ICOLD Dam Incident Data Base
Objectives, Data definition, Data Base Management

DRAFT V1

1. Objectives

1.1. Context

In all hazardous industries, Incident analysis is an important tool to improve safety. Understanding the causes of incident makes it possible to change what was identified as a weakness, either in the design, the construction or the operation of industrial plant. Dams obey to the same rules, and it is the reason why ICOLD has always been involved in Dam Incident collection and analysis. ICOLD has on three occasions investigated worldwide surveys to collect the largest amount of information on dam incidents. The nineteen seventies saw the appearance of "Lessons from Dams Accidents", the eighties produced "Deterioration of Dams and reservoirs" (1984), and in 1995 was issued "Dam failures statistical analysis" (bulletin 99). These three publications can be described as follow:

Lessons from Dam Incidents (1974): 266 cases of "large dams" incidents (before 1-1-1966) are listed among which about 70 are failures; each case is documented, in English and in French, with a short description of the dam characteristics, the condition of the failure, the consequences, and remedial measures if so. Some cases are more thoroughly investigated (MALPASSET, TETON, etc.). At the beginning of the bulletin, a lot of statistical analyses are presented, according to the ages, the types, etc…, of the incidents. Furthermore, several articles give more detailed information on "famous" failures and other articles provide recommendations about the design of dams and their foundations. This document is referenced in this note as "LFDI".

Deterioration of Dams and Reservoir – Examples and their Analysis (December 1983)**:** This publication is an actualization of "Lessons from dam incidents" and its content is similar; it describes 1105 deterioration cases, among which 107 are failures. A very important work of statistical analysis is included, dealing separately with concrete and masonry dams, earth and rock fill dams, appurtenant works and reservoirs. All the data gathered after the inquiry is printed, the questionnaire and the codes for dam type, deterioration type, failure causes, etc. are also available. The origins of data are: Lessons from dam incidents (ICOLD and USCOLD) and response of National Committees to the questionnaires. All these data have been entered in a computer by the Committee on Deterioration of Dams and Reservoirs, which was chaired by Pr Manuel ROCHA from Portugal. Unfortunately, the numerical copy of these data has not been found. This very interesting material deserves to be used: in this context a numerical version (pdf) will be done by ICOLD Central Office and all reasonable efforts to include these cases in the database are under way. This document is referenced in this note as "DDAR"

Bulletin 99: Statistical analysis of dam failure (1995)**:** This bulletin is an update in 1995 of the statistical analysis of "Lessons from Dam Incidents", but only for failures cases. The detailed questionnaire sent to all national committee is in the Annex 1 of the bulletin. A table of 179 failures is presented, with synthetic information on each dam. The committee in charge of this bulletin had prepared several lists of codes for dam type, types of failures, occasion of failures, causes of failures and remedial measures. There is no detailed description of the different failures in the bulletin. All these data were entered in a computer by Prof. L. SERAFIM in Coïmbra University. This document is referenced as "B99".

And also:

- Congress Questions: Question 75 (1997), etc, to be complemented
- Bulletin 109 (Dams less than 30 m high - Cost savings and safety improvements - 1997)
- Bulletin 120 (Design features of dams to resist seismic ground motion - 2001)
- Bulletin 164 (Internal erosion of existing Dams, Levees and Dykes, and their foundations)
- Jansen, Robert B. Dams and Public Safety. A Water Resources Technical Publication. , U.S. Department of the Interior, Water and Power Resources Service, Denver, CO, 1980
- DEFRA - Environment Agency - Evidence report, Lessons from historical dam incidents : Delivering Benefits through evidence - August 2011
- ICOLD World Dam Register (WDR)

Finally there are existing data base in several countries, as "National Performance of Dams Program Data Base (Stanford University)" (https://npdp.stanford.edu/) in the US, ARIA Data Base (http://www.aria.developpement-durable.gouv.fr/about-us/the-aria-database/?lang=en) in France (for all industrial incident, including dams), etc. (to be completed by committee members).

1.2. Objectives of the ICOLD Data Base on Dam Incidents

Give to the dam community a tool providing a list, as exhaustive as possible, of dam incidents. The objective is not to have very detailed information for each incident records; rather the data base will give all available references, many of them being now available on the Internet.

The first objective of the base is then to allow statistical analysis (similar to previous analysis by ICOLD Committees publication mentioned in 1.1).

The second one is to provide dam professionals with a reliable (as much as possible) source of dam incidents making it possible to sort by type of dams, countries, period, etc, in order to study in more details the cases related to some particular question. Obviously these detailed studies cannot be undertaken only with the data available in the base but must rely on specific research of reports, articles, etc. to be found.

1.3. Content

Typically, a data base contains mainly numbers or codes, in order to make sorting analysis; short description, pictures and drawings may be included, with or without sorting capabilities (research of a word in a text, etc.).

Dam incidents included in the base: the rules are the same than those used in the ICOLD World Register of Dams (WRD) i.e. the dam is H>15 m OR (H>5 m AND V > 3.10^6 m^3. However smaller dams may exceptionally be included in the base, provided that useful lessons can be learnt; this implies that these smaller dams' history cases are well documented. *Another suggestion could be to limit the small dams to the well documented cases having caused fatalities*.

Tailing dams are not presently included in the database (there are only six records), the priority being to develop the database for dams. It could be considered to add tailing dams later, with cooperation with the Relevant ICOLD Committee; this would probably need to add specific fields to properly describe these structures.

Levees and dykes could be included provided that their failures have caused fatalities or heavy damages (New Orleans dykes, for example).

Each record in the base is related to an incident (and not to a dam). It means that several records may concern the same dam if several incidents occurred.

Dam Incident: two types of incidents are considered, failure (F) and accident (A).

- A failure is a catastrophic type of incident characterized by the sudden and uncontrolled release of impounded water.
- An accident is a lesser catastrophic type of incident defined by malfunction or abnormality outside the design assumptions and parameters which adversely affect a dam's primary function of impounding water. Such lesser degrees of incident can progressively lead to or heighten the risk of a catastrophic failure. They are, however, normally amenable to corrective action.

Accidents related to safety appurtenant works (spillway, gates, bottom outlet) can also be introduced in the database. Examples of these accidents could be gates failure or inappropriate opening leading to an uncontrolled water release.

2. Data Definition

The data base contains one record for each incident case. The different fields concern the Dam characteristic, the failure characteristics and consequences, the failure causes, remedial measures, images and references. Some other fields are used for the base management. A detailed list of the fields and their content is presented at Appendix 1.

2.1. Dam characteristics

2.1.1. General data: country, year of completion, river, nearest town, scheme purpose;

2.1.2. Geometry: dam type, height, length of the crest, foundation type, dam body volume, reservoir capacity,

2.1.3. WRD code number.

2.1.4. Dam characteristics description: a text can be entered here to better describe the dam.

Dam Type and dam purpose use the same code than the WRD.

Dam Type		Scheme purpose
CB	buttress dam	I – irrigation
BM	barrage	C - flood protection, water regime regulation
ER	rock fill dam	R – recreation
MV	multiple arch	H – hydropower production
PG	gravity (masonry or concrete*)	F – Fish breeding
TE	earth	N – navigation
VA	arch	S – water supply
XX	unlisted	X – not listed above

(*) Some masonry dams are specified also as: PG (M) or VA (M). This has been kept in the database

Many dams consist of several longitudinal sections each with different types. The choice made in the data base is to indicate only the dam type of the section where the incident has taken place, making it more consistent for sorting research.

There is presently no specific code for RCC dam in the WRD.

For multipurpose dams several codes are possible (for example: IH)

Many dams in the data base are also listed in the ICOLD World Register of Dams (WRD) and, as far as possible, the data of this section are those of the WRD. If important gaps exist between the WRD and the data from other ICOLD publication cited in 1.1, this is documented in a specific field "Data Information" (2.7.2). These gaps are often explained when important repair works have taken place after the incident.

For some dam the country indicated in previous data sources is no more valid, because of geopolitical changes. When no doubt exists the new country is indicated, but the old one is noted in the "data observation" field.

2.2. Failure characteristics and consequences

The fields are:

2.2.1. Year of incident

2.2.2. Incident Time, with the following codes (origin of definition = LFDI):

Incident Time	Description
T1	During construction
T2	During first filling
T3	During first five years
T4	After five years
T5	Not available

2.3.

2.3.1. Type of incident, with following codes (origin of definition = LFDI):

Type of Incident	Description
A1	An accident to a dam which has been in use for some time but which has been prevented from becoming a failure by immediate remedial measures including possible drawdown of the water.
A2	An accident to a dam which has been observed during initial filling of the reservoir and which has been prevented from becoming a failure by immediate remedial measures including possible drawdown of the water.
A3	An accident to a dam during construction, i.e. by settlement of foundations, slumping of wide slope, etc., which have been observed before any water was impounded and where the essential remedial measures have been carried out, and the reservoir safely filled thereafter
A4	An accident to another structure than the dam (appurtenant works, gates, reservoir sliding, etc.) but which has been prevented from leading to a dam incident (failure or accident) by immediate remedial measures including possible drawdown of the water.
F1	A major failure involving the complete abandonment of the dam
F2	A failure which at the time may have been severe but yet was has permitted the extent of damage to be successfully repaired and the dam brought again into use

Comment: In LFDI indices for “T” and for “A” are used in an “inverse” way, T1 being under construction when A1 is during the dam life. Code A4 has been added to cope with important incidents which have not affected the dam itself.

It is curious that codes A1 to A3 relate to the accident time while F1 and F2 give an indication of failure gravity. Therefore codes A1 to A3 are a duplication of the field “incident time”. *A suggestion could be to replace A1 to A3 by A1 (accident to the dam) and A4 to A2 (accident to appurtenant works.*

2.3.2. Detection methods (This field is only present in DDAR document).

Detection methods	Description
D01	Direct observation
D02	Sampling and laboratory test
D03	Water flow measurement

D04	Phreatic level measurement
D05	Uplift measurements
D06	Pore pressure measurements
D07	Turbidity measurements
D08	Chemical analysis of water
D09	Seepage path investigations
D10	Joint and crack measurements
D11	Horizontal displacement measurements

2.3.3. **Incident Mode: this field appears in B99 but has not the meaning given nowadays to failure mode. In order to sort the different interesting cases the following limited numbers of incident mode are then proposed:**

- OV External erosion (overtopping of fill dams)
- IE Internal erosion (for fill dams and their foundations)
- SF Structural failure of the dam body (all dam types)
- FF Foundation failure (for "rigid" dams (*))
- MS Failure of a mechanical structure (ex Folsom, Sayano-Shushenskaya,..)

(*) foundation failure for fill dams is addressed by code "IE" as it is not relevant to distinguish between the dam body and its foundation for these dams. Internal erosion may affect the dam, the foundation, or both.

These incident modes are rather "failure modes" than "accident modes" because many different accident modes exist. Therefore this field is more pertinent for F1 or F2 incident types (failures) than for "An" (accident).

2.3.4. **Fatalities: number of human victims (sometimes the precise number is not known and only a range "mini-maxi" is available. This could be indicated in the "description of failure field" just below). *Alternatively it could be possible to have two fields for mini and maxi, with the same value when the precise number is known?***

2.3.5. **Description of the failure: a text can be entered here to provide a description of the failure context, process and consequences. There are not presently specific field in the database but the following information could be written in this field.**

- Reservoir elevation at the time of failure;
- Reservoir volume at the time of failure;
- Max. discharge;
- Reliability of fatalities estimate;
- Approximate distance between dam and zone with most fatalities;
- Warning time (time between warning of the population and arrival of failure discharge at zone with most fatalities)
- Direct economical damages (USD) and reliability of this value;
- Indirect economical damages, including environmental (USD) and reliability of this value;

If some of these values are available for a significant number of dams it would be possible to create new fields in the database.

2.4. Incident causes

Two fields were considered in DDAR and B99, one for "Main Causes" and one for "Secondary Causes" with a list of about one hundred of codes to characterize them. It appears first that there were not "causes" but rather "incident modes" and, second, that it is a too large number of codes for efficiency and reliability, and not even practical for sorting the causes.

Furthermore, all these causes were "technical" causes, whereas nowadays it is recognized that organizational or human behavior issues are the root cause of many incidents. Finally, finding the right causes need careful analysis which have been rigorously carried out for only some of the more important failures.

It is then proposed to keep these two fields but with the following attributes (the original values in B99 and DDAR will be kept elsewhere):

2.4.1. Main Cause: this field is linked to organizational issues or human behavior

- Faulty design
- Poor construction
- Inappropriate operation (applying mainly during flood event)
- Poor maintenance or surveillance
- Hostile Human action
- None (it is sometimes the case)

2.4.2. Secondary Cause: this field is linked to the external causes (natural hazards) and internal causes (technical issues, ineffective barriers of defense).

- Major flood
- Major earthquake
- Other natural hazards (debris, very cold weather, snow, wind,..)
- Geotechnical concerns
- Material ageing
- Hydro mechanical equipment failure (including loss of power supply)

2.4.3. Description of the failure (same as in 2.2): a text can be entered here to provide a description of the failure analysis and causes. For natural hazards it would be useful to give an indication about the probability of the event.

2.5. Remedial measures

There are two fields for remedial measures description:

2.5.1. Remedial measures code: defined in the following table (origin = B99; a more important list of codes has been used in DDAR, with about 60 codes).

	Code	Remedial measures
Of a General nature	R103	Lowering of the reservoir level
	R104	Raising of the dam crest
	R105	Overall reconstruction (same design)
	R106	Reconstruction with a new design
	R107	None
	R108	Not available
	R109	Scheme abandoned
In foundation	R210	Water tightening treatment
In concrete and masonry dams	R305	Reconstruction of deteriorated zones

In embankment dams	R401	Impervious core repair
	R405	Filling in of cracks and cavities
	R406	Reconstruction of deteriorated zones
	R407	Upstream slope flattening, construction of upstream berm or other stabilization methods
In appurtenant works	R501	Discharge increase
	R502	Construction of additional appurtenant works
	R509	Construction or repairs of drains
	R512	Construction, modification and repair of valves and gates

Very often, especially for the accidents, several remedial measures are taken (R210 and R509 for example); several codes can then been entered in this field.

2.5.2. **Remedial measures comments: a full text can be entered to explain in more details what has been made. Improvement of surveillance, or surveillance, or organization could be also remedial measures and may be indicated here.**

Some codes could be « merged » as R305 and R406 for example; R509 could be moved to the foundation remedial measures.

2.6. References

This field can be filled by references as books, articles, etc. where more information can been found. For recent failures there are a lot of Internet references but which are often not reliable on a technical point of view. It is then wise to limit the hyperlink possibilities to "official" websites

2.7. Base Management - Data source, validation etc.

Specific fields are available to indicate information about Data

2.7.1. **Data Main Source: LFDI, DDAR, B99, data provided by members of the ICOLD Committee on Dam Safety (CODS), others. This field is essentially useful to check the consistency of the base with LFDI DDAR and B99;**

2.7.2. **Data Information: various relevant information on data values origin, discrepancies between different values in different references, etc.**

2.7.3. **Update date: the date of the last modification of the record;**

2.7.4. **Validation: code used to mark the data with the following codes**

- Y the record is validated;
- ND the record cannot be validated due to insufficient data reliability;
- NV the record has not been validated by a responsible "entity", members of CODS or national committee of the concerned country.

Record marked ND or NV are kept in the base waiting for validation, and are not publicly available.

2.8. Images

Photos and technical drawings can been entered in this field, presently with a file name. All the photos and pictures from LFDI have been scanned and are referenced in this field.

In a Web format of the Data Base all the images could be displayed directly.

3. Data Base Management

To be completed.

There are presently some major difficult points:

- Some countries are reluctant to make these information more or less publicly available, due to not still ended legal issues or by lack of transparency;
- Continuous and reliable filling of the base is therefore a challenge. One way could be to launch regularly enquiries toward each country, as it is done for the WRD (with the same periodicity?);
- Management of this base could involve some additional funding;
- Getting interest and cooperation could be perhaps reached by issuing regularly the new cases collected, and updating statistics published in LFDI, DDAR and B99.

Presently the Base is developed and maintained by M. Poupart alone, which is not a “safe” situation.

APPENDIX 1

List of the fields and associated recommendations for entering data.

Record Number	a unique value from 1 to 9999, without any overlap. There can be missing numbers between two records. From 1-290: the LFDI records which have been entered with the same numbering than in the original book; From 1000 – 1300: records issued from B99 (when not already in LFDI) From 1310 – 1320: records documented by Dr Netzer (Austrian CODS member) in 2004 From 2000 – xxxx: records added after 2005
Dam name	
Country name	(question when country has changed (for example USSR => Russia, Ukraine,
Year of Completion	
Type of dam	CB buttress dam BM barrage ER rock fill dam MV multiple arch PG gravity TE earth VA arch XX unlisted Note : PG (M), VA (M) and MV (M) are used in DDAR for masonry dams and have been kept in the Database
Height of dam	Height in meter Range of height H1 to H6 • H1: 5 m ≤ H < 15 m • H2: 15 m ≤ H < 30 m • H3: 30 m ≤ H < 50 m • H4: 50 m ≤ H < 100 m • H5: 100 m ≤ H • H6: unknown
To be completed	……..