Upgrading of the flood retention basin Odenkirchen in Germany

Modernisation du bassin de rétention des crues d'Odenkirchen en Allemagne

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Abstract. The flood retention basin Odenkirchen on the river Niers in Germany was constructed around 60 years ago as consequence of a major, harmful flood event. The complete design and structures do not comply with up-to-date national regulations, the DIN 19700 [3], so that the owner, the Niers Association, decided to upgrade the basin. The upgrading works include different measures such as the adjustment of the reservoir operation management in consideration of the updated flood hydrographs and discharges as well as adjustments in respect to sewage disposal compensation. Latter purpose is an urgent consequence of the continuous urban development which led to a steady increase of the sewage discharges for which the required retention volumes cannot be realized locally. As part of the dam rehabilitation the reconstruction of the outlet works – a controlled weir with three bays and sluice gates – and construction of an overflow spillway as part of an embankment dam shall be realized. The complete project is dominated by the environmental restrictions comprising both environmental protection areas as well as requirements of fish passability and groundwater. The project area is located within a region with mining subsidence, groundwater management and high sediment loads.

Résumé. Le bassin de rétention des crues d'Odenkirchen sur la rivière Niers en Allemagne a été réalisé il y a environ 60 ans à la suite d'une inondation majeure et dangereuse. La conception complète et les structures n'étant pas conformes à la réglementation nationale en vigueur, à savoir la DIN 19700 [3], le propriétaire, l'Association de Niers, a décidé de moderniser le bassin. Les travaux de modernisation comprennent différentes mesures telles que l'ajustement de la gestion de l'exploitation du réservoir, en tenant compte des hydrogrammes de crue et des décharges, ainsi qu'une compensation de l'évacuation des eaux usées. Cette dernière mesure est une conséquence urgente du développement urbain continu qui a conduit à une augmentation constante des rejets d'eaux usées pour lesquelles le volume d'eau du bassin ne peut pas être fourni localement. Dans le

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cadre de la réhabilitation du barrage, la reconstruction des ouvrages d'exutoire - un déversoir contrôlé avec trois baies et des vannes d'écluse - et la construction d'un déversoir de débordement dans le cadre d'un barrage en remblai seront réalisés. L'ensemble du projet est dominé par les restrictions environnementales comprenant à la fois les zones de protection environnementale ainsi que les exigences de viabilité des poissons et des eaux souterraines. La zone du projet est située dans une région caractérisée par un affaissement du terrain dû aux activités minières, une gestion des eaux souterraines et des charges sédimentaires élevées.

1 Introduction

The Owner of the flood retention dam Odenkirchen, the Niers Association, decided to upgrade the dam in order to fulfil the requirements of the DIN 19700/2004 [3] and to improve the ecological situation downstream of the dam location by balancing out sewage disposals. Further, the sedimentation management concept shall be re-evaluated and, if required, the corresponding assets shall be also upgraded.

Many flood retention dams have and had to be upgraded to meet the requirements of the DIN 19700 [3,4], especially part 12 [5], which was updated and published 2004 (see [11]). Mainly the outlet works and the dam structures need adjustment due to the principle change of the DIN 19700 [3] in comparison to the previous code to a risk-based approach.

Due to the long period of operation the technical standards as well as hydrological and hydraulic requirements for retention dams changed so that a re-evaluation of the hydrological and hydraulic risks has to be performed. For the flood retention dam Odenkirchen the mentioned constraints apply. A replacement of the outlet works, a newly designed overflow spillway and the rehabilitation of the dam structures is required.

2 The Project

2.1 Classification

The flood retention dam Odenkirchen is a medium-sized retention basin according to the classification of DIN 19700 [4]. The maximum reservoir volume is approx. 260,000 m^3 at 57,10 masl which is larger than 100,000 m^3 which is the lower border for small sized basins and smaller than 1,000,000 m^3 which is the upper border to large sized basins. In this context also the damage potential or flood risks should be considered which are at least also medium or even higher (see also [8]).

2.2 Location and operation

The flood retention dam Odenkirchen is located on the river Niers within the upper catchment area only around 12 km from the spring area. The dam is located in Odenkirchen, a part of the city of Mönchengladbach in North Rhine-Westphalia (NRW), Germany.

The dam was built in the 1960s as a response of a major flood event. At that time shortly after World War II the engineering technologies and the available construction materials were limited.

The existing structures were constructed with homespun remedies leaving a scheme “fit for purpose”.

A flood occurred in 1963 just a few years after the dam started operation (Fig. 1).

The River Niers crosses the reservoir in the West from South to North and then flows at the northern border from West to East crossing the highway and the railway. The outlet works discharge to a pond which again leads to the river Niers.

Fig. 1. Picture of outlet structure during the flood 1963 – the flood water level reached the dam crest.

Since then, the flood retention dam was operating according to flood protection aspects defining a maximum flood water level at 57,56 masl which corresponds to +3,80 m above reservoir gauge zero-point. During the operation a reduced water level was dictated by the authorities due to safety consideration in relation with the overflow spillway and the non-conformance with the updated DIN 19700 [3]. It was reduced to 56,16 masl and reservoir level at +2,40 m.

2.3 Existing assets/structures

The reservoir is crossed by a highway and a railway showing the corresponding embankments. The railway embankment is passed via a conduit (see Fig. 2).

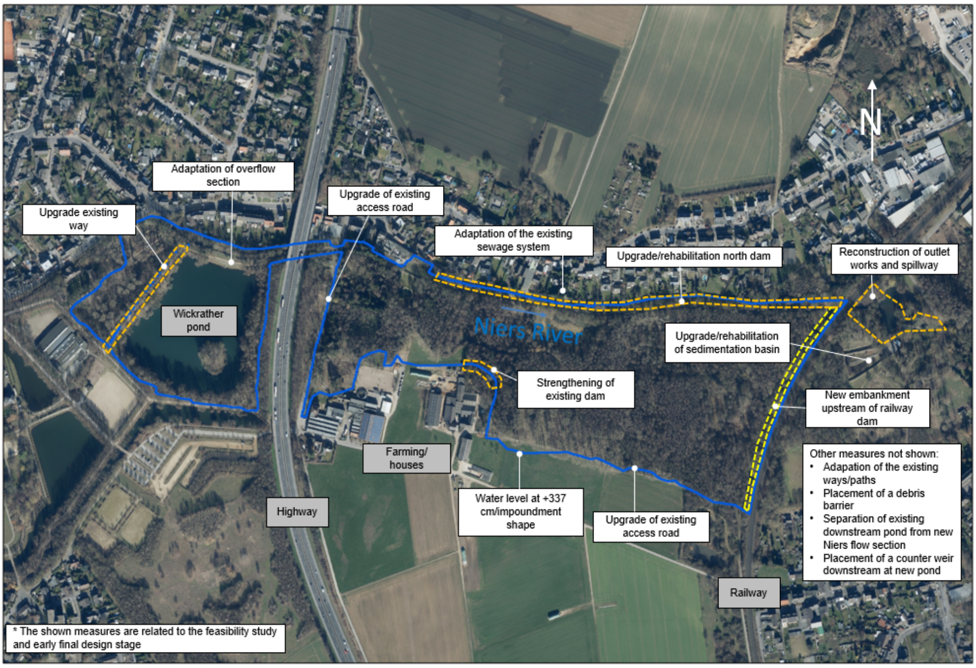

Fig. 2. Plan view of the complete reservoir with planned measures and the reservoir water level at +3,37 m above reservoir gauge zero-point.

The reservoir area is a nature conservation area and covered by wood and special protected vegetation which is on the red list in NRW. In the reservoir area residential houses, farms and private properties are located. Some access roads and many pathways are hosting all of leisure traffic. The reservoir area is used for local recreation matters. For a better understanding of the scheme a general plan view is given in Fig. 2 showing also the planned measures.

The existing structures and selected aspects describing the present situation are listed below. Some of the aspects were already mentioned before:

- The outlet works are composed of a controlled weir with a single sluice gate, an overflow section within the adjacent embankment dams which works as spillway and which is stabilized by a steel sheet pile wall.
- A conduit leads through the railway dam and hosts also a pedestrian way which is also used by cyclists (although this is forbidden).
- The North embankment dam closes the reservoir area of the “Wetscheweller Bruch” in the north, a railway dam is located at the east side.
- The reservoir also embraces the “Wickrather Lake” which is flooded via an overflow section directly by the bypassing Niers in case of impoundment. Afterwards the Niers flows through the basin parallel to the north dam.
- Between the reservoir sections “Wetschweller Bruch” and “Wickrather Lake” a highway dam is located which is neither affected by surface water levels nor by considered flood water levels.
- The composition and design of the embankment dam is mainly unknown, but it has to be assumed that also the design and performance does not comply to modern engineering requirements.
- Long sections of the existing embankment dams show large trees.

- Within the existing pond sedimentation takes place so that the pond is dredged regularly to a sedimentation basin located within the downstream outlet area of the dam. After drying the material, it is transported to a landfill.
- The reservoir area has developed valuable vegetation, flora and wildlife so that protection areas were defined there.
- Along the complete area groundwater pumps are located since due to mining processes the groundwater needed to be controlled. Hand in hand with those measures mining subsidence occurs and will continue during the next decades.
- The present controlled weir does only host one sluice gate which is used for controlling the downstream discharge. This does not comply to the (n-1) or (n-a) requirements of the corresponding codes, DIN 19700 [3,4].
- Roads, pedestrian and cycling ways are located throughout the whole area. Some of them are below the existing and planned flood level.
- Some houses and farms are located in the reservoir area, whilst north of the reservoir urban housing areas are located.
- Nearby the north dam sewage and drainage canals and pipes are discharging into the reservoir in case of heavy rainfall occurs.

For the time being the River Niers is discharging only through the existing weir. The passability of any organisms is not given.

In Fig. 2 and 5 the flood level at +3,37 m above reservoir gauge zero-point is shown which defines the impounded area in the reservoir. The gauge zero-point shows an elevation of 53,73 masl, thus the maximum water level is at 57,10 masl. The housing and farming areas in the "Wetscheweller Bruch" area are not directly affected.

3 Rehabilitation concept and works

3.1 General approach and philosophy

The complete scheme shall be adjusted according to the up-to-date regulations of the DIN 19700 [3,4], especially part 12 [5] for flood retention dams. The maximum reservoir flood water level is reduced from +3,80 m of the old permission to +3,37 m in the new design which corresponds to 57,10 masl.

The dam works shall be designed sustainable in order to cover also the development of the future decades in consideration of hydrological, environmental and technical aspects.

The operation shall not only cover flood protection but also retention rain events for the compensation of sewage disposals downstream. All assets and structures shall be designed for optimum and safe access during operation for maintenance and during floods.

The Owner puts emphasis on the application of modern techniques and the best practice in combination with a reasonable cost-benefit ratio.

3.2 Hydrological information and design water levels

Due to its location at the upper River Niers section the catchment area is only A_O = 72 km². It is noted that technical terms and abbreviations were taken from [3-5] and indices are referring to the German terms and are not translated to English in order to provide the correct values and terms. The hydrological and hydraulic characteristics are as follows:

- BHQ_1 = 8.2 m³/s (after flood routing; Q_{Inflow} = 9.4 m³/s)
- BHQ_2 = 8.7 m³/s (after flood routing, Q_{Inflow} = 17.0 m³/s)
- $HQ_{Spillway}$ = 10.0 m³/s (check flood for spillway)
- $Q_{Flood,out,1}$ = 2.0 m³/s (flood protection mode)
- $Q_{Flood,out,2}$ = 3.0 m³/s (flood protection mode)
- $Q_{Op,out,1}$ = 0.65 m³/s (compensation of sewage disposals)
- $Q_{Op,out,2}$ = 1.0 m³/s (compensation of sewage disposals)
- NQ = 0.15 m³/s
- MQ = 0.30 m³/s
- MHQ = 3.5 m³/s

The corresponding design water levels and the flood retention volumes are as follows:

- Z_{WD} = 55.93 masl (water level for waste disposal compensation, +2,20 m)
- Z_V = 56.90 masl (flood water level, +3,07 m)
- BHW_1 = BHW_2 = 57.10 masl (maximum flood water level, + 3,37 m)
- I_{GHR} = 215,000 m³ (in accordance to Z_V)
- I_{AHR} = 260,000 m³ (in accordance to BHW_1 = BHW_2)

Thanks to the hydraulic design of the outlet works the maximum flood levels resulting from the maximum flood discharges BHQ_1 and BHQ_2 could be levelled.

A detailed freeboard study was performed in order to take into account the specific reservoir geometry and the location of the specific structures. The resulting freeboard ranges from 0.5 m, as minimum value for the freeboard, to maximum 1.1 m areas with large wind fetch combined with strong winds and amplification. The specific reservoir geometry causes a wave-run-up amplification originating in the north-east corner upstream of the railway conduit. Through the railway conduit those high waves are transmitted and damped so that at the outlet works a freeboard of 0.7 m was applied [1, 6, 7, 14].

3.3 Dam and hydraulic works

The up-to-date design works recommend following adaptations:

- Removal and rearrangement of the complete outlet works including weir with gate house, spillway, side walls, etc.
- Construction of a controlled, three bayed weirs with sluice gates
  - 2 x gates for flood discharge
  - 1 x gate for normal operation designed as fish passable structure
- Construction of a new overflow spillway with a downstream slope protected against erosion and an accessible crest road (see [12])
- Reconstruction of an operation and control house
- Construction of a storage house
- Placement of a downstream control weir to create a stable pond level
- Separation of Niers flow section and existing downstream pond area by a separation embankment dam
- Design of roads and ways for operational issues and vehicles connected to the public access roads

- Rehabilitation of the north dam by reconstruction of the crest way/top layers and implementation of a steel sheet pile wall
- Construction of an upstream embankment with crest way along the railway dam and removal of nearby trees
- Rehabilitation or strengthening of a dam along farms in the south of the reservoir
- Reconstruction of parts of the adjacent canal system and placement of a pumping station in order to guarantee the drainage capacity of the system (see also section 3.5)
- Adaptation of the existing overflow section at the “Wickrather Lake”
- Placement of an embankment with crest road along the western border of the “Wickrather Lake”
- Adjustment of the access road at the western border of the “Wetscheweller Bruch”
- Adjustment and heightening of the adjacent pedestrian and cycling ways up to a height of minimum 57,60 masl in order to guarantee safe passage also during of extreme floods
- Placement of a debris barrier upstream of the railway conduit
- Upgrade or rehabilitation of existing sedimentation basin and procedure (see also section 3.5)

The steel sheet pile wall is applied for guaranteeing the stability on a long-term basis in spite of upcoming and existing trees located close to or on the dam body. The decisive design situation is the failure of a tree during impoundment, for which a relatively deep integration of the piles and strong profiles are required.

During the normal operation gates of weir will be adjusted according to the allowed downstream which reaches from 0,65 to 3,0 m³/s for ordinary flood and rain events. Usually for small flow the right gate is used, for increasing flow rate one of the other gates (left or middle) are used. The hydraulic capacity of the right operational gate is shown in Fig. 3 [2]. The width of the three weir fields is 1,50 m each. The maximum hydraulic discharge capacity of each the left and mid weir field is approx. $Q_{Out,max}$ = 6,8 m³/s at a reservoir level of 57,10 masl. Thus, the spillway and the mid gate are able to let the extreme flood design discharge BHQ_2 = 8,7 m³/s pass, whilst the spillway releases Q_{Spill} ≈ 2,0 m³/s. The number of gates and their designs were applied to provide best flexibility for operation also in the far future [3, 7, 13].

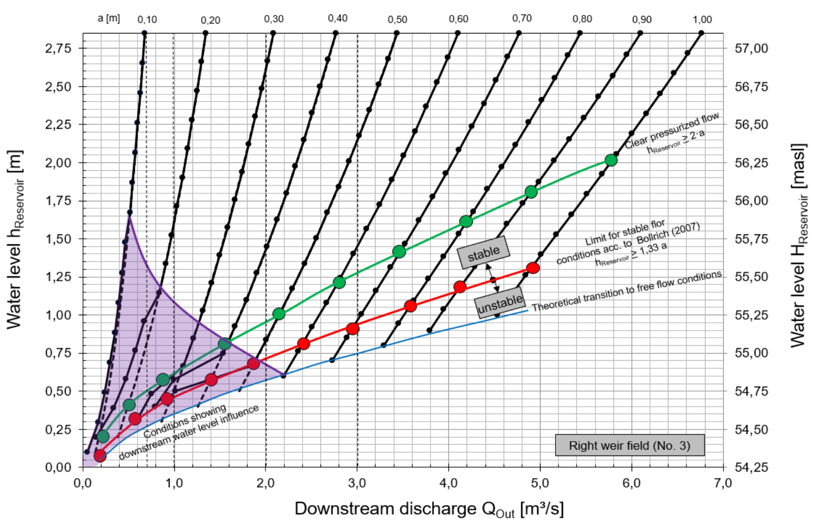

Fig. 3. Hydraulic characteristic of the right operational gate in consideration of different reservoir water levels and downstream water levels.

The hydraulic safety of the scheme is designed in consideration of the safety philosophy of the Niers association and future uncertainties concerning the long-term development of the hydrological situation also in terms of potential unfavourable climate change effects. Therefore, also a “check flood” was defined ($HQ_{Spillway}$ = 10,0 m³/s) which shall be passed already by the spillway alone without overtopping adjacent structures.

The crest ways and roads and all other access ways will show a minimum width of 3,0 to 3,5 m, except where heavy machinery shall pass. There, also 5,0 m width are applied. Where required strong concrete cobblestones will be placed onto the surface of the dam roads [3].

The existing overflow section between the River Niers and the “Wickrather Lake” will be adjusted so that the retention effect will be utilized best. Therefore, the overflow section will be enlarged hosting a way which still can be used by pedestrians, cyclists, and maintenance vehicles.

Principally, the foundation consists of fine grained soils at the top with a depth of a few meters which are underlain by permeable sediments consisting of sands and gravels with fine grained components. The impermeable horizon may be reached at 5.0 to 15 m depth in the project area. The foundation of structures on the fine grained upper layers seems to be difficult so that replacement of that soils or deep foundations will be applied.

3.4 Reservoir management adjustment

In former times, the reservoir was operated for the sake of flood protection, exclusively. In future also discharge from the Niers shall be retained to compensate the sewage disposals originating from downstream settlements. Therefore, the mentioned sewage systems need not to be upgraded for increased retention. The flood retention basin is taking over this task by reducing the outflow from the basin to $Q_{Op,Out,1}$ = 0,65 m³/s and $Q_{OP,Out,2}$ = 1,0 m³/s up to the flood water level of +2,20 m which corresponds to 55,93 masl shown in Fig. 4. The maximum reservoir area covered in case of full utilization of the flood retention volume is +3,37 m which corresponds to 57,10 masl. The flooded area is shown in Fig. 5.

Fig. 4. Reservoir area for the compensation of sewage disposals (+2,20 m / 55,93 masl).

For flood protection issues the downstream flow will be reduced to maximum QFlood,out,2 = 3,0 m³/s. For small discharges the right weir field will be operated. For the release of larger flows the left or middle field will be operated. For extreme floods (BHQ_{1+2}) the left or middle gates will be operated with the right gate offering additional safety. The consequence of this operation scheme are more frequent impoundment events.

Fig. 5. Maximum reservoir area by the maximum reservoir level (+3,37 m / 57,10 masl).

In general, following alternative methods are available for draining sediments:

- Centrifuge
- Chamber filter press
- Band filter press
- Dredging area/sedimentation basin
- Dredging by using geosynthetics
- Direct transport and dumping
- etc.

For river sediments without the need for quick draining and for limited amounts the use of geosynthetics and the classical dredging into a sediment basin are the most cost effective methods compared to the other mentioned methods. This is the reason why only these two methods are investigated in detail and compared. For the time being, no decision is done which methods will be applied.

The nearby canal works show four inlets to the reservoir area which are spilling rainwater to the reservoir in case strong rainfalls occur. In order to decrease the number of crossings through the northern dam all canals will be bundled and guided to a single crossing spot. There, a pumping station will be placed which shall pump discharge rainwater against the water pressure in the reservoir when impounded. Due to lack of space an underground pumping station will be applied, so that the existing infrastructural uses can be restored after completion of works.

3.5 Environmental and other aspects

As aforementioned, the reservoir area hosts special protected fauna and flora. Therefore, efforts for minimizing and avoiding the environmental impact were consequently followed up, e. g., by the application of a sheet pile wall at the northern dam or by defining taboo areas for structural measures in the reservoir.

The design also considered the establishment of river passability although up- and downstream the passability is not given yet.

The impact of the more frequent small impoundment events on existing vegetation in the reservoir for the sake of sewage disposal compensation is still under investigation. However, first results show that the impact is not critical, since other factors and not temporary flood events are dominating the local environmental conditions.

The effect of underground sealings such as applied for the north dam in form of a sheet pile wall and for the construction pits at the outflow works is considered by first the limitation of the embedment length and second by the application of groundwater flow windows where required [9, 10].

Along the existing and at the new structures trees need to be removed which will be done in the admissible period from 1st November to 28th February and will be compensated corresponding to results of the landscape management plan which is under preparation. More prohibition time periods, when construction of similar works are not allowed, are not known for the time being.

Since most of the works are only reflecting an upgrading of existing structures and some basic positive environmental measures, such as the passability of the structures, the environmental impact is considered to be acceptable for the time being.

The performed environmental scoping meeting did not reveal further requirements or postulations by the environmentalists which are working for the environmental impact assessment. Additional modelling regarding groundwater or water quality was also not demanded.

4 Conclusion

The upgrading of the flood retention basin Odenkirchen will be done primarily to improve the stability, operation and maintenance of the future basin and structures. Hand in hand with the upgrade of the structures the operational scheme will be changed by adding also impoundment scenarios for the compensation of downstream sewage disposals.

With the improvement of the sedimentation management the complete asset should be again manageable and safe for the next decades in accordance with the corresponding codes, the legal requirements and the internal technical specifications of the Niers association itself.

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