HARMONIZING DAM REHABILITATION WITH FLOODPLAIN MANAGEMENT

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Abstract. The Yellow River Watershed Structure No. 15 (Y-15) is a project that has been ongoing for Gwinnett County since the year 1999 with sometimes insurmountable political, technical, and financial hurdles. Residents did not support the project and application of the design criteria resulted in massive and costly spillway improvements to bring the structure into compliance with the high hazard design criteria. In mid 2004 Golder Associates Inc. was contracted by Gwinnett County for the design of the conceptual solution proposed by previous consultants. Golder's evaluation of the conceptual design identified several modifications could be made to the preliminary design parameters. During preliminary design, the proposed spillway was significantly modified such that the size of the chute was reduced by 30% (over 200 linear feet) and the proposed ogee weir was replaced by a broad-crested weir. These changes were possible by modifying the spillway crest to permit additional flow during more frequent storm events, but the existing mapped 100 year floodplain remains unchanged. Golder's proposed reduction in the size of the spillway structure aided in the final acceptance of the project by local residents.

INTRODUCTION

Gwinnett County currently operates and maintains 14 watershed structures constructed through funding supplied by the Soil Conservation Service (SCS) in the 1960's, 70's, 80's, and 90's. Each dam was designed and constructed as a low to medium hazard NRCS Class A or B structure and are located within the bustling suburbs of metropolitan Atlanta. Recently, twelve of Gwinnett County's watershed dams have been reclassified as high hazard structures in which a probable loss of life is predicted in the event of a dam breach. To address this issue, Gwinnett County has undertaken an aggressive capital improvement program to upgrade the NRCS dams to comply with the high hazard structure design criterion.

A common design constraint for these projects is to avoid increasing flooding frequency both upstream and downstream of the structure, as determined by impacts to the existing mapped 100 year floodplain. Simultaneous to the dam rehabilitation projects, Gwinnett County is also updating the County-wide flood insurance studies (FIS) and rate maps (FIRMs) to update the floodplain and floodway based on the current land use practices. Additional survey information, more detailed hydrologic studies, and better hydraulic modeling generally results in a reduction of the base flood elevation (BFE), but also complicates the dam rehabilitation objectives, as additional discharge is needed through the dam's spillway system to route the required design storms. The revised flood insurance studies remove any available buffer to increase peak discharge downstream of the structure.

EXISTING DESIGN CONFIGURATION

The Y-15 structure was constructed with an original dam height of 41 feet with a crest elevation of 974 ft. MSL. The dam retains 334 acre-feet (109 million gallons) of water at normal pool (el. 947.1 ft. MSL), 1194 acre-feet (389 million gallons) at the auxiliary spillway crest elevation (el. 968.9 ft. MSL), and 2,232 acre-feet (727 million gallons) at maximum pool, or top of dam, level. The watershed drainage area is approximately 5.9 square miles. The structure was constructed with a standard NRCS reinforced concrete open top-riser principal spillway and 30-inch diameter outlet pipe through the dam

Figure 1. Aerial view of the existing Y-15 structure (source NRCS).

embankment. A 200 foot wide grass lined open channel auxiliary spillway was excavated on the right abutment.

The auxiliary spillway was sized to accommodate flood run-off for the NRCS freeboard hydrograph storm with a total rainfall depth of 15 inches in 6 hours without overtopping the structure. Peak discharge was 6,060 cfs at a flow depth of 5.1 ft.

Immediately downstream of the Y-15 structure is Collins Hill Road which is a major arterial road that connects to State Highway 316. The road alignment is skewed to the dam crest and abuts the toe of the embankment on the left abutment. The Collins Hill Road culvert crossing consists of two, 10 ft. wide by 9 ft. high concrete box culverts. Analyses show that the culverts are overtopped by a flow of approximately 3,500 cfs.

Y-15 PROJECT BACKGROUND

A short time before the November 1, 2000 expiration of the NRCS watershed structure exemption for compliance with the State of Georgia Rules for Dam Safety, work began on the Y-15 structure. Previous consultants performed a hazard classification for the structure which identified that approximately 104 structures, three arterial roads, and two minor roads were impacted by a breach of the Y-15 dam and would result in the probable loss of life; therefore, the structure should be reclassified from a State of Georgia Category II or NRCS Class B to a Category I or Class C high hazard structure, respectively.

Upon confirmation of the hazard classification for the structure, conceptual planning work commenced to evaluate the most cost effective solution to bring the structure into compliance with the Georgia Rules for Dam Safety or NRCS Technical Release 60 design criteria. Previous consultants identified early on in the planning process that a major structural modification to the dam was needed to comply with State of Georgia and NRCS design criteria to route the ½ PMP (AMC-III watershed conditions) and PMP storm through the watershed, respectively. The results of the planning process identified 5 remedial solutions that would bring the structure into compliance. The remedial solutions consisted of 2 labyrinth weir and 3 ogee weir options with a roller compacted concrete chute. The most viable solution was the construction of a 660 ft. wide roller compacted concrete (RCC) chute spillway with an ogee weir at a crest elevation of 969.0 ft. MSL (0.1 ft. above the existing auxiliary spillway crest). The maximum water surface elevation for proposed structure was 974.7 ft. MSL, which is equivalent to the existing maximum dam crest elevation (due to an overbuild of the original structure for settlement purposes). The estimated cost to construct the proposed structure was $3.4 million.

In 2000, the Watershed Protection and Flood Prevention Act (PL-566) was revised to permit the NRCS to provide communities with assistance in rehabilitating existing NRCS watershed structures. For structures that meet the NRCS design criteria, the NRCS provides 65 percent of the total rehabilitation cost, while the project sponsor provides the remaining 35 percent. Gwinnett County opted to pursue the 65/35 percent cost-share to assist in the rehabilitation of Y-15 since it was more cost effective than paying for 100% of the project costs and only satisfying the State of Georgia Rules for Dam Safety. In September 2003, Gwinnett County entered into a Watershed Project Agreement with the NRCS to provide the financial assistance authorized under the amendments to PL-566.

Public participation in the planning process is a requirement for financial assistance through the NRCS. Public meetings with local residents were held in November 2002 and April 2003. Subsequent meetings were held in 2004 and 2005 with residents of the homeowner's association that abuts the Y-15 to discuss the status of the project. The NRCS Georgia State office issued a Watershed Plan and Environmental Assessment for the rehabilitation of the Y-15 structure in September 2003. The final Hazard Classification and Conceptual Planning reports for Y-15 were completed in December 2003.

Throughout 2003, the Upper Yellow River Watershed flood-study was being evaluated by Gwinnett County's flood-study consultant. The existing flood-study was last revised in 1984. The study resulted in the creation of HEC-HMS and HEC-RAS computer models for the entire Upper Yellow River Basin.

Golder Associates Inc. (Golder) was retained by Gwinnett County for the design of the 660 ft. wide RCC remedial option selected for the Y-15 rehabilitation. Disputes between homeowners and Gwinnett County over the existing flood easement elevation and concerns about the overall aesthetics of the proposed structure resulted in the need for Golder to re-evaluate additional remedial options to bring the structure into compliance, while maintaining the peak water surface elevation during the PMP design storm below the existing flood easement elevation of 974.0 ft. MSL.

EVALUATION OF REMEDIAL ALTERNATIVES

Golder obtained copies of the previous consultants' work to design an improved spillway configuration. After thorough checks and modifications to the work, Golder began to iterate numerous spillway options. Initially, the work involved no impact to the 100 year floodplain, such

that the proposed spillway crest was at or above elevation 968.1 ft. MSL (peak water surface elevation during the existing 24-hour 100-year storm). However, given the new criteria to not increase the peak water surface elevation during the PMP design storm above the existing flood easement of 974.0, with the auxiliary spillway crest set at elevation 968.1 ft. MSL only confirmed the analyses of the previous consultant for the need of a 660 ft. wide RCC spillway with an ogee weir. This affirmation resulted in the need to assess impacts to the 100 year storm floodplain.

As Golder proceeded with this exercise, it was noted that in addition to reducing the total spillway crest width needed to safely route the design storms through the watershed, peak stage during the 24-hour, 100-year storm event decreases and the peak discharge from the spillway remains similar to the existing conditions. Lowering the spillway crest effectively increases the duration of the peak flow, but does not drastically increase peak discharge downstream of Y-15. Throughout discussions with Gwinnett County and the flood-study consultant about the potential reduction in spillway crest width (if a small increase in the 100 year floodplain immediately downstream of the structure was acceptable), it was further noted that the peak in the Y-15 watershed and the watershed (sub-area 329) downstream of the dam, (upstream of Collins Hill Road) occurred at time periods approximately 6 hours apart. Watershed 329 has a peak discharge of approximately 427.6 cfs at a time of 12:02. The Y-15 watershed has peak discharge of approximately 116.35 cfs at a time of 13:46. During the peak of watershed 329, the Y-15 watershed has a peak of 70.8 cfs whereas, during the peak of the Y-15 watershed, watershed 329 has a peak of 21.50. At the confluence of the two watersheds at Collins Hill Road, the combined peak flow of 497.4 occurs at time equal to 12:02. Since the peak of the Y-15 watershed occurs approximately 100 minutes after the peak in watershed 329, flow out of the Y-15 structure can be increased by approximately 475 cfs so that the combined flows at Collins Hill Road are less or equal to the peak flows from watershed 329 and Y-15 at time equal to 12:02.

Based on these results, the proposed Y-15 spillway was designed with a lowered crest section, such that the spillway is engaged during more frequent storms. Peak flow at Collins Hill Road does not increase above 497.4 cfs. The proposed lowered crest section is 45 ft. long at elevation 964.0 ft. MSL. The main spillway control section is set at an elevation 2 ft. above (elevation 966.0 ft. MSL) the lowered section and does not engage for storms with a recurrence interval greater than 1%. Figure 2 illustrates the impact to the Upper Yellow River Watershed by the proposed modifications. The blue data line represents the existing conditions and the red data line represents the proposed spillway conditions. The data for existing conditions has one peak at time equal to 12 hours, thereafter the discharge decreases to approximately 120 cfs and remains constant until the Y-15 flood pool is drawn down to normal pool. The data for the proposed conditions has two peaks. The first peak coincides with the existing conditions peak at 12 hours. The second peak occurs at a time of 19.2 hours with a discharge of 481.8 cfs. Thereafter, discharge for the proposed conditions decreases until the flood pool is drawn back down to normal pool.

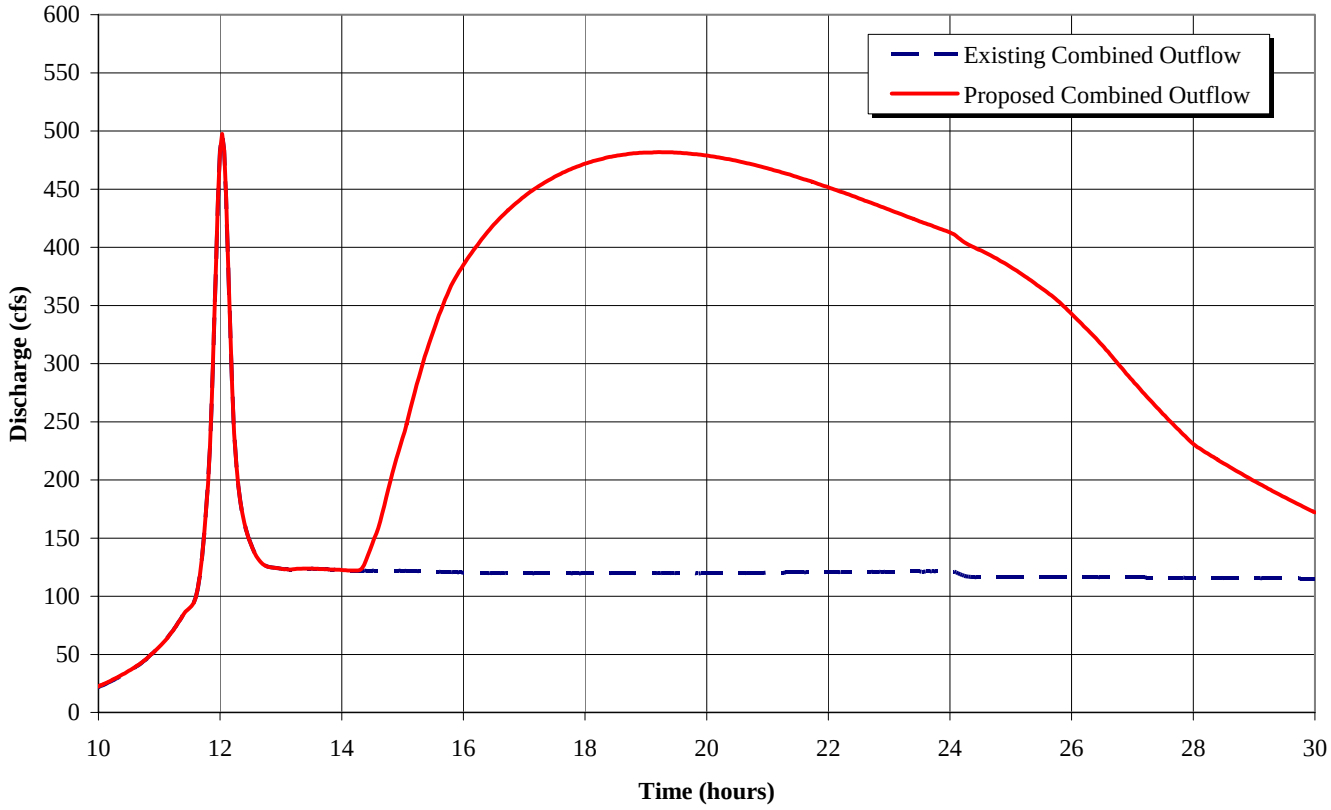
HYDRAULIC EVALUATION

The current flood-study HEC-RAS model was utilized throughout the design process to assess the impact of lowering the auxiliary spillway crest elevation on the downstream surface water elevations. The flood-study model comprises the hydraulic information for the entire Upper Yellow River flood study and consists of 154 cross-section entries, 16 bridge crossings, and 4 culvert crossings. The results of the revised HEC-HMS model for the proposed spillway were input into the existing flood-study HEC-RAS model and the impact to the Yellow River flood plain downstream of Y-15 was evaluated. The only increase in floodplain elevation was immediately downstream of the Y-15 dam at section 77028, where the floodplain water surface elevation increased from 935.67 ft. MSL to 935.82 ft. MSL. The water surface elevation rise of 0.15 ft. at cross-section 77028 can be shown as a no rise impact to the downstream channel, if the Manning's 'n' value for the center channel is changed from the existing conditions value of 0.055 to a value that better approximates the roller compacted concrete stilling basin at this location. A Manning's 'n' value equal to or less than 0.03 substantiates the no-rise outcome.

RESULTANT SPILLWAY DESIGN GEOMETRY

The effect of harmonizing dam rehabilitation with floodplain management by lowering the spillway crest to 964.0 ft. MSL allows the proposed spillway to route the 24-hour, 100 year design storm through the watershed without engaging the second stage spillway crest elevation of 966.0 ft. MSL. The second stage spillway engages for storms with a return frequency less than 1%. The combined spillway system routes both the State of Georgia and NRCS design storms through the watershed while reducing the required weir crest length by approximately 30 percent (reduction of 180 ft. to 480 ft.). Using the RCC quantities proposed for the original design, a reduction of 30% in the RCC quantity results in an estimated project savings of approximately $0.5 million.

Figure 2: HEC-HMS Model outflow hydrograph at Collins Hill Road for existing and proposed spillway conditions.



The length of the center and right portions of the Y-15 dam that are situated approximately perpendicular to the Yellow River are approximately 660 ft. The downstream creek valley beyond the toe of the existing dam is approximately 275 ft. wide. The most cost effective remedial spillway design which minimizes excavation, encroachment on adjacent properties and Collins Hill Road, and tree removal in the downstream abutments comprises an overflow crest parallel to the main dam centerline connected to the abutments by an angled overflow crest. The shape is similar to one cycle of a labyrinth weir except the apex of the weir is approximately 370 ft. long. The legs or wings of the spillway crest are approximately 55 ft. long. The effective weir length is approximately 480 ft, but the spillway chute width is only 450 ft., further reducing the total volume of RCC required for construction of the spillway. A plan view of the proposed spillway is illustrated in Figure 5.

Detailed analysis of the spillway crest resulted in additional cost savings of approximately $300,000 to the project by eliminating the ogee weir and replacing the spillway crest with a broad-crested weir. Flow through the proposed chute spillway was modeled using the empirical data for broad-crested spillways, as presented in Bos, 1989 [2]. The spillway has a relatively short crest width (6 ft.) and functions as a short-crested weir at larger hydraulic heads. The minimum and maximum "weir" coefficients determined for the proposed spillway at reservoir elevations of 966 and 974 ft. MSL are 2.61 and 3.46, respectively. Upon completion of the project, the broad-crested weir will also serve as a walkway for residents who live in the subdivision adjacent to the structure. This single modification has made the local residents less concerned about the aesthetic issues that originally hampered the planning process and more willing to accept the project.

CONCLUSIONS

Detailed analyses of the relationship between spillway performance and impacts to the 100-year storm floodplain resulted in significant cost savings at minimal loss of flood protection downstream of the Y-15 dam. The original conceptual design for the Y-15 spillway was improved by reducing the overall chute width by 30 percent and removing the ogee weir, resulting in an estimated cost savings of approximately $0.75 million. The design proposed by Golder, although still being evaluated and improved during the model study phase, will result in a technically and socially accepted solution, beginning the end of long seven-plus year project to rehabilitate the Y-15 structure.