APPENDIX F: EXAMPLE OF STANDARD IMPACT ANALYSIS

APPENDIX F.1 : EXAMPLE OF STANDARD IMPACT ASSESSMENT VOLUME 1 : A4 REPORT

STANDARD 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.

Volume Plan

Volume		Title
1	**Main report**	**Standard Impact assessment for reservoirs owned by Xenon plc on Rivers Anduin, Aries and Kappa**
2	Attachment B	Results for River Anduin
3	Attachment C	Results for River Aries
4	Attachment D	Results for River Kappa

Notes. 1. Volumes 2 and 3 not included with Guide to Emergency Planning for brevity

Note regarding this example of Impact assessment
This example has been derived, and amended in the course of development of the Guide. if prepared now the following would be done differently

a) *Notches through transportation embankments were modelled using the "as-supplied" vee-shaped notches within the IfSAR DTM; with no separate allowance made for openings in the embankments. If prepared now the embankments and structures would be modelled in accordance with the Guide. Thus in this example Table B.1 has columns for Hydraulic model output with all embankments intact, but these columns are not populated*
b) *the consequence impact element was derived using Address Point data; if prepared now the. National property database would be used*

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

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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 the reservoirs and dams in the lower cascade above the Rivers Anduin, Aries and Kappa owned by Xenon plc, 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 first issue has been prepared by Jacobs Babtie, Leatherhead under contract to Xenon plc.

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

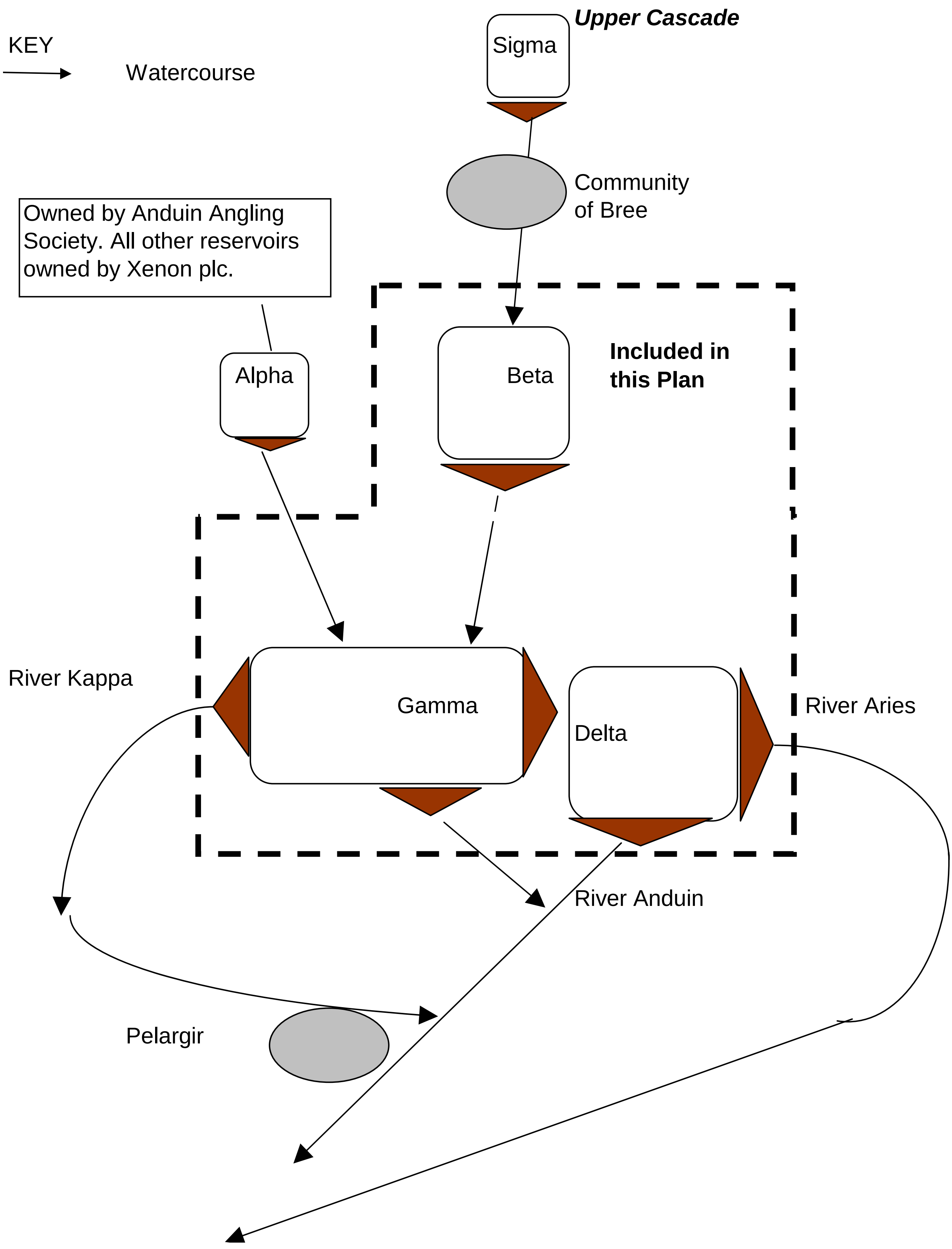
Reservoir		Dams				Reservoir or watercourse that would receive breach
Name	Capacity (m^3)	No.	Name	Grid Ref	Consq. Class	
Beta	3,500,000	1	Beta South	Xxxxx xxxx	A1	Gamma Reservoir
Gamma	4,200,000	3	Gamma East	Xxxxx xxxx	A1	Delta Reservoir
			Gamma South	Xxxxx xxxx	A1	River Anduin
			Gamma West	Xxxxx 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	Reason for exclusion
Name	Capacity (m^3)	No.	Name	Grid Ref		
Alpha	250,000	1	Alpha South	Xxxxx xxxx	Gamma Reservoir	Not owned by Xenon
Sigma	55,000	1	Sigma south	Xxxxx xxxx	River Anduin through Bree; then Beta reservoir	Separated by community of Bree

Figure 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 path 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. In addition one additional scenario, the sunny day failure of the lowest dam on the cascade on each watercourse has been modelled. The key points in this assessment are set out in Table 4 (note that all dams being considered are impounding dams).

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 and flow path	All three significant dams on the critical flow path (i.e. 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, leading to progressive failure cutting down from crest		Unexpected development of breach at foundation interface	
3	Timing of failure at individual dam	Breach commences at each dam at time of peak inflow to the reservoir.		Arbitrary timing	
4	Initial reservoir level and reservoir volume (in all reservoirs)	All reservoirs spill at an initial steady state inflow rate via unobstructed spillways. All dams (including those on non-critical dams in the reservoir group) have wave walls capable of withstanding overtopping for a short period		All reservoirs spill at an initial steady state inflow rate via unobstructed spillways.	
5	Steady state flow in the watercourse (prior to the dam failure)	Steady state flow achieved by setting minimum flow on each reservoir sub-catchment inflow to $20m^3/s$. Minimum flow at Delta South between 100 year and 1000 year routed peak flood but approximately equal to 1000 year flood from unreservoired catchment at first urban centre downstream. Initial flow 2% of peak dam-break flow.		As rainy day case but initial flow forms a larger proportion of the total flow.	
6	Inflows into reservoir(s)	10,000 year FEH flood event on all catchments above Delta South. Event duration disregards reservoir routing lag.		Initial flows from rainy day case maintained constant through event.	
7	Outflows	All outlets closed (no crest gates)		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)		No inflows downstream from Delta South	
9	Downstream boundary for impact assessment	Confluence with larger river and entry into broad coastal flood plain as Table 5. Flood impact reduced to inundation only and flood depth typically less than 0.5m.		As rainy day	

Issue (Heading in Standard Analysis Scenario)		**Failure mode**			
		Rainy day, whole cascade, for watercourse		**Sunny day, for watercourse**	
		Anduin	Aries/ Kappa	Anduin	Aries/ Kappa
10	Base Population at risk	It is considered 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	
11	Ground model	See Table A.5.			

3 DAM BREAK DISCHARGES AND CRITICAL FLOW PATH

All the dams are conventional embankment structures. Expected 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 8. Breach discharges were then identified iteratively to match the expected discharges

The critical flow paths for the Standard Analysis Scenarios has been identified as shown in Attachment A. Key points in identifying the critical flow paths are

- Neglects failure of Alpha reservoir, as this has an insignificant volume compared to the other reservoirs on the critical flow path.
- Neglects failure of Sigma reservoir, as this is upstream of the reservoirs covered by this plan.
- Failure via Delta South gives a higher dam break flood than via Gamma South
- 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 breach geometries are defined as shown in Table 5 to 7. The times quoted are measured from zero at the start of the standard 10,000 year flood rainfall and do not represent lead times for flood warning purposes. For the lower dams the modelled breach flows are higher than the nominal breach flow, due to the effect of the significantly increased volume of flow from the upstream reservoirs in the cascade causing significant overtopping of the lower dam

Table 5 : Breach geometry adopted in Infoworks modelling of critical flow path on R Anduin

Dam	Base width m	Base elevation mOD	Side slopes H:V	Time (hrs:mins)		Breach discharge	
				Initiation	Full breach	Rapid (as Table 8)	Model
Rainy day:							
Beta South	21	143.72	0.5	05:45	06:15	2900	2750
Gamma East	30	134.03	0.5	06:15	06:35	1300	2500
Delta South	42	119.15	0.5	06:35	06:55	1800	3000
Sunny day							
Delta South	11	119.17	0.5	06:35	06:55		860

Table 6 : Breach geometry adopted in modelling of critical flow path on R Aries

Table 7 : Breach geometry adopted in modelling of critical flow path on R Kappa

Table 8 : Estimation of dam breach flows and identification of critical flow path

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 Gamma East Delta South

4 METHODOLOGY FOR HYDRAULIC ROUTING

4.1 Level of analysis, software and ground model

It is clear by inspection that significant numbers of lives and properties are at risk from a breach in any of the Anduin group dams. It is therefore necessary to proceed directly to a "standard" impact analysis.

All three flow paths are well defined for most of their length although there is scope for flood waters to escape into relatively unpopulated lower lying flood plain areas in the lower reaches. It is therefore considered that a 1-D, unsteady flow analysis with the capability of dealing with multiple flow routes is appropriate.

The relatively gradual failure modes associated with embankment dams are also consistent with the choice of a conventional unsteady flow open channel 1-D hydraulics package.

The data and software used are shown in Table 9.

Table 9 : Data and software

Issue	Methodology used in preparation of this Impact assessment
Modelling Software	ISIS/ Infoworks
Flood Mapping software	InfoWorksRS. Version 7.0
Ground elevation data	IfSAR DTM
Channel cross-sections	Not available – channel modelled as in IfSAR data (effectively neglected, such that model flood plain only)
Structures and infrastructure embankments	See Table B.1
Urban areas across flow path	Only isolated buildings across the flow path; no dense urban area

General valley Manning's 'n' has been taken as 0.05 with areas beyond the main flow width being allocated an 'n' of 0.10.

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

4.2.1 River Anduin

The model extends 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 10. 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 further downstream.

4.2.2 River Aries

Omitted for brevity

4.2.3 River Kappa

Omitted for brevity

Table 10 : 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				

1. From FEH

4.3 Transportation embankments across flow path

The assumptions made are given in Table B.1.

4.4 Flood Zone Definition

4.4.1 River Anduin

Nine Flood Zones have been identified as shown in Table 11 and Figure B.4.

It should be noted that the hydrographs for "U/S Zones 8 & 9" are taken from a point just upstream from the start of lateral discharges into Zone 9 from the main river. The greater part of the flow in the main river has spilt into Zone 9 by the time the flow reaches the downstream boundary. Consequently the "Total flow at downstream boundary" is a summation of the relevant flow components rather than the flow at a single model node.

Table 11 : Definition of Flood zones on River Anduin

Flood Zone	Feature defining end of reach	Length of reach	Reason for defining as flood zone, description of zone covered
1	Motorway 1	2627	Mainly rural valley
2	Railway 1	1404	Infrastructure across flow path; some local development
3	Pelargir Centre	3064	Urban area with industry and a canal
4	Brook at Pelargir	n/a	Tributary (River Kappa) subject to flooding backing up from main river
5	Railway 2	7524	Long, largely rural reach
6	Axxxx	1486	Infrastructure across flow path, short reach upstream
7	u/s Rauros	6576	Mostly rural. Downstream boundary at upstream limit of Rauros and where flow starts to spill from left bank into Zone 9
8	Rauros Centre	1711	Urban area
9	Rauros Moss	n/a	Rural, largely low-lying off-stream area

4.4.2 River Aries

Omitted for brevity

Table 12 : Definition of Flood zones on River Aries

4.4.3 River Kappa

Omitted for brevity

Table 13 : Definition of Flood zones on River Kappa

5 CONSEQUENCE ASSESSMENT

The basis and assumptions made in the analysis are shown in Table 14, with the build up of results are shown on the sheets with the impact assessment and the summary of results in Tables 17 and 18.

Table 14 : Assumptions in consequence assessment

Issue	Residential	Non-residential
Property database	Address point	Address point, supplemented by manful addition of properties on map but not in database. Plan areas measured manually from 1;10,000 map
Subdivision of property type	None	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
Occupancy	Take as 2.3 persons per property (Value for Great Britain in 2003, as given in "Table 3.1 : Trends in household size: 1971 to 2003" on www.statistics.gov.uk	Area per person and % time occupied 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 15

Table 15 : 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 15 summarised the location in which the results of the impact assessment are presented.

The Consequence Class for reservoirs covered by this assessment area as follows:
Delta -Class A2.
Beta, gamma – Class A1

7 IMPACT ON INFRASTRUCTURE

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

The tables in which flood depths and average channel velocity at key transportation infrastructure points (as defined in the Technical specification) on the three watercourses are included in Table 15.

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

The panel Engineer has directed that
"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"

The Supervising Engineer will review downstream development, and inform the undertaker of any significant changes

Table 16 : Summary of output and Index to detailed results

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 11					
‘d’	Transportation embankments obstructing the flow path	Table B.1R	Table B.1S				
	Photographs at key points	Appendix A					
‘e’	Tabulated output by zone	Table B.2R	Table B.2S				
‘f’	Figures summarising						
	Flow hydrographs at zone boundaries	Figure B.1R	Figure B.1S				
	Peak flow down valley	Figure B.2					
	Longitudinal section down valley	Figure B.3					
‘g’	Total PAR, LLOL and third party damage	Table 16 (build-up in ‘c’, and Table B.3)					
	Consequence Class	Figure 2					
‘h’	Tabulated data at selected Key points						
	Transportation embankments obstructing the flow path	With ‘d’					
	Other points	Table B.4R	Table B.4S				
‘i’	Map information						
	Extent of inundation, velocity > 2m/s, flooded properties	Figure B.4					
	Locations of sections and structures	Figure B.5					
	Plan for use in an emergency	Figure B.6					

Table 17 Basis of property valuation

	Value	date	Escalation	Value used in this assessment	Source/ Remarks
Residential - Inundation					
	£34,622	Dec-05	100%	**34,622**	MCM < 12 hours inundation; 1.5 deep
Residential - destruction					
Building Cost	£191,000	Oct-05	100%	191,000	UK average; Land registry. (Q4, 2005)
Contents	£31,260	Dec-05	100%	31,260	1.5 times contents in MCM, 2005 to allow for 2 floors
				£222,260	
Residential - partial structural					
75% property value + full contents				**£174,510**	
Non residential: inundation					
	£695	Dec-05	100%	**£695**	MCM < 12 hours inundation; 1.5 deep
Non residential - destruction					
RV £/m2	44	2004			Region; 2004 - assume no change to Dec 2005
Yield	9%				
Building Cost	489		100%	489	
Services	400	2005	100%	400	
Moveable Equipment	280	2005	100%	280	MCM values doubled so 100% of replacement value
Fixtures and Fittings	280	2005	100%	280	MCM values doubled so 100% of replacement value
Stock	180	2005	100%	180	
Subtotal - damage	1,629		100%	**£1,629**	
Non Residential - partial structural					
75% property value + full contents				**£1,507**	

Time averaged occupancy for residential property

No people/ property	2.3
Average occupancy (24/7)	70%
Average occupancy	***1.61***

Table 18 Anduin: Summary of consequences of failure

Scenario		Rainy day			Sunny day		
		Maximum		Average	*Maximum*		Average
PAR	Residential	*2,075*		1,452	*589*		412
	Non reside	*1,771*		459	*1,009*		223
	R and NR	***na***		**1,949**	***na***		**674**
LLOL				**391**			**29**
Number of residential properties				902			256
Number of non-residential properties				73			42
Area of non residential property	m^2			69,722			36,576
Property damage	Residential			£61,814,038			£12,240,716
	Non residential			£57,014,934			£28,778,300
	Total			£118,828,972			£41,019,016
Emergency services			1%	£1,188,290			£410,190
Environment Agency - Emergency repairs and response			2%	£2,376,579			£820,380
Reconstruction of transport infrastructure	########		5	£7,500,000		4	£6,000,000
Total damages				**£129,893,842**			**£48,249,586**

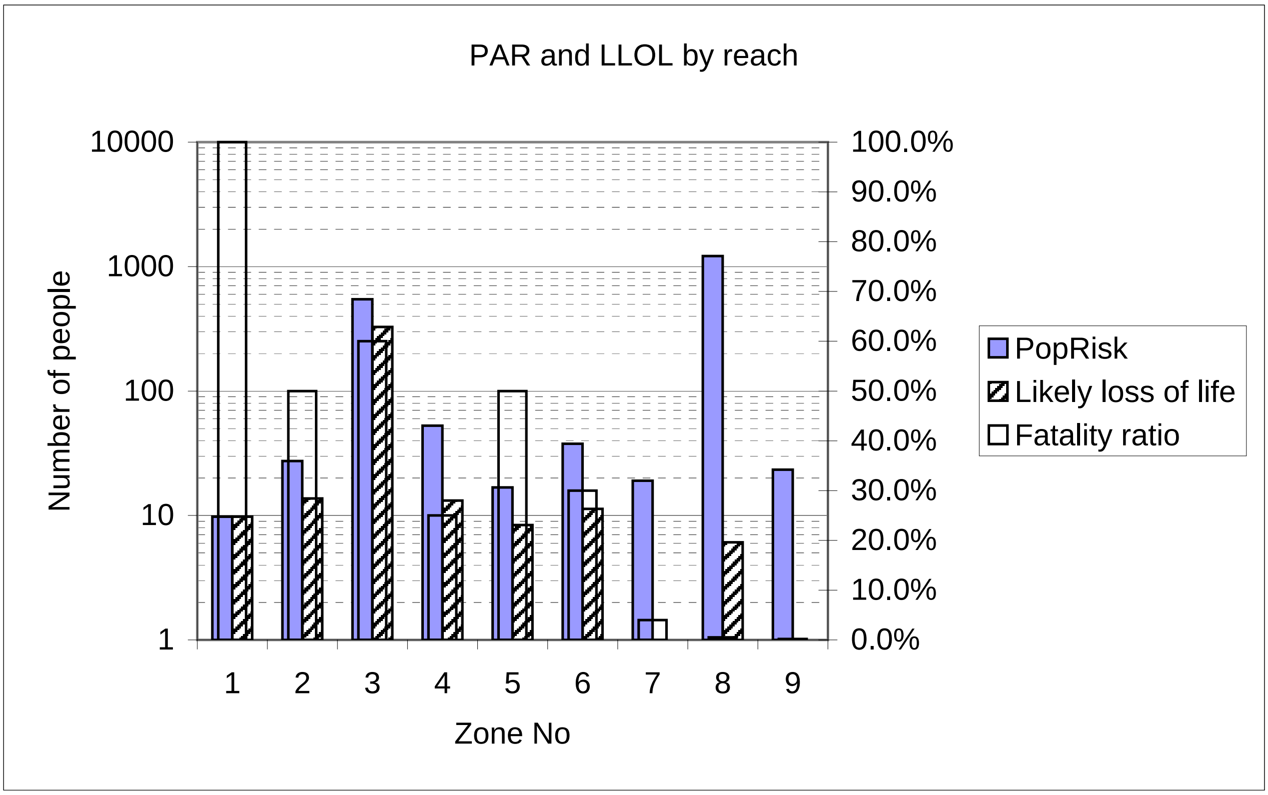


Figure 2 Consequence Class for reservoirs owned by Xenon plc on Rivers Anduin, Aries and Kappa