dense urban area |

Manning's 'n' has been taken as 0.075

The channel capacity is relatively modest, and it is reasonable to neglect this in the analysis. Although there are flood defences at Rauros, these are neglected in the dam break analysis as being unlikely to contain the flood wave.

## 4.2 Downstream limit of modelling

## 4.3 River Anduin

The model was extended to the confluence with the Aries River, which is tidal at this point. Estimated peak flood flows in this area, which is about 25 km downstream of Delta South, are summarised as shown in Table 7. The dam break flows at the confluence are intermediate between the 100 and 1000 year fluvial floods. It not considered necessary to extend the model downstream, particularly in view of the channel being tidal below that point.

## 4.4 River Aries

*Omitted for brevity*

## 4.5 River Kappa

*Omitted for brevity*

**Table 7 : Fluvial flood magnitudes (no dam failure) at points down downstream watercourses (used to define downstream boundary)**

| Watercourse | Point on watercourse | Flow ($m^3/s$) | | | |
|---|---|---|---|---|---|
| | | Fluvial[1] | | Dam break | |
| | | 100 year | 1000 year | Rainy day | Sunny dam |
| Anduin | Upstream of confluence Anduin/ Aries | 170 | 288 | 624 | 130 |
| | Downstream of confluence Anduin/ Aries | 390 | 952 | Not available | |
| Kappa | Terminate at same point as Anduin | | | | |
| Aries | Omitted for brevity | | | | |

Notes
1. From Rapid method in floods and reservoir safety.

## 4.6 Transportation embankments across flow path

The assumptions made are given in Sheets 1.7 and 8.5 of the Excel workbook.

## 4.7 Flood Zone Definition

## 4.8 River Anduin

Nine Flood Zones have been identified as shown in Table 8 and Sheet 8.5 of the Excel workbook.

**Table 8 : Definition of Flood zones on River Anduin**

| **Flood Zone** | **Name** | **Nature** |
|---|---|---|
| Zone 1 | Dam to Motorway 1 | Mainly rural valley |
| Zone 2 | Motorway 1 to Railway 1 | Small area with some development but significant amount of infrastructure |
| Zone 3 | Pelargir Centre | Urban area with industry and a canal |
| Zone 4 | Brook at Pelargir | Tributary subject to flooding backing up from main river |
| Zone 5 | D/S Pelargir to Railway 2 | Long, largely rural reach |
| Zone 6 | Railway 2 to Motorway 2 | Short reach bounded by infrastructure |
| Zone 7 | Motorway 2 to u/s Rauros | Mostly rural. Downstream boundary at upstream limit of Rauros and where flow starts to spill from left bank into Zone 9 |
| Zone 8 | Rauros Centre | Urban area |
| Zone 9 | Rauros Moss | Rural, largely low-lying off-stream area |

## 4.9 River Aries

*Omitted for brevity*

**Table 9 : Definition of Flood zones on River Aries**

## 4.10 River Kappa

*Omitted for brevity*

**Table 10 : Definition of Flood zones on River Kappa**

# 5 CONSEQUENCE ASSESSMENT

The basis and assumptions made in the analysis are shown in Table 11, with the build up of results are shown on the sheets with the impact assessment and the summary of results in Sheet 12.1 of the Excel workbook.

**Table 11 : Assumptions in consequence assessment**

| Issue | Residential | Non-residential |
|---|---|---|
| Property database | Address point | Address point.<br>Plan areas measured manually from 1;10,000 map |
| Subdivision of property type | None | Broadly Multicoloured manual 2 digit – used for PAR only |
| Property valuation | See Table 17 | |
| Level of property damage | Sub-totals in each zone, based on adjacent model section | Sub-totals in each zone, based on point depth at building, with velocity from adjacent model section |
| Occupant area / number / building | Take as 2.3 (Value for Great Britain in 2003, as given in "Table 3.1 : Trends in household size: 1971 to 2003" on www.statistics.gov.uk | Vary with property type |
| Occupancy factor | 70% | Vary with property type |
| Other damages | As shown in Table 17 | |

All three watercourses pass through major villages and towns, as shown in Table 12.

**Table 12 : Towns through which watercourses pass**

| Watercourse | Towns and villages which are likely to be affected by dam failure |
|---|---|
| Anduin | Pelargir, Rauros |
| Kappa | As Aries (joins Aries just upstream of Pelargir) |
| Aries | *Omitted for brevity* |

# 6 RESULTS OF IMPACT ASSESSMENT

Table 13 summarised the location in which the results of the impact assessment are presented.

The Consequence Class for all dams covered by this assessment are Class A1.

# 7 IMPACT ON INFRASTRUCTURE

## 7.1 Infrastructure at risk (in way of dam-break flood)

There are the following items of infrastructure crossing the floodplain in the lengths to the point at which the dam break flood is within the fluvial 100 year envelope. No assessment has been made of the risk of being severed as a result of dam failure. Broad brush hydraulic parameters are given in Appendices B to D.

| Type | | Number on River | | |
|---|---|---|---|---|
| | | Anduin | Aries | Kappa |
| Length of dam break | | 25km | | |
| Roads | Motorways | 2 | | |
| | A roads | 2 | | |
| Railways | | 2 | | |
| Canal | | 1 | | |

## 7.2 Hydraulic Mitigation

The impact of the imminent failure of a dam in the upper part of a cascade could be mitigated by lowering reservoirs further down the cascade.

There are no obvious opportunities to use transport infrastructure to mitigate the flood wave.

# 8 MAINTENANCE OF THE IMPACT ASSESSMENT

This Impact assessment should be reviewed (and updated or modified as appropriate) no later than the next Inspection of the most upstream reservoir, due in 2012.

In addition it should be reviewed (and updated or modified as appropriate) in the event of any major development in the potential inundation area

**Table 13 : Index to detailed results sheets**

| Technical Specification | | Results for watercourse and failure mode | | | | | |
|---|---|---|---|---|---|---|---|
| Clause | Content | Anduin | | Aries | | Kappa | |
| | | Rainy day | Sunny | Rainy | Sunny | Rainy | Sunny |
| 'a' | Standard Analysis | Yes, Table 4 | | All omitted for brevity | | | |
| | Other scenarios | Sunny day for bottom dam only | | | | | |
| 'b' | Peak breach outflows for different failure scenarios and flow paths | Table 8 | | | | | |
| 'c' | Zone details | Table 7 | | | | | |
| 'd' | Transportation embankments obstructing the flow path | Sheet 1.7 in workbook | | | | | |
| | Photographs at key points | Appendix A | | | | | |
| 'e' | Tabulated output by zone | | | | | | |
| | Hydraulic | Sheet 8.5 in workbook | | | | | |
| | Population at risk, Likely loss of life, property damage | Sheet 9,10 in workbook | | | | | |
| 'f' | Figures summarising | Sheet 12.1 in workbook | | | | | |
| | Flow hydrographs at zone boundaries | Not required for rapid method | | | | | |
| | Peak flow down valley | Sheet 8.5 in workbook | | | | | |
| | Longitudinal section down valley | Sheet 8.5 in workbook | | | | | |
| 'g' | Total PAR, LLOL and third party damage | (build-up in 'e') | | | | | |
| | Population at risk | 1673 | 651 | | | | |
| | Likely loss of life | 363 | 27 | | | | |
| | Third party damage £M | 104 | 47 | | | | |
| | Consequence Class | A1 | | | | | |
| 'h' | Tabulated data at selected Key points | Not required for rapid method | | | | | |
| 'i' | Map information | Not required for rapid method | | | | | |

# ATTACHMENT A: PHOTOGRAPHS OF KEY POINTS CONTROLLING FLOW DOWN VALLEY

## A.1 River Anduin

Motorway at CH xxx, from downstream (note car parked in left hand corner)

Railway at Ch 3600, from downstream

Bridge under Canal , from upstream

AX bridge, from downstream

## A.2 River Aries

## A.3 River kappa

# ATTACHMENT B : RELEVANT EXTRACTS OF ENVIRONMENT AGENCY ZONE 2 AND 3 MAPS (FROM INTERNET)

Omitted to maintain anonymity of the reservoir

# ATTACHMENT C : RAPID METHOD WORKBOOK FOR RIVER ANDUIN

# INTERIM GUIDE TO QRA : DOCUMENT CONTROL RECORD
# Sheet 0.0: Dates and individuals carrying out assessment

## 1. Base Workbook

| Revision | Date | Reason for issue | Originator | Chkd | Appd |
|---|---|---|---|---|---|
| A01 | 01-Apr-02 | Issue for use in trial of prototype Integrated System | AJB | JDG | AJB |
| R02 | 30-Apr-03 | Draft of preliminary Engineering Guide, for internal review. Changes from A01 include<br>a) Reduce external core threats to floods and cascade<br>b) Improve scoring system for internal threats<br>c) Dam break change from RMUKR to Froehlich<br>d) LLOL change from DeKay & McClelland to BOR<br>e) Physical damage change from RMUKR to quantitative system<br>f) Add ALARP calculation sheet (from table in main report) | AJB/AM | | |
| A02 | 30-Jul-03 | Issue for client review | AJB | JDG | AJB |
| A03 | 20-Feb-04 | Finalise after review by client and steering group | AJB | JDG | AJB |

The authors of this report are employed by KBR (Kellogg Brown & Root Limited). The work reported herein was carried out under a Contract placed on 6th September 2002 by the Secretary of State for Environment, Food and Rural Affairs. Any views expressed are not necessarily those of the Secretary of State for Environment, Food and Rural Affairs.



**Disclaimer**



The terms "he" and "her" are used for simplicity to denote either male or female, as appropriate.

## 2. Changes to workbook by user of System

Provide details

| Revision | Date | Reason for issue | Originator | Chkd | Appd |
|---|---|---|---|---|---|
| 1 | 30/03/2006 | Refine Consequence assessment: Merge sheets 9 and 10 so they use common property database; move Sheet 1.6 to be at start of Sheets 9, 10, to summarise data on property at risk; | AJB | | |
| 2 | 30/03/2006 | Refine Inundation mapping: add sheet 1.7 with details of transportation embankments across flood plain; In Sheet 8.5 add rows 20 to 31; 44-53; 65-73, long section down river | AJB | | |

## 3. Application of workbook

| | | Date completed |
|---|---|---|
| Lead user | AJB | 08-Mar-06 |
| Data input checked by | | |
| Output reviewed by | JDG | |
| Approved by (Inspecting Engineer) | AJB | |

Remarks e.g. if different Sections completed by different engineers

| | A | B | C | D |
|---|---|---|---|---|
| 1 | **SITE INSPECTION** | | | |
| 2 | **Sheet 1.1: Characteristics of Subject Reservoir** | | | |
| 3 | Dam name | | Cascade above Anduin (Beta South to Delta South) | |
| 4 | Grid ref. | | | |
| 5 | Calculation Number/ description | | Rapid dambreak for dams in cascade on River Anduin | |
| 6 | | | | |
| 7 | Information | Units | **Column to be completed, as far as possible** | |
| 8 | | | | Remarks |
| 9 | Crest wall : Is there one and if so can it withstand sustained overtopping with reservoir stillwater at or above top of crest wall? (choose from pick list) | | *Wall can withstand overtopping* | |
| 13 | **Level of -** | | | |
| 14 | Top of crest wall (Note 2) | mOD | 172.66 | |
| 15 | Lowest point on dam crest (Note 3) | mOD | 171.46 | |
| 16 | Maximum retention level | mOD | 169.52 | |
| 17 | Original ground level on dam axis (Note 4) | mOD | 143.72 | |
| 18 | Downstream stream bed | mOD | 143 | |
| 19 | Datum for level | | | |
| 20 | | | | |
| 21 | Height of dam crest above OGL on axis | m | 27.74 | |
| 22 | Height of dam crest above stream bed | m | 28.46 | |
| 23 | Freeboard to dam crest | m | 1.94 | |
| 24 | Height of wave wall above crest | m | 1.2 | |
| 25 | | | | |
| 26 | | | | |
| 27 | Reservoir capacity - at spillway crest level | $m^3$ | 3,300,000 | |
| 28 | Reservoir area - at spillway crest level | $m^2$ | 250,000 | |
| 29 | - at top of intact crest wall/ Dam crest level if no crest wall, or wall cannot withstand overtopping | $m^2$ | 300,000 | |
| 30 | Reservoir capacity at top of intact crest wall/ Dam crest level if no crest wall, or wall cannot withstand overtopping | $m^3$ | 4,163,500 | |
| 31 | Catchment area | $km^2$ | | |
| 32 | Downstream slope (overall) | H:V | | |
| 33 | Upstream slope (overall) | H:V | | |
| 34 | Notes | | | |
| 35 | 1. The contents of shaded cells are used in subsequent analysis and must be included | | | |
| 36 | 2. Insert "None" if no wall | | | |
| 37 | 3. Input lowest (used in estimate of overtopping flow) | | | |
| 38 | 4. Used to derive the dam height used in calculating the dam break flood | | | |
| 39 | | | | |
| 40 | **Caution : Data input is also required in other sheets. It is therefore recommended that in order to identify the data to be obtained from site inspection and measurement all sheets in this workbook are reviewed, and where possible completed, prior to the site visit.** | | | |

# SITE INSPECTION

## Sheet 1.2: Background Data (desk study)

**NB Completing sheet is optional - see text**

| | | |
|---|---|---|
| Dam name | Cascade above Anduin (Beta South to Delta South) | |
| Grid ref. | 0 | |
| Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin | |

**1. Location and general information**

| | |
|---|---|
| Name of Reservoir | |
| 50,000 topographic sheet No. | |
| 25,000 topographic sheet No. | |
| 50,000 geological sheet No. and Name | |
| Are there any other dams retaining this reservoir? | There are three reservoirs, each retained by several dams |
| Date built | |
| Date of first impounding/ Is reservoir still in "Wear-in period", or "In-service" | In-service |

**2. Last safety assessment of dam (give date, reason e.g. periodic, following incident)**

| | Date | Details |
|---|---|---|
| Inspection under Section 10 of Reservoirs Act, 1975 | | |
| Hydrological analysis (date, methods) | | |
| Seismic analysis (date, method) | | |

**3. Any other reports relevant to reservoir safety/ integration of different threats to the dam?**

| Report Title | Date | Remarks re effect on dam safety |
|---|---|---|
| | | |
| | | |
| | | |

| **4. Information on original design** | Date | Author; content e.g. length |
|---|---|---|
| Design Report | | |
| Description of works with Certificate of efficient execution, or with periodic Inspection | | |

| Drawing Title | Date | Author, other remarks |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

| | A | B | C |
|---|---|---|---|
| 40 | **5. Any major upgrades since original construction (give date and description)** | | |
| 41 | Embankment | | |
| 42 | Outlet | | |
| 43 | Spillway | | |
| 44 | | | |
| 45 | **6. General description of embankment** | | |
| 46 | Impervious element - type | | |
| 47 | Upstream shoulder - material | | |
| 48 | Downstream shoulder - material | | |
| 49 | Foundation cut-off | | |
| 50 | Foundation geology | | |
| 51 | Crest width | m | |
| 52 | Crest length | m | |
| 53 | Core - top elevation | m | |
| 54 | - width at top elevation, original ground level | m | |
| 55 | | | |
| 56 | **7. General description of appurtenant works** | | |
| 57 | **Outlets:** type(s)/ location(s) e.g. pipe in fill, pipe in tunnel, pipe in culvert through fill | No 1 | |
| 58 | | No 2 | |
| 59 | **Spillway :** type/ location | No 1 | |
| 60 | | No 2 | |
| 61 | | | |
| 62 | **8. Concrete gravity or service reservoirs - desk study information relevant to consequence assessment** | | |
| 63 | | | |
| 64 | | | |
| 65 | | | |
| 66 | | | |
| 67 | | | |

| | A | B | C | D |
|---|---|---|---|---|
| 1 | **SITE INSPECTION** | | | |
| 2 | **Sheet 1.5: Downstream Reservoirs** | | | |
| 3 | Dam name | Cascade above Anduin (Beta South to Delta South) | | |
| 4 | Grid ref. | 0 | | |
| 5 | Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin | | |
| 6 | | | | |
| 7 | **Downstream reservoirs (in order from subject dam)** | Units | Dam No D1 | Dam No D2 |
| 8 | Name | | Gamma east | Delta south |
| 9 | OS Grid Reference | | | |
| 10 | Distance from subject dam | km | | |
| 11 | Date Built | | | |
| 12 | Has QRA been applied to this dam? Give date, reason, Panel Engineer | | | |
| 13 | **Levels and dimensions** | | | |
| 14 | Basis of levels | | | |
| 15 | Will crest wall withstand sustained overtopping with reservoir stillwater at or above top of crest wall? (choose from pick list; expand in Other remarks at bottom) | | Wall can withstand overtopping | Wall can withstand overtopping |
| 19 | Top of crest wall (Note 1) | mOD | 144.88 | 132.45 |
| 20 | Maximum retention level | mOD | 142.38 | 129.28 |
| 21 | Original ground level on dam axis | mOD | 134 | 119.15 |
| 22 | Dam height (crest to OGL on axis) | m | 10.88 | 13.3 |
| 23 | Freeboard | m | 2.5 | 3.17 |
| 24 | Crest width; surfacing | m | | |
| 25 | Crest length | m | | |
| 26 | Reservoir volume at spillway crest | $m^3$ | 4,000,000 | 1,100,000 |
| 27 | Surface area of reservoir - at spillway | $m^2$ | 740,000 | 240,000 |
| 28 | - at top of crest wall (Note 1) | $m^2$ | 740,000 | 240,000 |
| 29 | Reservoir volume at top of crest wall (Note 1) | $m^3$ | 5,850,000 | 1,860,800 |
| 30 | **Description of elements of dam** | | | |
| 31 | Embankment | | | |
| 32 | Spillway capacity | | | |
| 33 | Outlet(s) | | | |
| 34 | Other | | | |
| 35 | **Qualitative Risk assessment** | | | |
| 36 | Condition - give description | | | |
| 37 | Summary of risk of failure if subject dam breached | | | |
| 38 | Conclusion as to what account should be taken in risk assessment | | | |
| 39 | | | | |
| 40 | Any other remarks about potential consequential failures, caused by failure of subject dam | | | |
| 41 | | | | |
| 42 | Notes | | | |
| 43 | 1. Embankment crest level if no crest wall; or if crest wall cannot withstand overtopping | | | |

## SITE INSPECTION

## Sheet 1.7: Transportation embankments which could obstruct flow path

| | |
|---|---|
| Dam name | Cascade above Anduin (Beta South to Delta South) |
| Grid ref. | 0 |
| Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin |

| Point definition | | | Embankment | | | | | Structure through embankment | | | | | All structures and embankments intact | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | % blockage | |
| Flood Zone Reference | Name of Transportation embankment | Floodplain Elevation | Crest Level | Max height | Crest width (along flow route) | Crest length which could be overtopped | Notes re vulnerability to breach | Type | Bottom Width | Height of crown above flood plain | Open area above flood plain (unrestricted) | Source of data | % blockage in dam break event | Effective open area above flood plain |
| | | mAOD, to one decimal place | mAOD | m | m | | | mAOD | m | m | $m^2$ | | % | $m^2$ |
| Zone 1 | Mxx motorway bridge SE Pelargir. C road on right bank | 108.5 | 116.0 | 7.5 | 30 | | Low | Vertical RC side walls | 20 | 15.0 | 300 | Site visit | 0 | 300 |
| Zone 2 | Railway 1 - bridge SE Pelargir | 86.8 | 93.2 | 6.4 | 6 | | High | Masonry arch bridge | 5 | 9 | 40 | Site visit | 50% | 20 |
| Zone 3 | Canal bridge over river SW of Railway 1 | 87.4 | 91 | 3.6 | 10 | | Medium | Masonry arch bridge | 6 | 3 | 15 | Site visit | 80% | 3 |
| Zone 3 | Ax road bridge at Pelargir | 75.3 | 80 | 4.7 | 12 | | Medium | Masonry arch bridge | 9 | 5 | 40 | Site visit | 50% | 20 |
| Zone 5 | Railway 2 - dual bridges near Euxton | 28.1 | 45.5 | 17.4 | 6 | | High | RC Culvert | 10 | 4 | 40 | Air photos; no public access | 50% | 20 |
| | | | | | | | | High Viaduct - would have no significant incremental effect on flow relative to upstream culvert | | | | | | |
| Zone 6 | Axx road - Pxxxxx Bridge | 28.3 | 39 | 10.7 | 10 | | Low | Masonry Arch bridge | 10 | 10 | 100 | Site visit | 10% | 90 |
| Zone 6 | Byway immediately downstream (original route) | | Neglect as broadly at flood plain | | | | | masonry humpback | 10 | 3 | 30 | Site visit | 80% | 6 |
| Zone 6 | Ax motorway bridge. Gravel track under one side, access to houses | 18.3 | 27.7 | 9.4 | 30 | | Medium | 3 span bridge, two rows of 1x 1.5m columns plus bank seats for abutments | 20 | 7 | 120 | Site visit | 20% | 96 |
| Zone 8 | Axxx road at Rauros | 6.0 | Neglect as broadly at flood plain | | | | | masonry arch bridge | 7 | 2 | 12 | Site visit | 80% | 2 |
| Zone 8 | Railway 3 - bridge West (downstream) of Rauros | 6.0 | 6.6 | 0.6 | 4 | | High | Horizontal steel bridge | 7 | 0.5 | 3 | Site visit | 80% | 1 |
| Zone 9 | Railway 3 - structures SW of Rauros | | | | | | | | | | | | | 0 |

# DAMBREAK ANALYSIS

## Sheet 8.1: Summary of Assessment

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | Dam name | Cascade above Anduin (Beta South to Delta South) | | | | |
| 4 | Grid ref. | 0 | | | | |
| 5 | Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin | | | | |
| 6 | | | | | | |
| 7 | Steps in Process | Key variables (linked to analysis sheets, to allow checking that main inputs and output seem reasonable) | | | | |
| 8 | **Sheet 8.2 : Dam Break Hydrograph for Subject Dam and any Downstream Dams** | | | | | |
| 9 | (rainy day when at dam crest, and sunny day when at spillway crest) | | | Sunny Day | Rainy Day | Units |
| 10 | Physical characteristics of subject reservoir | | Height | 25.8 | 27.7 | m |
| 11 | | | Reservoir capacity | 3,300,000 | 4,163,500 | $m^3$ |
| 12 | | | | | | |
| 13 | 8.2.1 Estimated breach discharge hydrograph of subject reservoir | | | 2861 | 3353 | $m^3/s$ |
| 14 | | | | | | |
| 15 | 8.2.2 Estimated breach discharge hydrograph of cascade failure triggered by failure of subject dam | | | | | |
| 16 | Cascade failure including subject dam to downstream Dam 1 | | | 897 | 1,361 | $m^3/s$ |
| 17 | Cascade failure including subject dam to downstream Dam 2 | | | 1,183 | 1,836 | $m^3/s$ |
| 18 | | | | | | |
| 19 | **Sheet 8.3 : Data for Routing Downstream** | | | | | |
| 20 | Used to provide data for attenuation analysis; including distance for which dam break flood is to be routed | | | | | |
| 21 | | | | | | |
| 22 | **Sheet 8.4 : Rapid method for estimating 100 year flood at each downstream confluence** | | | | | |
| 23 | If applicable, use these sheets (inserting additional sheets where necessary) for each affected downstream confluence | | | | | |
| 24 | | | | | | |
| 25 | **Sheet 8.5 : Attenuation Downstream** | | | At dam | End of first reach | End of penultimate reach |
| 26 | | | **Case 1 :** | Cascade failure - rainy day | | |
| 27 | | | Peak discharge | 2870 | 2,713 | 1,435 $m^3/s$ |
| 28 | | | Time period at > half discharge | 50 | 53 | 100 minutes |
| 29 | | | Water depth | 18.5 | 5.7 | 6.0 m |
| 30 | | | | | | |
| 31 | | | **Case 2 :** | Sunny day ; Bottom dam (Delta south) only | | |
| 32 | | | Peak discharge | 650 | 616 | 329 $m^3/s$ |
| 33 | | | Time period at > half discharge | 57 | 60 | 112 minutes |
| 34 | | | Water depth | 17.2 | 3.2 | 3.1 m |
| 35 | | | | | | |
| 36 | | | **Measures of force of water as Sheet 9, for Case 1** | | | |
| 37 | | | Average velocity | | 7.0 | 3.4 m/s |
| 38 | | | Velocity x depth | | 40.2 | 20.5 $m^2/s$ |
| 39 | | | Discharge/ width | | 21.7 | 14.4 $m^2/s$ |
| 40 | | | Cumulative time to end of reach | | 4 | 53 mins |

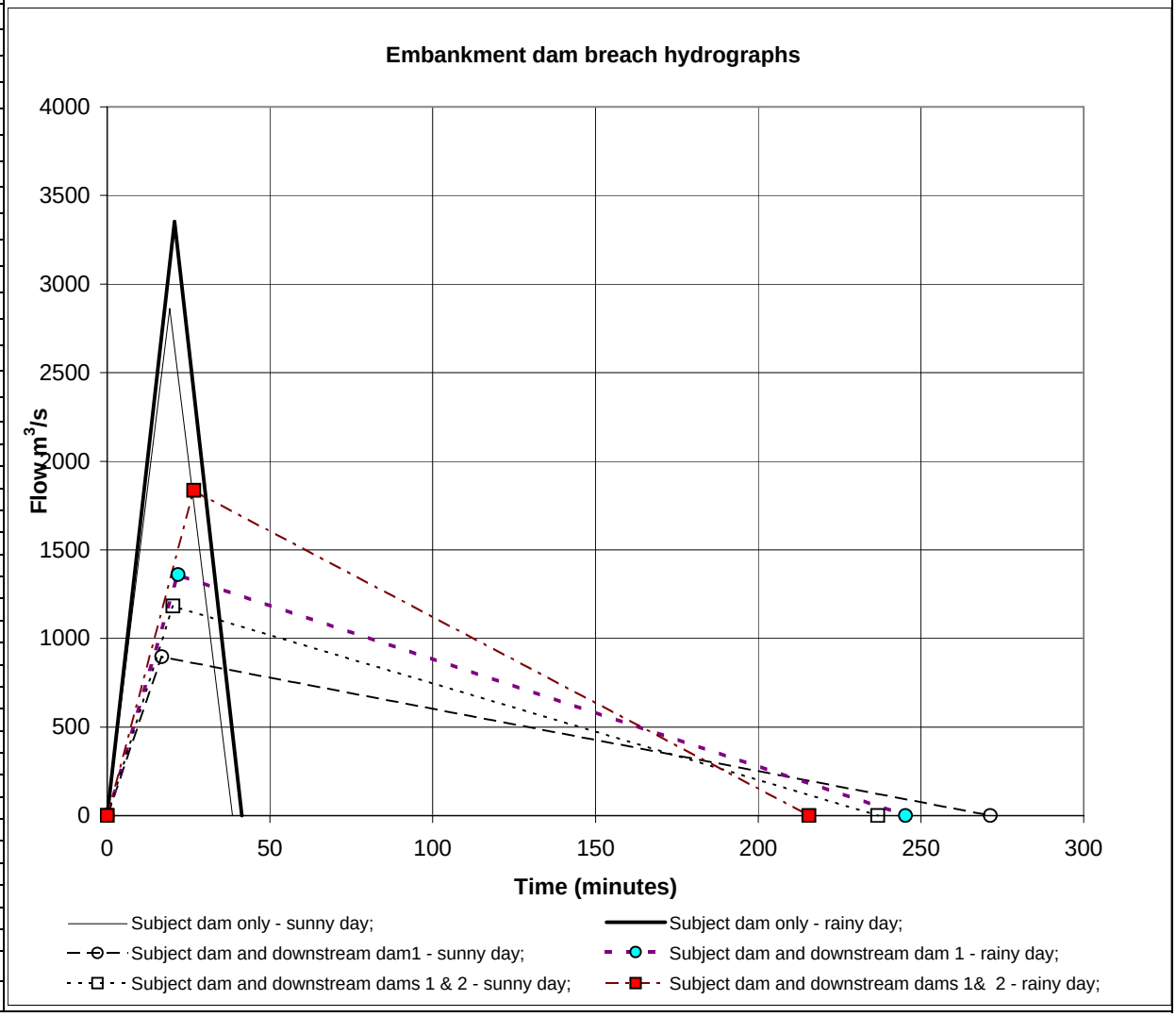
# DAMBREAK ANALYSIS

## Sheet 8.2E: Dambreak Hydrograph for Cascade of Embankment Dams

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | Dam name | Cascade above Anduin (Beta South to Delta South) | | | | | |
| 4 | Grid ref. | 0 | | | | | |
| 5 | Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin | | | | | |
| 6 | | Symbol | Units | | | | |
| 7 | **8.2.1 Determine top dam breach hydrograph** | | | | | | |
| 8 | **Failure conditions** | | | **Sunny day** | **Rainy day** | | |
| 9 | **Physical characteristics of subject reservoir (from Sheet 1.1)** | | | | | | |
| 10 | Height of peak reservoir level above base of dam | H | m | 25.8 | 27.7 | | |
| 11 | Reservoir Capacity | V | $m^3$ | 3,300,000 | 4,163,500 | | |
| 12 | **Initial estimate** | | | | | | |
| 13 | ***Breach discharge as Froehlich, 1995*** | | | | | | |
| 14 | Peak Qp=0.607(V)$^{0.295}$ (H)$^{1.24}$ | $Q_p$ | $m^3/s$ | 2861 | 3353 | | |
| 15 | ***Time base as RMUKR, Section 5.2.2*** | | | | | | |
| 16 | Time to peak discharge, Tp=120(H) | Tp | sec | 3,096 | 3,329 | | |
| 17 | Time to end of discharge (so hydrograph vol. = reservoir vol.) | Te | sec | 2,307 | 2,484 | | |
| 18 | **Where warning message in this row (i.e. Te < 2Tp) correct by one of the following** | | | **NEED TO REDUCE Tp** | **NEED TO REDUCE Tp** | | |
| 19 | 1. Keeping Qp unchanged, reduce Tp (Te= 2Tp), | Tp | sec | 1,153 | 1,242 | | |
| 20 | where warning message, as Tp<40H | | | | | | |
| 21 | 2. Assuming Tp=40H reduce Qp until volume of | Tp | sec | | | | |
| 22 | flood hydrograph equals reservoir volume | Qp | $m^3/s$ | | | | |
| 24 | **Adopted dam break hydrograph** | Qp | $m^3/s$ | 2,861 | 3,353 | | |
| 25 | **at subject dam** | Tp | sec | 1,153 | 1,242 | | |
| 26 | | Te | sec | 2,307 | 2,484 | | |
| 27 | Remarks | | | | | | |
| 28 | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 30 | **8.2.2 Breach discharge of downstream reservoirs; if failure triggered by failure of subject dam** | | | | | | |
| 31 | | | | Downstream reservoir No (dimensions taken from Sheet 1.5) | | | |
| 32 | | | | **Dam No 1** | | **Dam No 2** | |
| 33 | | | | **Gamma east** | | **Delta south** | |
| 34 | **Failure conditions for downstream dam** | Symbol | Units | **Sunny day** | **Rainy day** | **Sunny day** | **Rainy day** |
| 35 | Height of peak reservoir level above base of dam | H | m | 8.4 | 10.9 | 10.1 | 13.3 |
| 36 | Volume of downstream reservoir | V | $m^3$ | 4,000,000 | 5,850,000 | 1,100,000 | 1,860,800 |
| 37 | Total volume of subject dam and downstream reservoir(s) | V | $m^3$ | 7,300,000 | 10,013,500 | 8,400,000 | 11,874,300 |
| 38 | **Initial estimate** | | | | | | |
| 39 | ***Breach discharge as Froehlich, 1995*** | | | | | | |
| 40 | Peak Qp=0.607(V)$^{0.295}$ (H)$^{1.24}$ | Qp | $m^3/s$ | 897 | 1361 | 1183 | 1836 |
| 41 | ***Time base as RMUKR, Section 5.2.2*** | | | | | | |
| 42 | Time to peak discharge, Tp=120(H) | Tp | sec | 1,006 | 1,306 | 1,216 | 1,596 |
| 43 | Time to end of discharge (so hydrograph vol. = reservoir vol.) | Te | sec | 16,280 | 14,718 | 14,207 | 12,938 |
| 44 | **Where warning message in this row (i.e. Te < 2Tp) correct by one of the following** | | | | | | |
| 45 | 1. Keeping Qp unchanged, reduce Tp (Te= 2Tp), | Tp | sec | | | | |
| 46 | where warning message, as Tp<40H | | | | | | |
| 47 | 2. Assuming Tp=40H reduce Qp until volume of | Tp | sec | | | | |
| 48 | flood hydrograph equals reservoir volume | Qp | $m^3/s$ | | | | |
| 50 | **Dam break hydrograph, at each downstream** | Qp | $m^3/s$ | 897 | 1,361 | 1,183 | 1,836 |
| 51 | **dam, for failure of cascade from subject dam** | Tp | sec | 1,006 | 1,306 | 1,216 | 1,596 |
| 52 | **to this downstream dam** | Te | sec | 16,280 | 14,718 | 14,207 | 12,938 |
| 53 | **Remarks** | | | | | | |
| 54 | For routing adopt Peak of 2872 m3/s (sunny day failure of upstream dam) | | | | | | |

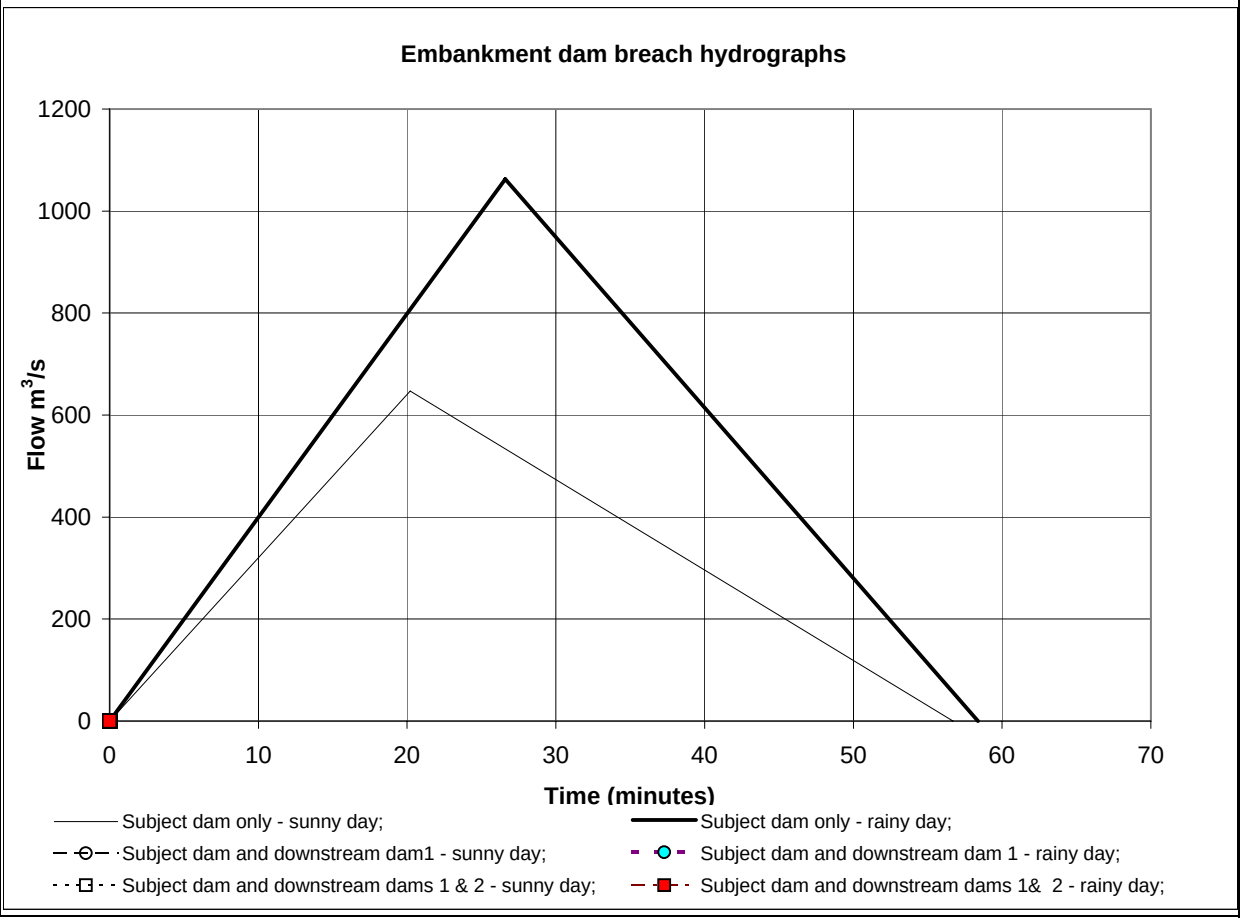
| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 55 | Take Te=2x Total vol/ peak =2x 8.6Mm3/Q=5988 sec | | | | | | |



# DAMBREAK ANALYSIS

## Sheet 8.2E: Dambreak Hydrograph for failure of bottom dam only

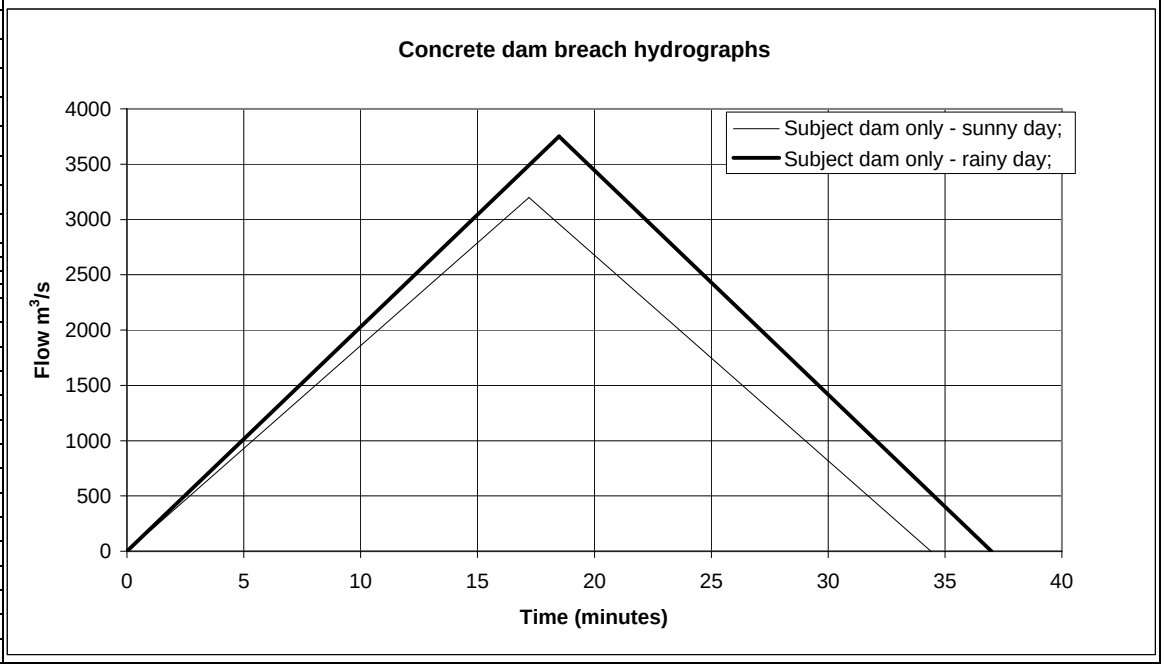
| | | | | | | |
|---|---|---|---|---|---|---|
| Dam name | Cascade above Anduin (Beta South to Delta South) | | | | | |
| Grid ref. | 0 | | | | | |
| Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin | | | | | |
| | Symbol | Units | | | | |
| **8.2.1 Determine top dam breach hydrograph** | | | | | | |
| **Failure conditions** | | | **Sunny day** | **Rainy day** | | |
| **Physical characteristics of subject reservoir** | | | | | | |
| Height of peak reservoir level above base of dam | H | m | 10.1 | 13.3 | | |
| Reservoir Capacity | V | $m^3$ | 1,100,000 | 1,860,800 | | |
| **Initial estimate** | | | | | | |
| ***Breach discharge as Froehlich, 1995*** | | | | | | |
| Peak Qp=0.607(V)$^{0.295}$ (H)$^{1.24}$ | $Q_p$ | $m^3/s$ | 647 | 1062 | | |
| ***Time base as RMUKR, Section 5.2.2*** | | | | | | |
| Time to peak discharge, Tp=120(H) | Tp | sec | 1,212 | 1,596 | | |
| Time to end of discharge (so hydrograph vol. = reservoir vol.) | Te | sec | 3,401 | 3,503 | | |
| **Where warning message in this row (i.e. Te < 2Tp) correct by one of the following** | | | | | | |
| 1. Keeping Qp unchanged, reduce Tp (Te= 2Tp), | Tp | sec | | | | |
| where warning message, as Tp<40H | | | | | | |
| 2. Assuming Tp=40H reduce Qp until volume of | Tp | sec | | | | |
| flood hydrograph equals reservoir volume | Qp | $m^3/s$ | | | | |
| **Adopted dam break hydrograph** | Qp | $m^3/s$ | 647 | 1,062 | | |
| **at subject dam** | Tp | sec | 1,212 | 1,596 | | |
| | Te | sec | 3,401 | 3,503 | | |
| Remarks | | | | | | |



# DAMBREAK ANALYSIS

## Sheet 8.2C : Dambreak Hydrograph for Subject Concrete Dam

| | | | | | |
|---|---|---|---|---|---|
| 3 | Dam name | | | Cascade above Anduin (Beta South to Delt | |
| 4 | Grid ref. | | | 0 | |
| 5 | Calculation Number/ description | | | Rapid dambreak for dams in cascade on R | |
| 7 | **8.2.1 Determine subject dam breach hydrograph** | Symbol | Units | | |
| 8 | **Failure conditions** | | | **Sunny day** | **Rainy day** |
| 9 | **Physical characteristics of subject reservoir (from Sheet 1.1)** | | | | |
| 10 | Reservoir water level at breach | | mOD | 169.52 | 171.5 |
| 11 | Height of peak reservoir level above base of dam | H | m | 25.8 | 27.7 |
| 12 | Reservoir Capacity | V | $m^3$ | 3,300,000 | 4,163,500 |
| 13 | ***At these reservoir levels input*** | | | | |
| 14 | Length of dam across valley | L | m | 250 | 250 |
| 15 | Breach area (below reservoir level) | $A_B$ | $m^2$ | 100 | 100 |
| 16 | Total dam face area (below reservoir level) | $A_{DF}$ | $m^2$ | 2,500 | 2,500 |
| 18 | Breach formation time - select from following | $T_P$ | sec | 720 | |
| 19 | Arch; buttress dams (as page 50 of RMUKR) | | sec | 30 | |
| 20 | Gravity dam (as page 50 of RMUKR) | | sec | 720 | |
| 21 | ***Breach discharge as RMUKR*** | | | | |
| 22 | Peak Qp=0.9 $(A_B / A_{DF})^{0.28}$ L $H^{1.5}$ | $Q_p$ | $m^3/s$ | 11973 | 13348 |
| 23 | ***Time base as RMUKR, Section 5.2.2*** | | | | |
| 24 | Time to peak discharge, Tp=120(H) | Tp | sec | 720 | 720 |
| 25 | Time to end of discharge (so hydrograph vol. = reservoir vol.) | Te | sec | 551 | 624 |
| 26 | **Where warning message in this row (i.e. Te < 2Tp) correct by one of the following** | | | **NEED TO REDUCE Tp** | **NEED TO REDUCE Tp** |
| 27 | 1. Keeping Qp unchanged, reduce Tp (Te= 2Tp), | Tp | sec | 276 | 312 |
| 28 | where warning message, as Tp<40H | | | **Reduce Qp** | **Reduce Qp** |
| 29 | 2. Assuming Tp=40H reduce Qp until volume of | Tp | sec | 1,032 | 1,110 |
| 30 | flood hydrograph equals reservoir volume | Qp | $m^3/s$ | 3,198 | 3,752 |
| 32 | **Adopted dam break hydrograph** | Qp | $m^3/s$ | 3,198 | 3,752 |
| 33 | **at subject dam** | Tp | sec | 1,032 | 1,110 |
| 34 | | Te | sec | 2,064 | 2,219 |
| 35 | Remarks | | | | |



# DAMBREAK ANALYSIS

## Sheet 8.3: Data for Routing Downstream

| | |
|---|---|
| Dam name | Cascade above Anduin (Beta South to Delta South) |
| Grid ref. | 0 |
| Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin |

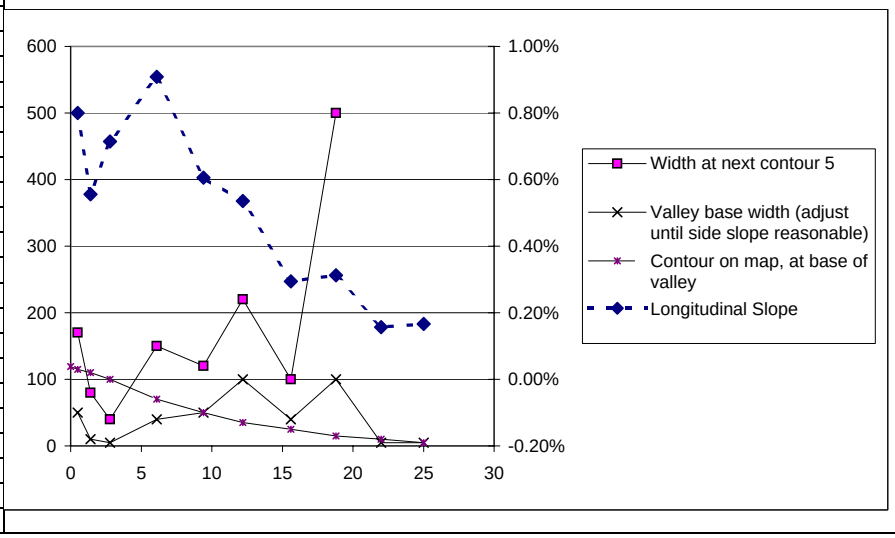
**8.3.1 Downstream confluence where consideration of effect of dam break is to be terminated**

| | |
|---|---|
| Basis of assessment | |
| OS sheet No/ scale/ date | |

| Confluence with River name | Grid Ref of point just downstream of confluence | Distance downstream of subject dam | Q ($m^3/s$) of flood downstream of confluence if no dam break :FEH or rapid method (Sheet 8.4) | | | Conclusion : terminate impact assessment? |
|---|---|---|---|---|---|---|
| | | km | 100 year | 1000 year | Source | |
| Kappa - us of confluence | | 4 | 160 | 283 | | No |
| Kappa - ds of confluence | | 4 | 260 | 460 | | No |
| U/S of conflcune with R Aries | | 25 | 300 | 600 | | No |
| Ds of conf with R Aries | | 25 | 619 | 1092 | | Yes |
| | | | | | | |
| | | | | | | |

**8.3.2 Valley bed slope downstream of dam**

| Contour on map, at base of valley | Chainage downstream of subject dam (scaled) | Longitudinal Slope | Valley base width (adjust until side slope reasonable) | Width at next contour | | Implied side slope H:V | | Consider if slope constant between each set of contours |
|---|---|---|---|---|---|---|---|---|
| mOD | km | | | 5 | 10 | 5 | 10 | |
| 119 | 0 | | | | | | | |
| 115 | 0.5 | 0.80% | 50 | 170 | 270 | 12.0 | 11.0 | |
| 110 | 1.4 | 0.56% | 10 | 80 | 150 | 7.0 | 7.0 | |
| 100 | 2.8 | 0.71% | 5 | 40 | 100 | 3.5 | 4.8 | |
| 70 | 6.1 | 0.91% | 40 | 150 | 540 | 11.0 | 25.0 | |
| 50 | 9.4 | 0.61% | 50 | 120 | 140 | 7.0 | 4.5 | |
| 35 | 12.2 | 0.54% | 100 | 220 | 280 | 12.0 | 9.0 | |
| 25 | 15.6 | 0.29% | 40 | 100 | 169 | 6.0 | 6.5 | |
| 15 | 18.8 | 0.31% | 100 | 500 | 600 | 40.0 | 25.0 | |
| 10 | 22 | 0.16% | 5 | | 5 | -0.5 | 0.0 | |
| 5 | 25 | 0.17% | 5 | | 5 | -0.5 | 0.0 | |
| | | -0.02% | | | | 0.0 | 0.0 | |
| | | #DIV/0! | | | | | | |



# DAMBREAK ANALYSIS

## Sheet 8.4.1: Rapid Method for Estimating 100Yr Flood at Each Downstream Confluence

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | Dam name | Cascade above Anduin (Beta South to Delta South) | | | | |
| 4 | Grid ref. | 0 | | | | |
| 5 | Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin | | | | |
| 6 | **If applicable, use this sheet (inserting additional sheets where necessary) for** | | | | | |
| 7 | | | | | | |
| 8 | | Symbol | Units | Input by user | Output/ linked input | Remarks |
| 9 | **For point at which inflow to be determined** | | | | | |
| 10 | Description e.g. subject dam/ downstream confluence | | Just upstream of conflucne with Kappa Brook | | | |
| 11 | Grid reference of point flow determined | | | | | |
| 12 | Grid reference of centre of relevant catchment | | | | | |
| 13 | Catchment Area | A | $km^2$ | 83.7 | | |
| 14 | | | | | | |
| 15 | **Estimate PMF using Rapid Method in Floods and Reservoir Safety** | | | | | |
| 16 | Identify mainstream entering reservoir and measure length L (km) to end of stream (blue line on 1:25,000 scale of OS Map, Ref. FSR) | L | km | | | |
| 17 | Estimate altitude at points 10% and 85% of length from lowest point on mainstream ($H_{10}$ and $H_{85}$) | $H_{10}$ | mOD | | | |
| 18 | | $H_{85}$ | mOD | | | |
| 19 | Slope is then: $S_{1085} = H_{85}-H_{10} / 0.75 \times L$ | $S_{1085}$ | m/km | | 48.30 | DPSBAR from F |
| 20 | Average Annual Rainfall on Catchment, SAAR (mm); - obtained from FSR Vol. 5 maps | SAAR | mm | 1046 | | |
| 21 | Peak of PMF Inflow $Qm = 0.454 A^{0.937} S_{1085}^{0.328} SAAR^{0.319}$, in which it is assumed that the catchment soils are impermeable and that there is no urban area in the catchment | PMF | $m^3/s$ | | 942 | |
| 22 | | | | | | |
| 23 | **Determine magnitude vs. annual probability** | | | | | |
| 24 | Factor to appropriate return period | Return period (years) | Annual probability | Factor | Q | |
| 25 | Return period for PMF | PMF | 1.0E-06 | 1 | 942 | |
| 26 | | 10,000 | 1.0E-04 | 0.5 | 471 | |
| 27 | | 1,000 | 1.0E-03 | 0.3 | 283 | |
| 28 | | 150 | 6.7E-03 | 0.2 | 188 | |
| 29 | Extrapolated on log-log paper from factors in FRS | 100 | 1.0E-02 | 0.17 | 160 | |
| 30 | | | | | | |
| 31 | **For completeness include average inflow as FRS** | | | | | |
| 32 | Catchment Wetness Index | CWI | | | 125 | |
| 33 | Adopt average non-separated flow, or base flow, ANSF from FSSR 16: $ANSF=[33(CWI-125) + 3.0 SAAR + 5.5] 10^{-5}$ ($m^3/s/km^2$) | ANSF | $m^3/s/km^2$ | | 0.031 | |
| 34 | Average inflow q =ANSFxA($m^3/s$) | q | $m^3/s$ | | 2.6 | |

# DAMBREAK ANALYSIS

## Sheet 8.4.2: Rapid Method for Estimating 100Yr Flood at Each Downstream Confluence

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | Dam name | | Cascade above Anduin (Beta South to Delta South) | | | |
| 4 | Grid ref. | | 0 | | | |
| 5 | Calculation Number/ description | | Rapid dambreak for dams in cascade on River Anduin | | | |
| 6 | **If applicable, use this sheet (inserting additional sheets where necessary) for each affected downstream confluence** | | | | | |
| 7 | | | | | | |
| 8 | | Symbol | Units | Input by user | Output/ linked input | Remarks |
| 9 | **For point at which inflow to be determined** | | | | | |
| 10 | Description e.g. subject dam/ downstream confluence | | Downstream of confluence with Kappa Brook | | | |
| 11 | Grid reference of point flow determined | | | | | |
| 12 | Grid reference of centre of relevant catchment | | | | | |
| 13 | Catchment Area | A | $km^2$ | 149.9 | | |
| 14 | | | | | | |
| 15 | **Estimate PMF using Rapid Method in Floods and Reservoir Safety** | | | | | |
| 16 | Identify mainstream entering reservoir and measure length L (km) to end of stream (blue line on 1:25,000 scale of OS Map, Ref. FSR) | L | km | | | |
| 17 | Estimate altitude at points 10% and 85% of length from lowest point on mainstream ($H_{10}$ and $H_{85}$) | $H_{10}$ | mOD | | | |
| 18 | | $H_{85}$ | mOD | | | |
| 19 | Slope is then: $S_{1085} = H_{85}-H_{10} / 0.75 \times L$ | $S_{1085}$ | m/km | | 41.70 | DPSBAR from F |
| 20 | Average Annual Rainfall on Catchment, SAAR (mm); - obtained from FSR Vol. 5 maps | SAAR | mm | 1029 | | |
| 21 | Peak of PMF Inflow $Qm = 0.454\ A^{0.937}\ S_{1085}^{0.328}\ SAAR^{0.319}$, in which it is assumed that the catchment soils are impermeable and that there is no urban area in the catchment | PMF | $m^3/s$ | | 1542 | |
| 22 | | | | | | |
| 23 | **Determine magnitude vs. annual probability** | | | | | |
| 24 | Factor to appropriate return period | Return period (years) | Annual probability | Factor | Q | |
| 25 | Return period for PMF | PMF | 1.0E-06 | 1 | 1,542 | |
| 26 | | 10,000 | 1.0E-04 | 0.5 | 771 | |
| 27 | | 1,000 | 1.0E-03 | 0.3 | 463 | |
| 28 | | 150 | 6.7E-03 | 0.2 | 308 | |
| 29 | Extrapolated on log-log paper from factors in FRS | 100 | 1.0E-02 | 0.17 | 262 | |
| 30 | | | | | | |
| 31 | **For completeness include average inflow as FRS** | | | | | |
| 32 | Catchment Wetness Index | CWI | | | 125 | |
| 33 | Adopt average non-separated flow, or base flow, ANSF from FSSR 16: $ANSF=[33(CWI-125) + 3.0\ SAAR + 5.5]\ 10^{-5}$ ($m^3/s/km^2$) | ANSF | $m^3/s/km^2$ | | 0.031 | |
| 34 | Average inflow q =ANSFxA($m^3/s$) | q | $m^3/s$ | | 4.6 | |

# DAMBREAK ANALYSIS

## Sheet 8.4.3: Rapid Method for Estimating 100Yr Flood at Each Downstream Confluence

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | Dam name | | Cascade above Anduin (Beta South to Delta South) | | | |
| 4 | Grid ref. | | 0 | | | |
| 5 | Calculation Number/ description | | Rapid dambreak for dams in cascade on River Anduin | | | |
| 6 | **If applicable, use this sheet (inserting additional sheets where necessary) for each affected downstream confluence** | | | | | |
| 7 | | | | | | |
| 8 | | Symbol | Units | Input by user | Output/ linked input | Remarks |
| 9 | **For point at which inflow to be determined** | | | | | |
| 10 | Description e.g. subject dam/ downstream confluence | | Just upstream of confluence with River Aries | | | |
| 11 | Grid reference of point flow determined | | | | | |
| 12 | Grid reference of centre of relevant catchment | | | | | |
| 13 | Catchment Area | A | $km^2$ | 376.5 | | |
| 14 | | | | | | |
| 15 | **Estimate PMF using Rapid Method in Floods and Reservoir Safety** | | | | | |
| 16 | Identify mainstream entering reservoir and measure length L (km) to end of stream (blue line on 1:25,000 scale of OS Map, Ref. FSR) | L | km | | | |
| 17 | Estimate altitude at points 10% and 85% of length from lowest point on mainstream ($H_{10}$ and $H_{85}$) | $H_{10}$ | mOD | | | |
| 18 | | $H_{85}$ | mOD | | | |
| 19 | Slope is then: $S_{1085} = H_{85}-H_{10} / 0.75 \times L$ | $S_{1085}$ | m/km | | 41.70 | DPSBAR from F |
| 20 | Average Annual Rainfall on Catchment, SAAR (mm); - obtained from FSR Vol. 5 maps | SAAR | mm | 1015 | | |
| 21 | Peak of PMF Inflow $Qm = 0.454\ A^{0.937}\ S_{1085}^{0.328}\ SAAR^{0.319}$, in which it is assumed that the catchment soils are impermeable and that there is no urban area in the catchment | PMF | $m^3/s$ | | 3639 | |
| 22 | | | | | | |
| 23 | **Determine magnitude vs. annual probability** | | | | | |
| 24 | Factor to appropriate return period | Return period (years) | Annual probability | Factor | Q | |
| 25 | Return period for PMF | PMF | 1.0E-06 | 1 | 3,639 | |
| 26 | | 10,000 | 1.0E-04 | 0.5 | 1,820 | |
| 27 | | 1,000 | 1.0E-03 | 0.3 | 1,092 | |
| 28 | | 150 | 6.7E-03 | 0.2 | 728 | |
| 29 | Extrapolated on log-log paper from factors in FRS | 100 | 1.0E-02 | 0.17 | 619 | |
| 30 | | | | | | |
| 31 | **For completeness include average inflow as FRS** | | | | | |
| 32 | Catchment Wetness Index | CWI | | | 125 | |
| 33 | Adopt average non-separated flow, or base flow, ANSF from FSSR 16: ANSF=[33(CWI-125) + 3.0 SAAR + 5.5] $10^{-5}$ ($m^3/s/km^2$) | ANSF | $m^3/s/km^2$ | | 0.031 | |
| 34 | Average inflow q =ANSFxA($m^3/s$) | q | $m^3/s$ | | 11.5 | |

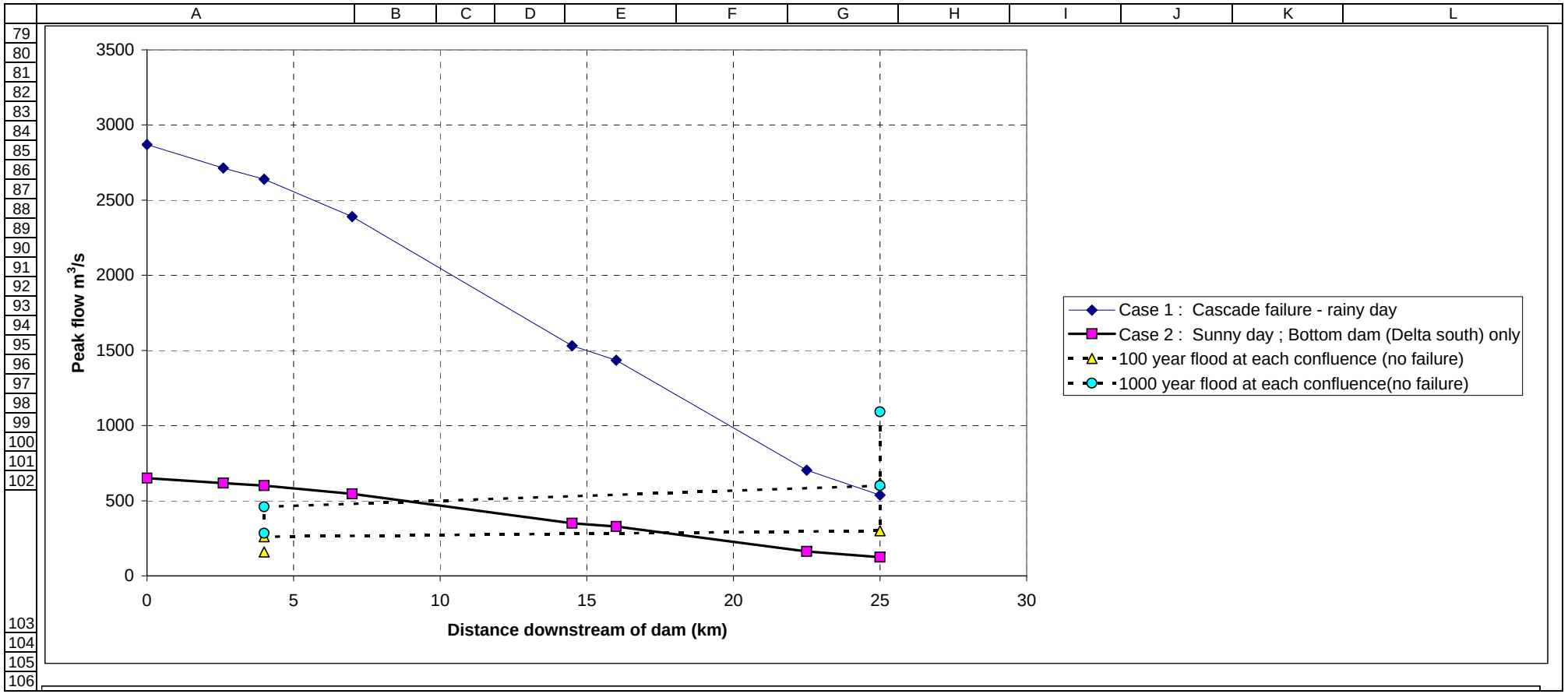
# DAMBREAK ANALYSIS

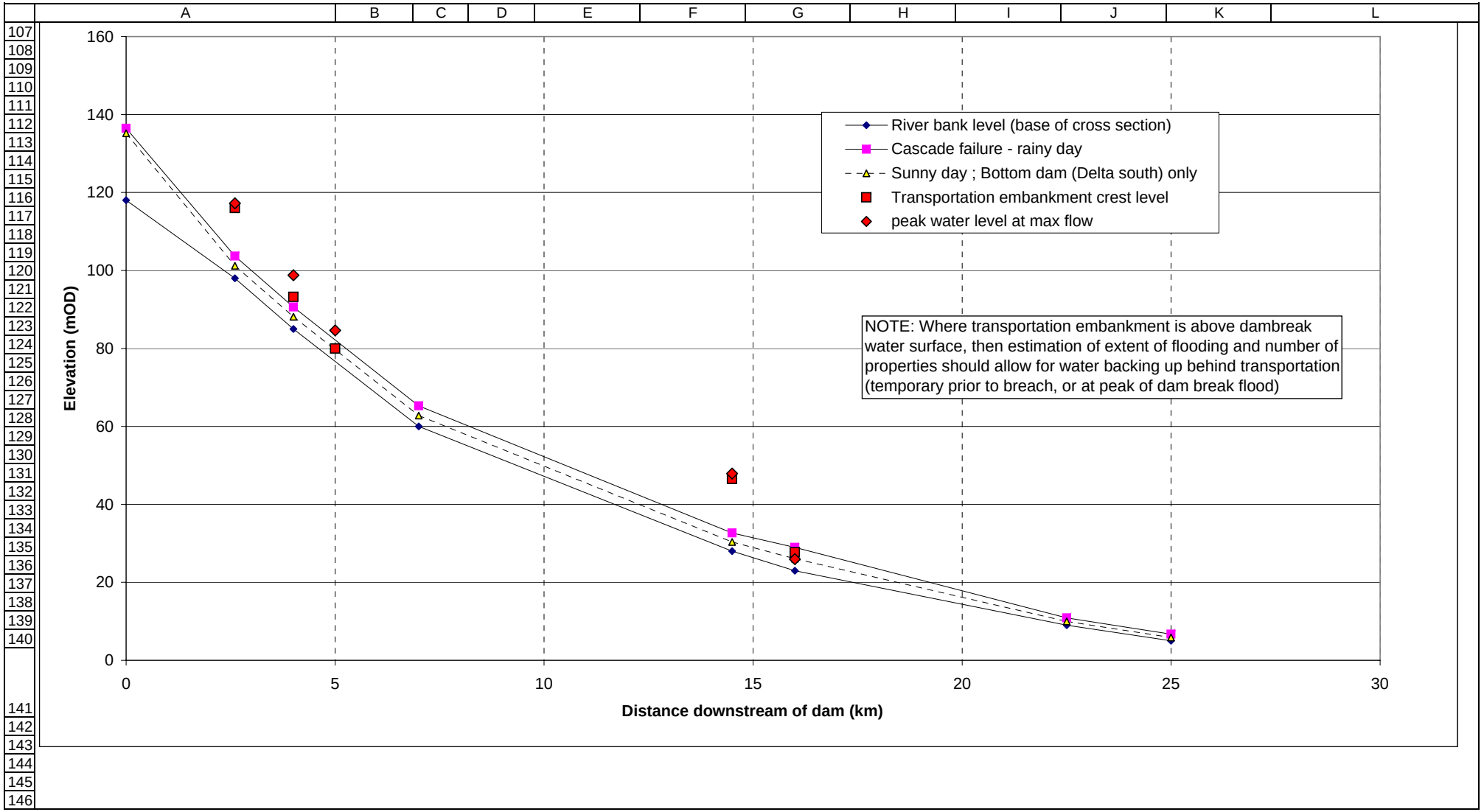
## Sheet 8.4.4: Rapid Method for Estimating 100Yr Flood at Each Downstream Confluence

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | Dam name | | Cascade above Anduin (Beta South to Delta South) | | | |
| 4 | Grid ref. | | 0 | | | |
| 5 | Calculation Number/ description | | Rapid dambreak for dams in cascade on River Anduin | | | |
| 6 | **If applicable, use this sheet (inserting additional sheets where necessary) for each affected downstream confluence** | | | | | |
| 7 | | | | | | |
| 8 | | Symbol | Units | Input by user | Output/ linked input | Remarks |
| 9 | **For point at which inflow to be determined** | | | | | |
| 10 | Description e.g. subject dam/ downstream confluence | | Downstream of confluence with River Aries | | | |
| 11 | Grid reference of point flow determined | | | | | |
| 12 | Grid reference of centre of relevant catchment | | | | | |
| 13 | Catchment Area | A | $km^2$ | 376.5 | | |
| 14 | | | | | | |
| 15 | **Estimate PMF using Rapid Method in Floods and Reservoir Safety** | | | | | |
| 16 | Identify mainstream entering reservoir and measure length L (km) to end of stream (blue line on 1:25,000 scale of OS Map, Ref. FSR) | L | km | | | |
| 17 | Estimate altitude at points 10% and 85% of length from lowest point on mainstream ($H_{10}$ and $H_{85}$) | $H_{10}$ | mOD | | | |
| 18 | | $H_{85}$ | mOD | | | |
| 19 | Slope is then: $S_{1085} = H_{85}-H_{10} / 0.75 \times L$ | $S_{1085}$ | m/km | | 41.70 | DPSBAR from F |
| 20 | Average Annual Rainfall on Catchment, SAAR (mm); - obtained from FSR Vol. 5 maps | SAAR | mm | 1015 | | |
| 21 | Peak of PMF Inflow $Qm = 0.454\ A^{0.937}\ S_{1085}^{0.328}\ SAAR^{0.319}$, in which it is assumed that the catchment soils are impermeable and that there is no urban area in the catchment | PMF | $m^3/s$ | | 3639 | |
| 22 | | | | | | |
| 23 | **Determine magnitude vs. annual probability** | | | | | |
| 24 | Factor to appropriate return period | Return period (years) | Annual probability | Factor | Q | |
| 25 | Return period for PMF | PMF | 1.0E-06 | 1 | 3,639 | |
| 26 | | 10,000 | 1.0E-04 | 0.5 | 1,820 | |
| 27 | | 1,000 | 1.0E-03 | 0.3 | 1,092 | |
| 28 | | 150 | 6.7E-03 | 0.2 | 728 | |
| 29 | Extrapolated on log-log paper from factors in FRS | 100 | 1.0E-02 | 0.17 | 619 | |
| 30 | | | | | | |
| 31 | **For completeness include average inflow as FRS** | | | | | |
| 32 | Catchment Wetness Index | CWI | | | 125 | |
| 33 | Adopt average non-separated flow, or base flow, ANSF from FSSR 16: $ANSF=[33(CWI-125) + 3.0\ SAAR + 5.5]\ 10^{-5}$ ($m^3/s/km^2$) | ANSF | $m^3/s/km^2$ | | 0.031 | |
| 34 | Average inflow q =ANSFxA($m^3/s$) | q | $m^3/s$ | | 11.5 | |

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **DAMBREAK ANALYSIS** | | | | | | | | | | | |
| 2 | **Sheet 8.5: Attenuation Downstream** | | | | | | | | | | | |
| 3 | Dam name | Cascade above Anduin (Beta South to Delta South) | | | | | | | | | | |
| 4 | Grid ref. | 0 | | | | | | | | | | |
| 5 | Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin | | | | | | | | | | |
| 6 | | Symbol | Units | | | | **Downstream end of Reach No** | | | | | Remarks |
| 7 | | | | **0** | **1** | **2** | **3** | **5** | **6** | **7** | **8** | |
| 8 | OS Grid Ref | | | | | | | | | | | Reach 4 omitted as side stream |
| 9 | Distance downstream of dam | | km | 0 | 2.6 | 4 | 7 | 14.5 | 16 | 22.5 | 25 | |
| 10 | River bank level (base of cross section) | | mOD | 118 | 98 | 85 | 60 | 28 | 23 | 9 | 5 | |
| 11 | Feature defining end of reach | | | Dam | M way | railway | bend in river at end of pelagrir | railway 2 | A road | u/s Rauros; spill to east | confluence with tidal creek | |
| 12 | Topography of zone | | | | steep sides | | wide flood plain | | | flat | flat | |
| 13 | Note any other special feature in zone that would affect flow and/ or damage | | | | | | skirt town of Pelargir | Village of Chi straddles railway | | | village of Rauros on west side | |
| 14 | Length of zone | x | m | | 2600 | 1400 | 3000 | 7500 | 1500 | 6500 | 9000 | |
| 15 | **Channel geometry of valley in each zone** | | | | | | | | | | | |
| 16 | Average slope of base of valley that would be inundated | $S_o$ | % | | 0.80% | 0.80% | 0.60% | 0.40% | 0.30% | 0.20% | 0.20% | |
| 17 | Manning's n | n | | | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | 0.075 | |
| 18 | Channel base width (trapezoid) | $W_B$ | m | | 10 | 10 | 40 | 50 | 40 | 100 | 100 | |
| 19 | Channel side slopes H:V | | | | 10 | 10 | 10 | 10 | 5 | 80 | 80 | |
| 20 | **Infrastructure embankment across flow path (transfer from Sheet 1.7)** | | | | | | | | | | | |
| 21 | Description | | | | Mxx | Railway | A road | Railway 2 | A road | | | |
| 22 | Distance downstream of dam | | km | | 2.6 | 4 | 5 | 14.5 | 16 | | | |
| 23 | Transportation embankment crest level | | mOD | | 116 | 93.2 | 80 | 46.5 | 27.7 | | | |
| 24 | River bank level (base of cross section) | | | | 98 | 85 | 75 | 28.1 | 18.3 | | | |
| 25 | Length of crest which could be overtopped | | m | | 200 | 125 | 150 | 150 | 150 | | | |
| 26 | Average width of bridge opening (as slot) | | m | | 20 | 5 | 9 | 10 | 20 | | | |
| 27 | % blocked | | | | 0% | 50% | 50% | 50% | 20% | | | |
| 28 | Coefficient of discharge | | | | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | | | |
| 29 | Height | | m | | 18 | 8.2 | 5 | 18.5 | 4.7 | -9 | -5 | |
| 30 | Flow when upstream ponded to top of embankment | | m3/s | | 2,291 | 88 | 75 | 597 | 245 | #NUM! | #NUM! | |
| 31 | | | | | | | | | | | | |
| 32 | **Estimated flow conditions** | | | | | | | | | | | |
| 33 | **Case 1 :** | | | | **Cascade failure - rainy day** | | | | | | | |
| 34 | Reach Number | | | **0** | **1** | **2** | **3** | **5** | **6** | **7** | **8** | |
| 35 | Flooded width (adjust estimate until **ERROR** below is acceptable, or see workbook comment) | B1 | m | | 125 | 125 | 145 | 140 | 100 | 410 | 370 | |
| 36 | Attenuation factor k | | | | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | |
| 37 | Attenuation length scale | La | m | | 46,253 | 51,178 | 30,213 | 16,838 | 23,245 | 9,113 | 33,586 | |
| 38 | Discharge | Qp(x) | $m^3/s$ | 2870 | 2,713 | 2,640 | 2,390 | 1,531 | 1,435 | 703 | 538 | |

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | Time period at > half discharge | $T_h$ (=$T_e$/2) | sec | 3,000 | 3,173 | 3,261 | 3,602 | 5,623 | 5,998 | 12,240 | 16,002 | |
| 40 | ***Max water depth (from Manning)*** | D | m | **18.5** | **5.7** | **5.6** | **5.3** | **4.7** | **6.0** | **1.9** | **1.7** | assume d<<width |
| 41 | **ERROR** - initial estimate of width (B1) as percentage of width implied by depth | | | | 1% | 2% | 0% | -2% | 0% | 2% | -1% | |
| 42 | Flood level | | mOD | 136.49 | 103.70 | 90.61 | 65.27 | 32.65 | 28.97 | 10.89 | 6.71 | |
| 44 | **Check effect of Infrastructure embankment** | | | | | | | | | | | |
| 45 | Flow depth (intact) - above river bank | | m | | 19.3 | 13.8 | 9.6 | 19.8 | 7.6 | #NUM! | #NUM! | |
| 46 | Peak flood level | | mOD | | 117.3 | 98.8 | 84.6 | 47.9 | 25.9 | #NUM! | #NUM! | |
| 47 | **Flooded width at this flow** | | **m** | | **395** | **285** | **232** | **446** | **116** | **#NUM!** | **#NUM!** | |
| 48 | Check if embankment is an obstruction | | | | WARNING, OBSTRUCTION | WARNING, OBSTRUCTION | WARNING, OBSTRUCTION | WARNING, OBSTRUCTION | WARNING, OBSTRUCTION | #NUM! | #NUM! | |
| 49 | Depth overtopping above top of embankment | | m | | 1.3 | 5.6 | 4.6 | 1.3 | 2.9 | #NUM! | #NUM! | |
| 50 | Breach width as Froehlich | | m | | 58.0 | 50.0 | 45.5 | 58.3 | 45.0 | #NUM! | #NUM! | |
| 51 | Breach width (average) - set to zero if not breached | | m | | 58 | 50 | 45 | 58 | 45 | #NUM! | #NUM! | |
| 52 | Flow depth (breached) - above river bank | | m | | 9.9 | 11.0 | 8.7 | 6.7 | 6.9 | #NUM! | #NUM! | |
| 53 | Depth overtopping above top of embankment | | m | | -8.1 | 2.8 | 3.7 | -11.8 | 2.2 | #NUM! | #NUM! | |
| 54 | | | | | | | | | | | | |
| 55 | **Case 2 :** | | | | **Sunny day ; Bottom dam (Delta south) only** | | | | | | | |
| 56 | Reach Number | | | **0** | **1** | **2** | **3** | **5** | **6** | **7** | **8** | |
| 57 | Flooded width (adjust estimate as for Base Case) | B1 | m | | 75 | 75 | 95 | 100 | 70 | 270 | 250 | |
| 58 | Attenuation length scale | La | m | | 48,891 | 53,802 | 31,133 | 16,964 | 23,374 | 9,270 | 33,259 | |
| 59 | Discharge | Qp(x) | $m^3/s$ | 650 | 616 | 601 | 545 | 350 | 329 | 163 | 124 | |
| 60 | Time period at > half discharge | $T_h$ (=$T_e$/2) | sec | 3,400 | 3,586 | 3,680 | 4,053 | 6,306 | 6,724 | 13,556 | 17,768 | |
| 61 | ***Max water depth (from Manning)*** | D | **m** | **17.2** | **3.2** | **3.1** | **2.8** | **2.4** | **3.1** | **1.0** | **0.9** | assume d<<width |
| 62 | **ERROR** - initial estimate of width (B1) as percentage of width implied by depth | | | | 2% | 3% | -1% | 3% | -1% | 3% | 3% | |
| 64 | Flood level | | mOD | 135.20 | 101.18 | 88.13 | 62.80 | 30.35 | 26.05 | 10.01 | 5.90 | |
| 65 | **Check effect of Infrastructure embankment** | | | | | | | | | | | |
| 66 | Flow depth (intact) - above river bank | | m | | 7.5 | 10.2 | 6.6 | 12.9 | 5.2 | #NUM! | #NUM! | |
| 67 | **Flooded width at this flow** | | **m** | | **160** | **213** | **173** | **309** | **92** | **#NUM!** | **#NUM!** | |
| 68 | Check if embankment is an obstruction | | | | WARNING, OBSTRUCTION | WARNING, OBSTRUCTION | WARNING, OBSTRUCTION | WARNING, OBSTRUCTION | WARNING, OBSTRUCTION | #NUM! | #NUM! | |
| 69 | Depth overtopping above top of embankment | | | | -10.5 | 2.0 | 1.6 | -5.6 | 0.5 | #NUM! | #NUM! | |
| 70 | Breach width as Froehlich | | m | | 37.5 | 32.3 | 29.4 | 37.7 | 29.1 | #NUM! | #NUM! | |
| 71 | Breach width (average) - set to zero if not breached | | m | | 0 | 30 | 30 | 0 | 0 | | | |
| 72 | Flow depth (breached) - above river bank | | m | | 7.5 | 5.6 | 5.3 | 12.9 | 5.2 | #NUM! | #NUM! | |
| 73 | Depth overtopping above top of embankment | | m | | -50.5 | -44.4 | -40.2 | -45.4 | -39.7 | #NUM! | #NUM! | |
| 74 | ***Remarks*** | | | | | | | | | | | |
| 75 | | | | | | | | | | | | |
| 76 | | | | | | | | | | | | |
| 77 | | | | | | | | | | | | |


Peak flow m³/s
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
Distance downstream of dam (km)
Case 1 : Cascade failure - rainy day
Case 2 : Sunny day ; Bottom dam (Delta south) only
100 year flood at each confluence (no failure)
1000 year flood at each confluence(no failure)


Elevation (mOD)
Distance downstream of dam (km)
River bank level (base of cross section)
Cascade failure - rainy day
Sunny day ; Bottom dam (Delta south) only
Transportation embankment crest level
peak water level at max flow
NOTE: Where transportation embankment is above dambreak water surface, then estimation of extent of flooding and number of properties should allow for water backing up behind transportation (temporary prior to breach, or at peak of dam break flood)

# SITE INSPECTION

## Sheet 1.6: Installations Downstream of Subject Reservoir

| | |
|---|---|
| Dam name | Cascade above Anduin (Beta South to Delta South) |
| Grid ref. | 0 |
| Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin |
| Basis of assessment | |
| OS sheet No/ scale/ date | |

| Reach Number | Distance d/s of dam (km) | (OS Grid ref.) | Feature | Residential: Rainy day: Length resid frontage: Total (m) | Residential: Rainy day: Length resid frontage: Unit length | Residential: Rainy day: Number of dwellings flooded | Residential: Sunny day: Number of dwellings flooded | Non-residential - property flooded: Rainy day: Building area m2 | Non-residential - property flooded: Rainy day: Num. floors | Non-residential - property flooded: Rainy day: Total area $m^2$/ person | Non-residential - property flooded: Sunny day: Total area | Remarks - see checklist in text e.g. hydraulic controls on dam break flood, installations, any quantitative data on threshold levels of individual properties |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.4 | | farm building 150m d/s dam | | | | | 1600 | 1 | 1600 | 1,600 | |
| | | | farm building by FB | | | | | 100 | 1 | 100 | | |
| 1 | 2.2 | | residential just before M way | | | 2 | 2 | | | | | |
| | | | | | | | | | | | | |
| 2 | 2.4 | | Pub and other buildings on minor road crossing watercourse | | | 6 | 3 | 300 | 2 | 600 | 600 | |
| 3 | | | row of houses along main road | 60 | 6 | 10 | 4 | | | | | |
| 3 | | | estate in Reach 3 flooded across road) | 1400 | 8 | 175 | 50 | | | | | |
| 3 | | | isolated houses | | | 4 | 2 | | | | | |
| 3 | | | Motel | | | | | 400 | 1 | 400 | 400 | |
| 3 | | | large (60 x 150) building | | | | | 9000 | 1 | 9000 | 9,000 | |
| 3 | | | complex of buildings- only one on low ground affected | | | | | 1800 | 1 | 1800 | | |
| 4 | | | backed up to 85mOD from A road embankment - one large works | | | 2 | 2 | 7800 | 2 | 15600 | 15,600 | |
| | | | six smaller industrial buildings | | | | | 1200 | 1 | 1200 | 1,200 | |
| 5 | | | scattered buildings in flood plain | | | 7 | 5 | 200 | 1 | 200 | 200 | |
| 6 | | | scattered buildings in flood plain | | | 10 | 5 | | | | | |
| 6 | | | works on right bank just before motorway | | | | | 1600 | 1 | 1600 | 1,600 | |
| | | | **Sub-total** | | | 216 | 73 | 24000 | | 32100 | 30200 | |
| 7 | | | buildings at B road crossings, incl church | | | 3 | 3 | 1200 | 1 | 1200 | 1,200 | |
| 8 | | | 2nd B road; incl 2 farms | | | 12 | 12 | 1200 | 1 | 1200 | 1,200 | sunny day = approx 1000 year Q |
| | | | Mill | | | | | 1600 | 1 | 1600 | 1,600 | adjust occupancy |
| | | | 575m wide strip though Psi | 5000 | 8 | 625 | 150 | | | 0 | 0 | Eyeball estimate!! |
| | | | one large building | | | | | 2000 | 1 | 2000 | 2,000 | |
| | | | sewage works, school, church say 6 shops @200sqm | | | | | 2400 | 1 | 2400 | 1,200 | |
| | | | | | | 856 | 238 | 32,400 | | 40,500 | 37,400 | |

# CONSEQUENCE ASSESSMENT

## Sheet 9: Estimate of Population at Risk and Likely Loss of Life

## Sheet 10: Estimate of direct cost of third party flood damage

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Dam name | Cascade above Anduin (Beta South to Delta South) | | | | | | | | | | | | |
| 5 | Grid ref. | 0 | | | | | | | | | | | | |
| 6 | Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin | | | | | | | | | | | | |
| 7 | | Symbol | Units | | | | | | | | | | | |
| 8 | **9.1.1 Physical description and peak flow conditions** | | | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | | |
| 9 | **(C/F from Sheet 8.5)** | | | | | | | | | | | | | |
| 10 | Distance downstream of dam | | km | 0 | 2.6 | 4 | 7 | | 14.5 | 16 | 22.5 | 25 | | |
| 11 | Feature defining end of reach | | | Dam | M way | railway | bend in river at end of pelagrir | side valley | railway 2 | A road | u/s Rauros; spill to east | confluence with tidal creek | | |
| 12 | Note any other special feature in zone that would affect flow and/ or damage | | | 0 | 0 | 0 | skirt town of Pelargir | backed up from A road-inudnation only | Village of Chi straddles railway | 0 | 0 | village of Rauros on west side | | |
| 13 | **State which case on Sheet 8.5 is to be used** | | | Case 1 | Cascade failure - rainy day | | | | | | | | | |
| 14 | Discharge | Qp(x) | $m^3/s$ | 2,870 | 2,713 | 2,640 | 2,390 | | 1,531 | 1,435 | 703 | 538 | | |
| 15 | Flooded width | B1 | m | | 125 | 125 | 145 | | 140 | 100 | 410 | 370 | | |
| 16 | Max water depth (from Manning) | D | m | 18.5 | 5.7 | 5.6 | 5.3 | | 4.7 | 6.0 | 1.9 | 1.7 | | |
| 17 | ***Other measures of forcefulness of flow*** | | | | | | | | | | | | | |
| 18 | Average velocity | V | m/s | 13.5 | 7.0 | 7.0 | 4.9 | | 3.5 | 3.4 | 1.5 | 1.3 | | |
| 19 | Velocity x depth | VD | $m^2/s$ | 249.1 | 40.2 | 39.1 | 25.8 | | 16.1 | 20.5 | 2.8 | 2.3 | | |
| 20 | Discharge/ flooded width | Q/W | $m^2/s$ | | 21.7 | 21.1 | 16.5 | | 10.9 | 14.4 | 1.7 | 1.5 | | |
| 21 | ***Time for peak dambreak flood to reach key points*** | | | | | | | | | | | | | |
| 22 | Time to travel reach | | mins | | 4 | 3 | 8 | | 30 | 7 | 44 | 63 | | |
| 23 | Cumulative time to end of reach | | mins | | 4 | 8 | 16 | | 46 | 53 | 97 | 109 | | |
| 24 | **10.1.2 Number of properties vulnerable to Flood Damage in Each Zone** | | | | | | | | | | | | | |
| 25 | **Select one of the categories shown within input box (pick list)** | | | | | | | | | | | | | |
| 30 | ***Residential Properties at Risk in Each Zone*** | | | | No. of properties in each damage category: | | | | | | | | Sub-total | Remarks |
| 31 | Property destroyed | | No. | | 2 | 6 | 14 | | 7 | 10 | | | 39 | |
| 32 | Partial structural damage | | No. | | | | 175 | | | | | 12 | 187 | |
| 33 | Inundation damage only | | No. | | | | | 2 | | | 3 | 625 | 630 | |
| 34 | ***Non Residential Properties at Risk in Each Zone (build up in Table 1.6)*** | | | | Total area ($m^2$) of non-residential properties in each damage category | | | | | | | | **856** | No. |
| 35 | Property destroyed | | $m^2$ | | 1,700 | 600 | 2,200 | | | 1,600 | | | 6,100 | |
| 36 | Partial structural damage | | $m^2$ | | | | 9,000 | | 200 | | | | 9,200 | |
| 37 | Inundation damage only | | $m^2$ | | | | | 16,800 | | | 1,200 | 7,200 | 25,200 | |
| 38 | | | | | | | | | | | | | ***40,500*** | m2 |

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | **9.1.2 Population (pedestrians) at risk (water > 0.5m) (PAR)** | | | | | | | | | | | | | Remarks |
| 40 | | | | | When occupied | | Occupancy | *Time averaged PAR* | | | | | | |
| 41 | Residential: Number of PAR/ property | | | | 2.3 | | 70% | *1.61* | */property* | | | | | |
| 42 | Non- residential: PAR as area (m2)/ occupant | | | | | 40 | 25% | *160* | *m2/ occupant* | | | | | |
| 43 | | | | | | | | | | | | | Sub-total | |
| 44 | Number of residential properties | | | | 2 | 6 | 189 | 2 | 7 | 10 | 3 | 637 | 856 | |
| 45 | Residential properties: Max PAR (either accept equation, or overwrite) | | | | 4.6 | 13.8 | 434.7 | 4.6 | 16.1 | 23.0 | 6.9 | 1,465.1 | **1,969** | |
| 46 | Non residential : Max PAR (either accept equation, or overwrite) | | | | 42.5 | 15.0 | 280.0 | 420.0 | 5.0 | 40.0 | 30.0 | 180.0 | **1012.5** | |
| 47 | On transportation routes | | | | | 6 | | 2 | 6 | | | 10 | 24 | |
| 48 | Other open air e.g. playing fields, recreational areas | | | | 1 | 1 | 2 | | 2 | 1 | 1 | 10 | 18 | |
| 49 | Assessed total PAR (time averaged) | | | | 15 | 20 | 376 | 110 | 21 | 27 | 13 | 1,091 | **1,673** | |
| 51 | **9.2.3 Likely loss of life (LLOL)** | | | | ***No warning*** | | | | | | | | | |
| 52 | Fatality rate (Ratio LLOL to PAR) - see Guide Figure 9.1 | | % | | 100% | 100% | 70% | 30% | 30% | 50% | 1% | 1% | | |
| 53 | LLOL | | | | 14.85 | 20.41 | 263.40 | 33.07 | 6.16 | 13.55 | 0.13 | 10.91 | 362.47 | |
| 54 | | | | | ***Warning (hours as below)*** | | | | | | | | | |
| 55 | Fatality rate (Ratio LLOL to PAR) - see Guide Figure 9.1 | | % | | 10.0% | 10.0% | 7.0% | 4.0% | 4.0% | 5.0% | 0.2% | 0.2% | | |
| 56 | LLOL | | | | 1.48 | 2.04 | 26.34 | 4.41 | 0.82 | 1.36 | 0.03 | 2.18 | 38.66 | |
| 58 | **Adopted likely loss of life** | | No warning | | **362.47** | | With warning time | | 1.5 | hours: | hours: | **38.66** | | |
| 60 | **10.1.3 Estimated Cost of Damage** | | | | | | | | | | | | | |
| 61 | ***a) Postcode (use for Internet searches of property value)*** | | | | | | | | | | | | | |
| 62 | ***b) Per Residential Property per zone (average)*** | | | | | | | | Cost of damage £k | | | | | |
| 63 | Property destroyed | | £/property | | 222,260 | 222,260 | 222,260 | 222,260 | 222,260 | 222,260 | 222,260 | 222,260 | | |
| 64 | Partial structural damage | | £/property | | 174,510 | 174,510 | 174,510 | 174,510 | 174,510 | 174,510 | 174,510 | 174,510 | | |
| 65 | Inundation damage only | | £/property | | 34,622 | 34,622 | 34,622 | 34,622 | 34,622 | 34,622 | 34,622 | 34,622 | | |
| 66 | Total damage per zone | | £ | | 444,520 | 1,333,560 | 33,650,890 | 69,244 | 1,555,820 | 2,222,600 | 103,866 | 23,732,870 | 63,113,370 | |
| 67 | ***c) Total per zone for non-residential property*** | | | | | | | Cost of damage £/m$^2$ (spreadsheet multiples by area, and gives total damage in bottom row) | | | | | | |
| 68 | Property destroyed | | £/m$^2$ | | 1,629 | 1,629 | 1,629 | 1,629 | 1,629 | 1,629 | 1,629 | 1,629 | | |
| 69 | Partial structural damage | | £/m$^2$ | | 1,507 | 1,507 | 1,507 | 1,507 | 1,507 | 1,507 | 1,507 | 1,507 | | |
| 70 | Inundation damage only | | £/m$^2$ | | 695 | 695 | 695 | 695 | 695 | 695 | 695 | 695 | | |
| 71 | Total damage per zone | | £ | | 2,769,300 | 977,400 | 17,146,800 | 11,676,000 | 301,400 | 2,606,400 | 834,000 | 5,004,000 | 41,315,300 | |
| 72 | ***d) Total by reach*** | | £ | | 3,213,820 | 2,310,960 | 50,797,690 | 11,745,244 | 1,857,220 | 4,829,000 | 937,866 | 28,736,870 | 104,428,670 | |
| 73 | | | | | | | | | | | | **Sum of third party property damages (£k)** | | **104,428,670** |
| 74 | | | | | | | | | | | | **Other damages (Optional at discretion of user e.g. replacement cost of dam)** | | |
| 75 | | | | | | | | | | | | **Value carried forward to Section 11 (£k)** | | **104,428,670** |
| 76 | | | | | | | | | | | | | | |

# CONSEQUENCE ASSESSMENT

## Sheet 9: Estimate of Population at Risk and Likely Loss of Life

## Sheet 10: Estimate of direct cost of third party flood damage

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Dam name | Cascade above Anduin (Beta South to Delta South) | | | | | | | | | | | | |
| 5 | Grid ref. | 0 | | | | | | | | | | | | |
| 6 | Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin | | | | | | | | | | | | |
| 7 | | Symbol | Units | | | | | | | | | | | |
| 8 | **9.1.1 Physical description and peak flow conditions** | | | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | | |
| 9 | **(C/F from Sheet 8.5)** | | | | | | | | | | | | | |
| 10 | Distance downstream of dam | | km | 0 | 2.6 | 4 | 7 | | 14.5 | 16 | 22.5 | 25 | | |
| 11 | Feature defining end of reach | | | Dam | M way | railway | bend in river at end of pelagrir | side valley | railway 2 | A road | u/s Rauros; spill to east | confluence with tidal creek | | |
| 12 | Note any other special feature in zone that would affect flow and/ or damage | | | 0 | 0 | 0 | skirt town of Pelargir | 0 | Village of Chi straddles railway | 0 | 0 | village of Rauros on west side | | |
| 13 | **State which case on Sheet 8.5 is to be used** | | | Case 2 | Sunny day ; Bottom dam (Delta south) only | | | | | | | | | |
| 14 | Discharge | Qp(x) | $m^3/s$ | 650 | 616 | 601 | 545 | | 350 | 329 | 163 | 124 | | |
| 15 | Flooded width | B1 | m | | 75 | 75 | 95 | | 100 | 70 | 270 | 250 | | |
| 16 | Max water depth (from Manning) | D | m | 17.2 | 3.2 | 3.1 | 2.8 | | 2.4 | 3.1 | 1.0 | 0.9 | | |
| 17 | ***Other measures of forcefulness of flow*** | | | | | | | | | | | | | |
| 18 | Average velocity | V | m/s | 13.0 | 4.6 | 4.5 | 2.9 | | 2.0 | 2.0 | 0.9 | 0.8 | | |
| 19 | Velocity x depth | VD | $m^2/s$ | 223.4 | 14.5 | 14.1 | 8.1 | | 4.7 | 6.0 | 0.9 | 0.7 | | |
| 20 | Discharge/ flooded width | Q/W | $m^2/s$ | | 8.2 | 8.0 | 5.7 | | 3.5 | 4.7 | 0.6 | 0.5 | | |
| 21 | ***Time for peak dambreak flood to reach key points*** | | | | | | | | | | | | | |
| 22 | Time to travel reach | | mins | | 5 | 5 | 14 | | 51 | 13 | 77 | 109 | | |
| 23 | Cumulative time to end of reach | | mins | | 5 | 10 | 24 | | 75 | 88 | 164 | 184 | | |
| 24 | **10.1.2 Number of properties vulnerable to Flood Damage in Each Zone** | | | | | | | | | | | | | |
| 25 | **Select one of the categories shown within input box (pick list)** | | | | | | | | | | | | | |
| 30 | ***Residential Properties at Risk of Flood in Each Zone*** | | | | | | No. of properties in each damage category: | | | | | | Sub-total | Remarks |
| 31 | Property destroyed | | No. | | | | | | | | | | 0 | |
| 32 | Partial structural damage | | No. | 2 | 3 | | | | 5 | 5 | | | 15 | |
| 33 | Inundation damage only | | No. | | | | 56 | 2 | | | 3 | 162 | 223 | |
| 34 | ***Non Residential Properties at Risk of Flood in Each Zone*** | | | | | | Total area ($m^2$) of non-residential properties in each damage category | | | | | | ***238*** | No. |
| 35 | Property destroyed | | $m^2$ | | | | 400 | | | | | | 400 | |
| 36 | Partial structural damage | | $m^2$ | 1,600 | 600 | | 9,000 | | 200 | 1,600 | | | 13,000 | |
| 37 | Inundation damage only | | $m^2$ | | | | | 16,800 | | | 1,200 | 6,000 | 24,000 | |
| 38 | | | | | | | | | | | | | ***37,400*** | $m^2$ |
| 39 | **9.1.2 Population (pedestrians) at risk (water > 0.5m) (PAR)** | | | | | | | | | | | | | Remarks |
| 40 | | | | | When occupied | | Occupancy | *Time averaged PAR* | | | | | | |
| 41 | Residential: Number of PAR/ property | | | | 2.3 | | 70% | *1.61* | */property* | | | | | |
| 42 | Non- residential: PAR as area (m2)/ occupant | | | | | 40 | 25% | *160* | *m2/ occupant* | | | | | |
| 43 | | | | | | | | | | | | | Sub-total | |
| 44 | Number of residential properties | | | 2 | 3 | 56 | 2 | 5 | 5 | 3 | 162 | 238 | | |
| 45 | Residential properties: Max PAR (either accept equation, or overwrite) | | | 5 | 7 | 129 | 5 | 12 | 12 | 7 | 373 | **547** | | |
| 46 | Non residential : Max PAR (either accept equation, or overwrite) | | | 40.0 | 15.0 | 235.0 | 420.0 | 5.0 | 40.0 | 30.0 | 150.0 | **935** | | |
| 47 | On transportation routes | | | | 3 | | | 3 | | | 10 | 16 | | |
| 48 | Other open air e.g. playing fields, recreational areas | | | 1 | 1 | 2 | | 2 | 1 | 1 | 10 | 18 | | |
| 49 | Assessed total PAR (time averaged) | | | 14 | 13 | 151 | 108 | 14 | 19 | 13 | 318 | **651** | | |

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51 | **9.2.3 Likely loss of life (LLOL)** | | | | ***No warning*** | | | | | | | | | |
| 52 | Fatality rate (Ratio LLOL to PAR) - see Guide Figure 9.1 | | % | | 20.0% | 20.0% | 10.0% | 4.0% | 4.0% | 4.0% | 0.3% | 0.3% | | |
| 53 | LLOL | | | | 2.84 | 2.52 | 15.09 | 4.33 | 0.57 | 0.76 | 0.04 | 0.95 | 27.11 | |
| 54 | | | | | ***Warning (hours as above)*** | | | | | | | | | |
| 55 | Fatality rate (Ratio LLOL to PAR) - see Guide Figure 9.1 | | % | | 3.0% | 3.0% | 2.0% | 1.0% | 1.0% | 2.0% | 0.2% | 0.2% | | |
| 56 | LLOL | | | | 0.56 | 0.58 | 5.59 | 1.13 | 0.26 | 0.61 | 0.04 | 1.38 | 10.16 | |
| 58 | **Adopted likely loss of life** | | No warning | | **27.11** | | With warning time | | 1.5 | hours: | hours: | **10.16** | | |
| 60 | **10.1.3 Estimated Cost of Damage** | | | | | | | | | | | | | |
| 61 | ***a) Postcode (use for Internet searches of property value)*** | | | | | | | | | | | | | |
| 62 | ***b) Per Residential Property per zone (average)*** | | | | | | | Cost of damage £k | | | | | | |
| 63 | Property destroyed | | £/property | | 222,260 | 222,260 | 222,260 | 222,260 | 222,260 | 222,260 | 222,260 | 222,260 | | |
| 64 | Partial structural damage | | £/property | | 174,510 | 174,510 | 174,510 | 174,510 | 174,510 | 174,510 | 174,510 | 174,510 | | |
| 65 | Inundation damage only | | £/property | | 34,622 | 34,622 | 34,622 | 34,622 | 34,622 | 34,622 | 34,622 | 34,622 | | |
| 66 | Total damage per zone | | £ | | 349,020 | 523,530 | 1,938,832 | 69,244 | 872,550 | 872,550 | 103,866 | 5,608,764 | 10,338,356 | |
| 67 | ***c) Total per zone for non-residential property*** | | | | | | Cost of damage £/m$^2$ (spreadsheet multiples by area, and gives total damage in bottom row) | | | | | | | |
| 68 | Property destroyed | | £/m$^2$ | | 1,629 | 1,629 | 1,629 | 1,629 | 1,629 | 1,629 | 1,629 | 1,629 | | |
| 69 | Partial structural damage | | £/m$^2$ | | 1,507 | 1,507 | 1,507 | 1,507 | 1,507 | 1,507 | 1,507 | 1,507 | | |
| 70 | Inundation damage only | | £/m$^2$ | | 695 | 695 | 695 | 695 | 695 | 695 | 695 | 695 | | |
| 71 | Total damage per zone | | £ | | 2,411,200 | 904,200 | 14,214,600 | 11,676,000 | 301,400 | 2,411,200 | 834,000 | 4,170,000 | 36,922,600 | |
| 72 | ***d) Total by reach*** | | £ | | 2,760,220 | 1,427,730 | 16,153,432 | 11,745,244 | 1,173,950 | 3,283,750 | 937,866 | 9,778,764 | 47,260,956 | |
| 73 | | | | | | | | | | | **Sum of third party property damages (£k)** | **47,260,956** | | |
| 74 | | | | | | | | | | | **Other damages (Optional at discretion of user e.g. replacement cost of dam** | | | |
| 75 | | | | | | | | | | | **Value carried forward to Section 11 (£k)** | **47,260,956** | | |
| 76 | | | | | | | | | | | | | | |

# CONSEQUENCE CLASS AND ESTIMATION AND TOLERABILITY OF RISK

## Sheet 11.2: Consequence Class (Sheet 11.1 not used)

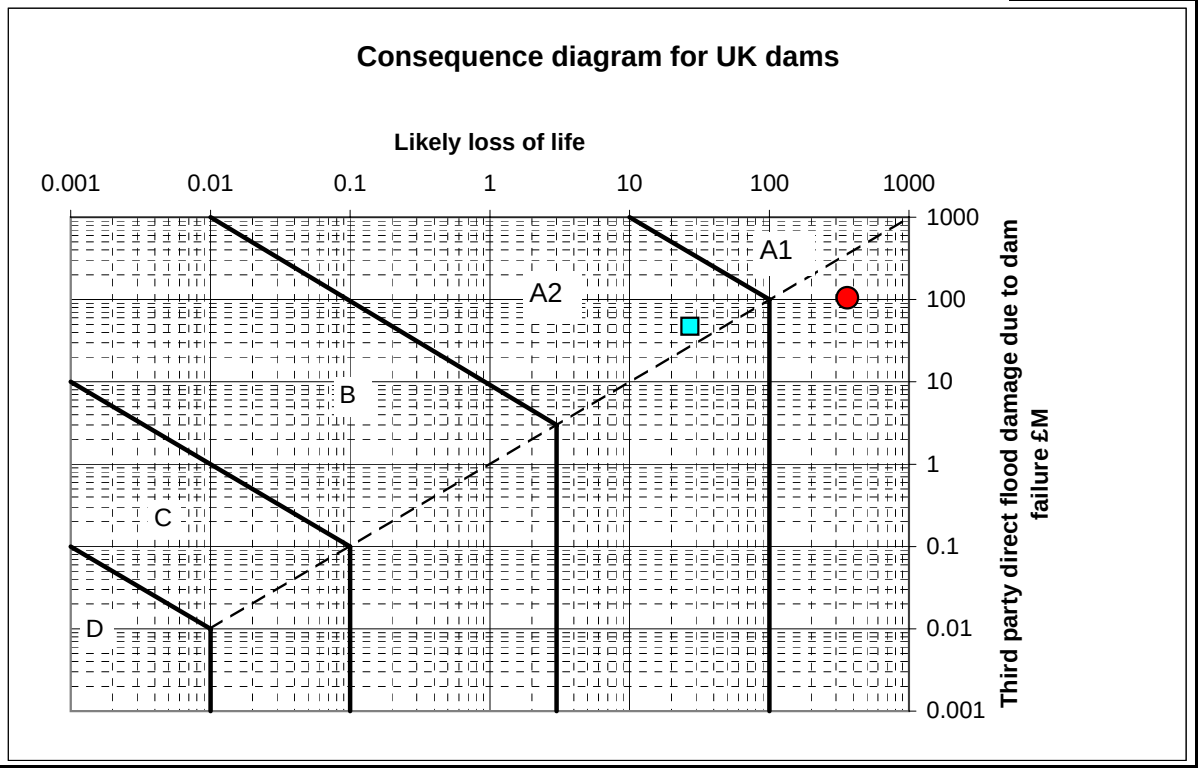
| | | |
|---|---|---|
| Dam name | Cascade above Anduin (Beta South to Delta South) | |
| Grid ref. | 0 | |
| Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin | |

| ***Consequence data (from Sheets 9, 10)*** | | Rainy day | Sunny day |
|---|---|---|---|
| Population at Risk (PAR) | No. lives | 1,673 | 651 |
| Likely Loss of Life (LLOL) | No. lives | 362.5 | 27.1 |
| Cost of physical damage (£k) | £ | 104,428,670 | 47,260,956 |

***Previous assessment of Consequence Class***

| | |
|---|---|
| Are there any dam break analysis, estimates of population at risk, likely loss of life if dam failed (if so give details incl date) | None |
| Dam (Flood) Category (and when/ who assigned) | A |
| Dam (Earthquake) Category (and when/ who assigned) | |

***Updated assessment of Consequence Class; following this assessment (no warning)*** A1



# REVIEW OF OUTPUT

## Sheet 12.1: Summary of Quantitative Risk Assessment

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | Dam name | Cascade above Anduin (Beta South to Delta South) | | | | | | | |
| 4 | Grid ref. | 0 | | | | | | | |
| 5 | Calculation Number/ description | Rapid dambreak for dams in cascade on River Anduin | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | Inspect dam and environs, establish basic characteristics | | | | | | |
| 8 | | | ***Sheets 1.1 to 1.6*** | | | | | | |
| 9 | **Consequences of failure** | Raiy day | | | | Sunny day | | | |
| 10 | Estimate dambreak flood, and flood hydrographs with distance downstream | | | | | | | | |
| 11 | Section 8 (Sheet 8.2) - Dam break | 2,870 | $m^3/s$ at | | dam site | 650 | $m^3/s$ at | | dam site |
| 12 | Section 8 (Sheet 8.5) - Attenuation | 538 | $m^3/s$ at | 25 km | | 124 | $m^3/s$ at | 25 km | |
| 13 | | | | | | | | | |
| 14 | Assess the overall impact of the dam break flood; estimating the population at risk and the **likely loss of life** | | | | | | | | |
| 15 | Section 9 (Sheet 9) | **PAR** = 1,673 | | | | **PAR** = 651 | | | |
| 16 | No warning | LLOL = 362.5 | | | | LLOL = 27.1 | | | |
| 17 | | | | | | | | | |
| 18 | Number of residential properties | 856 | | | | 238 | | | |
| 19 | Area of non residential property | 40,500 $m^2$ | | | | 37,400 $m^2$ | | | |
| 20 | Assess the cost of physical damage | £104,428,670 | | | | £47,260,956 | | | |
| 21 | This may require consideration of several failure scenarios e.g. sunny day vs. rainy day, subject dam only vs. whole cascade | | | | | | | | |
| 22 | Section 10 | | | | | | | | |
| 23 | | | | | | | | | |
| 24 | | | | | | | | | |
| 25 | Assign **Consequence Class** | **A1** | | | | A2 | | | |
| 26 | Section 11 (Sheet 11.2) | | | | | | | | |
| 27 | | | | | | | | | |

| | A | B | C | D |
|---|---|---|---|---|
| 1 | **REVIEW OF OUTPUT** | | | |
| 2 | **Sheet 12.2: User Review of Output from the Guide to QRA** | | | |
| 3 | Dam name | | | Cascade above Anduin (Beta South to Delta South) |
| 4 | Grid ref | | | 0 |
| 5 | Calculation Number/ description | | | Rapid dambreak for dams in cascade on River Anduin |
| 6 | | | | |
| 7 | Section | | Remarks including Insights from using system | Results reasonable? |
| 8 | | | **Consequence assessment** | |
| 9 | 8 | **Dam break/ attenuation** | Analysis had to be adjusted to match detailed analysis, by 1. Increase breach Q for cascade to highest in cascade (not necessarily bottom dam); 2 Reduce k factor used to calculate attenuation length, to get La of 20 to 80km (was >1000km with default value from CIRIA Guide) | |
| 10 | 9 | **Population at Risk and Likely loss of life** | Underestimate relative to detailed analysis, because few non-residential properties picked up from 25,000 map | |
| 11 | 10 | **Third party damage** | | |
| 12 | | | **Summary** | |
| 13 | 12 | **Is output from assessment reasonable?** | | |
| 14 | | **Is more detailed assessment required (pick list)?** | | |
| 15 | | **Actions arising from risk assessment** | | |

## ATTACHMENT D : RAPID METHOD WORKBOOK FOR RIVER ARIES

## ATTACHMENT E : RAPID METHOD WORKBOOK FOR RIVER KAPPA

Both omitted for brevity