SECOND GENERATION CONTINGENCY PLANNING AND 2D SIMULATIONS IN LULE RIVER IN SWEDEN

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ABSTRACT

As a follow-up to paper "Q. 91 - R. 16 Coordinated Emergency Preparedness Planning in Swedish Rivers" presented at the ICOLD Congress in Brasilia 2009 and paper nr. 174 at the international symposium on Dams in Global Environmental Challenges at Bali, Indonesia 2014, this paper will present an updated status on one of these projects which has undergone a thorough revision 11 years after the first study was published.

There are approximately 10 000 dams in Sweden. Most of them would result in only minor consequences in the case of a dam failure. However about 200 are classified as high hazard dams, where a dam failure could lead to severe consequences, including threats to life and/or the environment, and have adverse social, cultural and economic affects. A small number of these could cause extensive consequences and require emergency activities from a large number of nationwide organizations. None of them can on their own establish an acceptable preparedness for dam failure, thus a coordinated and regularly co-exercised preparedness planning is necessary. For coordinated emergency preparedness planning it is of the foremost importance to prepare reliable inundation maps based on a range of dam failure scenarios.

There are 16 high hazard dam facilities in Lule River in Sweden, and failure at some of them would result in a domino effect leading to dam failures and associated consequences along the whole river. The first generation of contingency plans for Lule River were prepared for more than a decade ago. The technology has improved significantly since then and a new generation of contingency plans were developed using a modern approach and best industry practice. New and more sophisticated dam failure scenarios were developed, which were based on the new Swedish dam safety guidelines. Laser scanning for digital elevation modelling was used, as well as 2D hydraulic simulations of flood wave propagation. This paper presents the new methodology and discusses major findings within preparation of the second-generation contingency plans for Lule River

1 COORDINATED EMERGENCY PREPAREDNESS PLANNING

1.1 Swedish hydropower

There are approximately 10 000 dams in Sweden. Most of them would result in only minor consequences in the case of a dam failure. However about 200 are classified as high hazard dams, where a dam failure could lead to severe consequences, including threats to life and/or the environment, and have adverse social, cultural and economic affects. A small number of these could cause extensive consequences and require emergency activities from a large number of nationwide organizations. Most of these dams are located in the ten major hydropower rivers in the country, Figure 1.

Lule River in the most Northern of these rivers. The river is approximately 700 km long including its main tributary and the river basin covers 25240 km2. In the lower reach, the mean runoff is 560 m3/s. Figure 2.

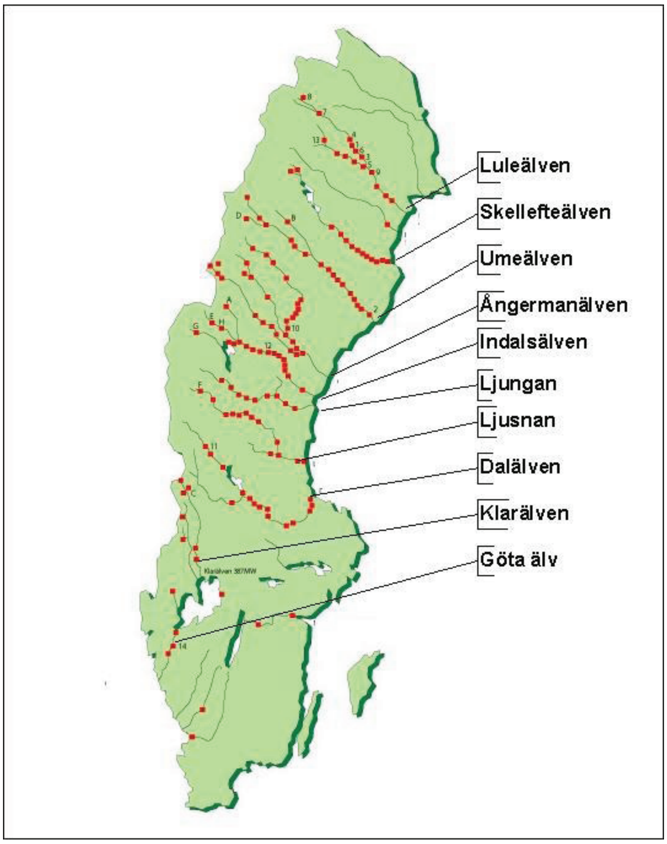

Figure 1 : Major hydropower rivers and dams in Sweden.

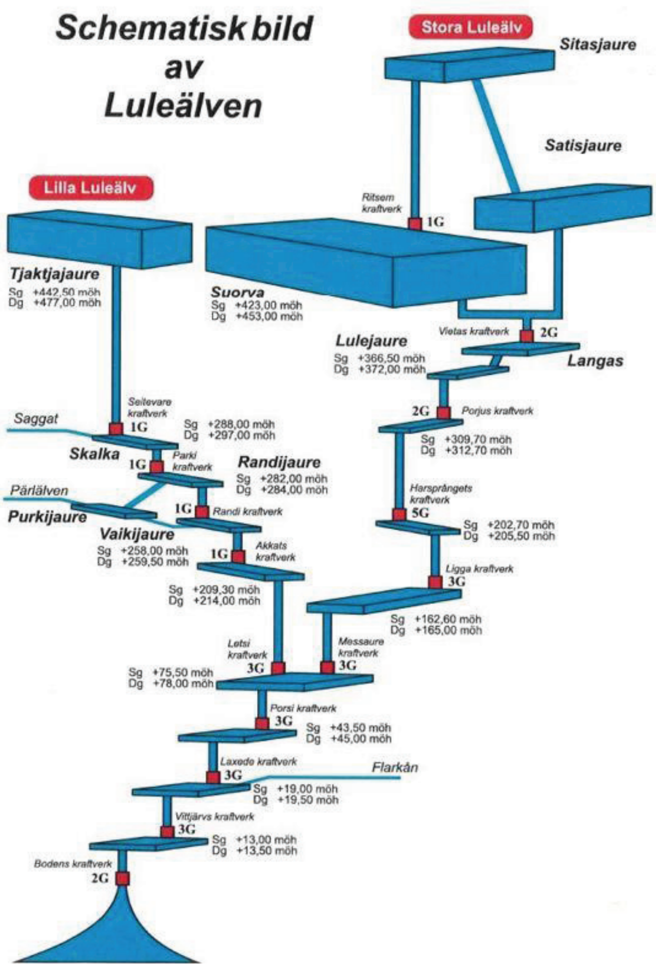

Figure 2 : General layout of Lule River in Sweden.

1.2 River Groups

The most important parties in interest involved in an emergency situation are the dam owners, the Water Regulation Enterprises (Vattenregleringsföretagen), the municipalities and the County Administration Boards of Sweden. None of them can solely on their own establish an adequate preparedness for dam failure or major flood event, thus a coordinated and regularly co-exercised emergency preparedness planning (EPP) is necessary. Historically, dam owners have put most efforts and focused on development of working methods and criteria for design, construction and safe operation of dams. Working methods and routines for development of emergency preparedness plans for dam failure and co-ordination with the responsible authorities for emergency action planning and rescue services have been given more attention during the last 10-15 years and the cooperation between dam owners, authorities and municipalities are still under development.

For all major rivers "River Groups" have been formed by the County Administration Boards on the request of the Swedish Civil Contingencies Agency. In the River Groups all municipalities, County Administration Boards, Water Regulation Enterprises, dam owners and other parties such as road and railway utilities, the police etc. are represented. The purpose is to develop the regional knowledge and competence, the contact network and also strengthen the trust between the different parties. All together this improves the possibility to handle a flood situation, and/or a dam failure emergency, to the best extent. The initiative to start up coordinated emergency preparedness planning for a river is taken by the River Group.

It is the responsibility of the dam owners with dam facilities in the specific river to finance the development of flood maps, etc. However, in order to stimulate the development of coordinated emergency action planning, The Swedish National Grid, in the role as national authority for dam safety, normally sponsors 50% of the projects costs, on the condition that all main parties involved have signed an agreement to actively take part in the planning process.

2. METHODOLOGY

2.1 Original methodology

In order to strengthen the development of coordinated emergency action planning for dam failures and major floods, a development project was carried out during 2003-2005 (Elforsk, 2006 and A. Engström Meyer et al, 2009). Experiences from historical floods have shown that it is important to treat the whole watercourse as one unit in planning and coordination efforts, since the management of the situation in one part of the river directly affects what happens in other parts.

Moreover, in most Swedish rivers where hydropower is present there are usually several facilities in a cascade. The usual configuration of a typical hydropower river consists of big reservoirs in the upper part of the river and smaller reservoirs or just run-of-the-river type of facilities in the lower part of the river. This would usually lead to a domino effect in case of a dam failure in the upper part of the river. Water management in the whole river in such a situation can be of crucial importance. The systematic view on the river issues is very important.

Therefore, a pilot project was carried out on a representative river basin covering the whole watercourse with existing dam facilities. The pilot project involved major dam owners operating in Sweden, the Swedish National Grid, Water Regulation Enterprises, County Administration Boards and municipalities along the Ljusnan River.

The method involves three phases that are carried out for each watercourse:

- The first phase serves to produce a common transparent and reliable basis for the emergency preparedness and action planning for all parties involved. This includes inundation maps, tabular information on the characteristics of the flooding and the dam break flood, GIS-layers of inundated areas etc. In addition, alarm routines and alarm plans to be used in the event of serious problems or a dam failure are established.
- The second phase is the development of the emergency preparedness plan for each party involved; i.e. the dam owners, the municipalities, the County Administration Boards etc. and the co-ordination of these plans.
- The third phase is the distribution of information to the public concerning emergency preparedness for dam failure flooding. The information should describe which areas that are at risk of becoming flooded, how dam-break warnings would be issued, provide information on safe evacuation routes and assembly points etc.

2.2 Revised methodology

Within Lule River 2.0 project the main components subject to revision are the terrain model, a new hydraulic model, new dam break scenarios and new flood maps.

In the first phase, a new Digital Elevation Model (DEM) is built up. Thereby, a need for revising the river cross sections in the hydraulic model is identified. Cross sections drawn in a coarse and inaccurate terrain model may be located at the wrong location and the cross-section geometry changes significantly. See Figure 3 and 4 for a sample of the two versions of DEM.

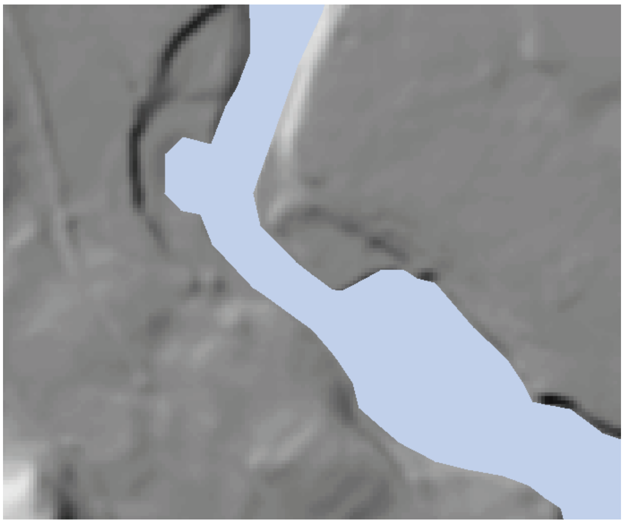

Figure 3 : DEM generated by photogrammetry. Blue surface represents the river.

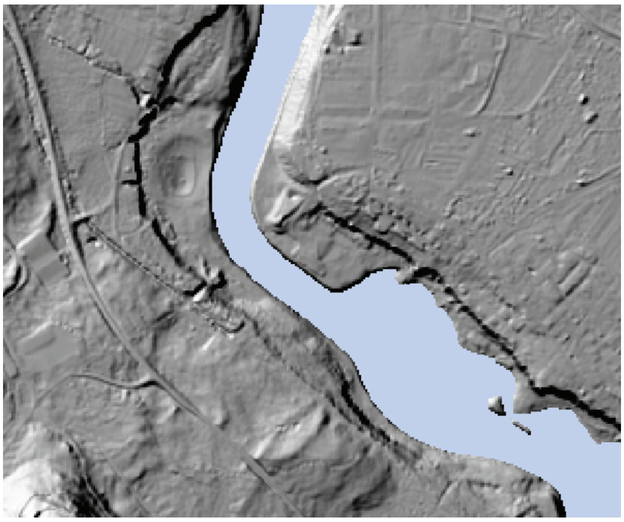

Figure 4 : DEM generated by Lidar scanning. Blue surface represents the river.

It is noticeable that the photogrammetric method creates a much smoother and less accurate DEM than the Lidar scanning. Disturbance of woods are significant in Lule River valley.

It is noticeable that the photogrammetric method creates much smoother and less accurate river cross sections than the Lidar scanning. At the section presented in Figure 5 and 6, the same bathymetric data is used. Thereby, the difference occurs above the water where a difference of 1-2 meter is observed.

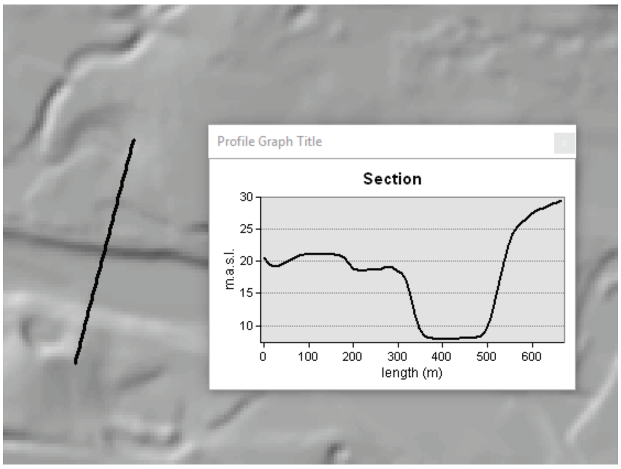

Figure 5 : DEM generated by photogrammetry. Blue surface represents the river.

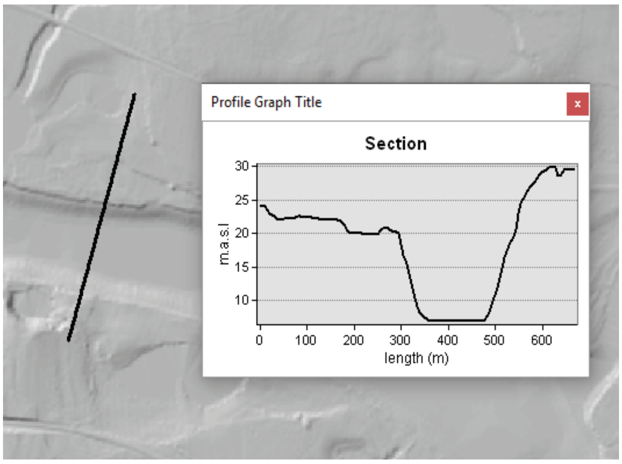

Figure 6 : DEM generated by Lidar scanning. Blue surface represents the river.

Flood mapping of the scenarios are done on a new and more dense terrain model. The old terrain model has a resolution of 10*10 m. The new terrain model is done with 5*5 m. Still, there is a limitation in hydraulic software to handle large terrain models. MIKE Hydro was used to generate cross-sections and a terrain model of 2*2 m was first produced in ArcGIS. That model was too large for MIKE Hydro, and a coarser model was used.

It is noticeable that the level of detail is much higher in the flood mapping on the Lidar-based DEM. Small lakes and tributaries at the side of the main river are better represented which gives better lateral connectivity of the flood mapping.

2.3 Dam failure scenarios

Dam failure scenarios are revised due to a new version of the Swedish dam safety guidelines (Energiföretagen, 2016). In order to improve the initial methodology, it was concluded to develop more realistic dam failure scenarios. As in previous version, current methodology anticipates development of a dam failure scenario for "sunny day" conditions. Regarding dam failure during high flood situation, some new thinking was introduced. The dam owner must do an analysis of possible dam failure situations which might occur followed by high flood situation. One possible scenario is dam failure in connection to 100-year flood. This dam failure can be combined with potential problems with the spillway

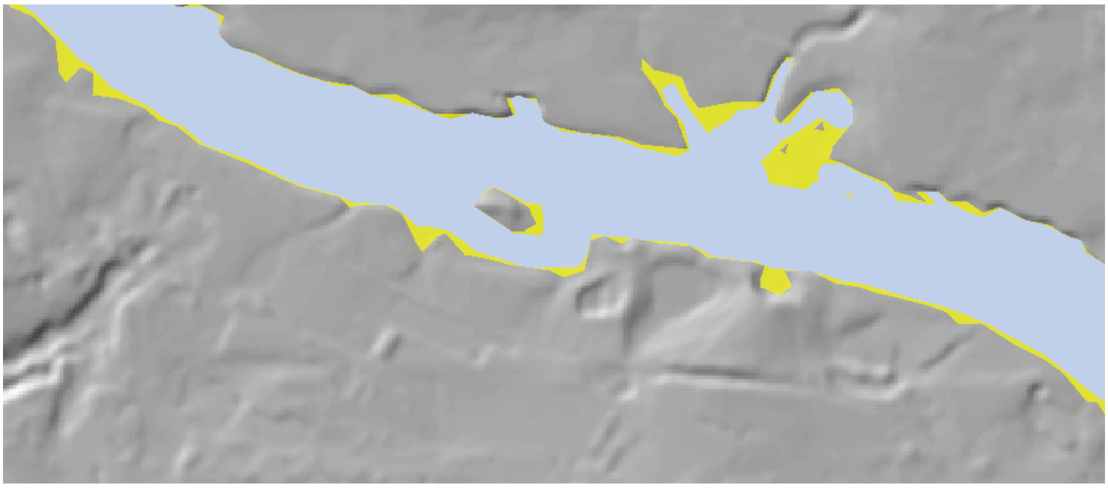

Figure 7 : Flood mapping interpolated on the photogrammetric DEM.

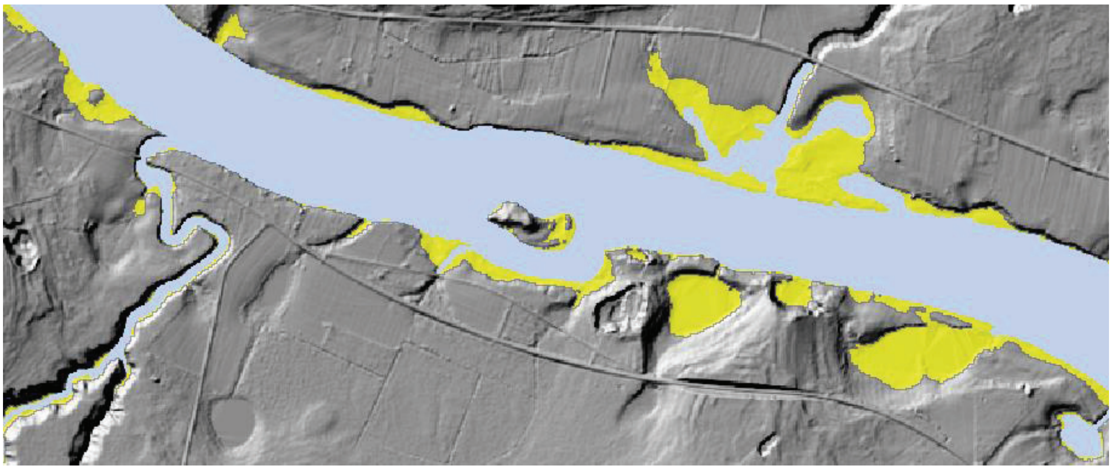

Figure 8 : Flood mapping interpolated on the Lidar-based DEM.

gates. Another scenario is dam failure during the 10 000-year flood. It is not probable that one would experience problems with the gates at the same time, these events are extreme by themselves, and therefore it is not realistic to combine them. This set up would generate 4 to 5 scenarios per individual dam.

3. DEVELOPMENTS

After the pilot project in the Ljusnan River in 2003-2005 the emergency preparedness planning process has gradually been initiated for all other major hydropower rivers in Sweden. The main focus for this paper is the second project which now are subject to revision.

There are 16 high hazard dam facilities in Lule River in Sweden, and failure at some of them would result in a domino effect leading to dam failures and associated consequences along the whole river. The first generation of contingency plans for Lule River were prepared for more than a decade ago. The technology has improved significantly since then and a new generation of contingency plans were developed using a modern approach and best industry practice. New and more sophisticated dam failure scenarios were developed, which were based on the new Swedish dam safety guidelines. Lidar scanning for digital elevation modelling was used, as well as 2D hydraulic simulations of flood wave propagation.

The common practice in Sweden has been to evaluate dam safety with respect to spillway capacity. Power station capacity has not been accounted for when it comes to spillway capacity for design discharges. Depending on the hazard classification class, dams have to release the 100-year flood (medium hazard dams) or the 10000-year flood (high hazard dams) through the spillway. Normally, dam break simulations are done on full supply level (FSL) or higher, up to the dam crest, if the spillway can't discharge at FSL. Embankment dams are assumed to be overtopped at dam crest whereas concrete dams are allowed to overflow without breaking.

The new version of RIDAS recommends that power stations are accounted for to create more realistic scenarios. A typical power station in Lule River may have 30% extra spillway capacity if the power station is accounted for. That means, if a flood wave from an upstream dam break, more capacity is available to discharge water downstream. Not only automatic emergency spillway installation can be accounted for but also dispatch centers with 24/7 operation for the staff at site. Gates downstream a dam may be operated if the can be run on remote control.

The overall purpose with the new scenarios is to account for more realistic scenarios with respect to how gates and power stations are operated. One can argue that this approach is less conservative than if only gates are taken into consideration. On the other hand, since the contingency plans are used in planning and training of hydropower staff, rescue personnel and authorities, more realistic scenarios will probably lead to better understanding of the river system.

4. CONCLUSIONS

Coordinated emergency preparedness planning, where all parties in interest are involved during the whole process, give excellent opportunities for all parties to better understand each other's businesses, needs and activities. This is a key factor for successful operations in an emergency situation.

The developed method for coordinated emergency preparedness planning has been used for the major hydropower rivers in Sweden and more rivers will follow in the coming years. The River Groups are important promoters for such actions.

The development of digital inundation maps with flood wave parameters as a basis for the coordinated emergency planning has led to a number of spin-off applications, for instance as basis for dam owners' internal emergency resources planning or exercises to coordinate and test the parties' emergency plans.

A more realistic approach of the dam break scenarios makes it possible to train dam safety staff and operators to handle dam break events by lowering downstream reservoirs to make space for incoming flood waves. It also gives a possibility to allocate rescue resources with better precision.

5. REFERENCES

A. Engström Meyer, M. Bartsch, R. Ascila, P. Stenström and M. Jender (2009): Coordinated Emergency Preparedness Planning In Swedish Rivers, ICOLD Congress, Brasilia,

Elforsk (2006): Dammsäkerhet. Beredskapsplanering för dammbrott – Ett pilotprojekt i Ljusnan, Sweden.

Energiföretagen (2016). RIDAS 2016. Kraftföretagens riktlinjer för dammsäkerhet

Klassificering av dammar och dammanläggningar. Tillämpningsvägledning - kapitel 3.