MEMORANDUM

Project 12116

TO: **Beorn Courtney, P.E., Director of Water Resource Engineering – Platte River Recovery Implementation Program Executive Directors Office**

FROM: **Robert J. Huzjak, P.E. – RJH Consultants, Inc.**

DATE: **March 14, 2013**

RE: **Draft J-2 Regulating Reservoir - Concept Comparison Memorandum**

1 Introduction

This memorandum presents a comparison of the primary differences between two concepts for the J-2 Regulating Reservoir Project (Project). Olsson and Associates (Olsson) presented a previous concept (previous concept) for the Project as documented in the CNPPID J-2 Reregulating Reservoir, Feasibility Report (Olsson, 2012). The Platte River Recovery and Implementation Program (Program) retained RJH Consultants, Inc. (RJH) to perform an independent evaluation of the Olsson concept and if needed, provide technical changes to improve the safety and functionality of the Project, and develop an independent opinion of Project costs. RJH presented an updated design concept (updated concept) in the Conceptual Design Report (RJH, 2013).

2 Technical Differences

2.1 General

The primary technical differences between the previous concept and the updated concept resulted from a need to address layout, safety, reliability, and operational issues. The following components are significantly different in the updated concept when compared to the previous concept:

- Upstream Slope Protection
- Reservoir Liner
- Dam Embankments
- Reservoir Grading
- Exterior Embankment Protection
- Hydraulic Structures
- Phelps Canal

The primary differences are summarized in Table 1. Additional comparison and discussion for each difference is provided in the following sections. There are many similarities and some other minor differences between the previous concept and the updated concept. Neither the similarities nor the minor differences are discussed in this memorandum. In general, limited information regarding the updated concept is provided in this memorandum. For more information regarding the updated concept, refer to RJH, 2013.

TABLE 1
SUMMARY OF PRIMARY TECHNICAL DIFFERENCES

Component	Previous Concept	Updated Concept	Reason Change was Needed
Upstream Slope Protection	9-inch-thick zone of riprap on upper 7 feet of the dam slopes.	Soil-cement slope protection from top of slope to bottom.	Reservoir levels will routinely fluctuate and waves could erode all portions of the dam if unprotected or if inadequately protected.
Clay Liner	12-inch-thick, unprotected liner.	18-inch-thick clay liner with a 3-foot-thick soil cover layer to protect the liner.	Frost, burrowing animals, and vegetation could damage an unprotected liner. A 12-inch-thick liner provides no allowance for variation in thickness of materials during construction and provides a higher potential for construction defects.
Dam Embankments	Homogeneous clayey dam with 3 horizontal to 1 vertical (3H:1V) slopes on both the upstream and downstream sides.	Zoned earthfill dam with central clayey core, filter zone, upstream sandy zone, and downstream random fill zone. The upstream slopes would be 4H:1V and the downstream slopes would be 3H:1V.	Piping is more likely in homogeneous dams than in filter-protected dams and current standard practice is to provide an internal drainage system. Extreme and frequent rapid drawdown of the reservoir could fail a clayey 3H:1V upstream slope.
Reservoir Layout, Grading, and Capacity	Location of downstream toe of dams did not consider property boundaries and did not provide space for an access road; the reservoir bottom was graded to be relatively flat with about 2 feet of dead pool; the total beneficial storage was about 14,115 acre-feet (ac-ft).	Located downstream toes of dam about 50 feet inside of Project boundaries; sloped the reservoir bottoms toward the outlets; the total beneficial storage would be about 15,400 ac-ft.	Space on the downstream side of the dam will facilitate maintenance access and provide flexibility in future stages of design; a sloped reservoir bottom would reduce the potential for uplift pressures on the clay liner; and additional storage capacity is preferred. The additional capacity with a smaller reservoir footprint was achieved in the updated concept by enabling a higher water surface in the Area 1 Reservoir.
Exterior Embankment Protection	No protection provided	Sheet pile and soil-cement protection where subject to Plum Creek flows	The abrupt turn in Plum Creek would erode the foundation and dam embankment. Without consideration of the erosive force of Plum Creek, the dam could catastrophically fail during a large storm event.

Component	Previous Concept	Updated Concept	Reason Change was Needed
Hydraulic Structures	Except for the Area 2 inlet structure, each structure had a single radial gate.	Except for Area 2 inlet structure, each structure would have both a radial gate and a slide gate.	There is a wide range of anticipated flows into and out of the reservoir (i.e., from less than 10 cfs to 2,000 cfs). Two gates provide the required flow control needed to accurately convey and measure this range of flows. The Area 2 inlet structure is configured similarly in both concepts.
Emergency Spillway	No spillway provided.	Spillway provided with overflow radial gates.	Although inflow is generally controlled, equipment malfunctions or operator errors could flood the reservoir and cause failure of the dam.
Phelps Canal	Provides 2 feet of freeboard and required various modifications to the canal and significant armoring of the canal banks.	Provides 1 foot of freeboard; generally similar canal modifications; and no canal bank armoring. Also includes a check dam to increase the canal operating level at the Area 1 Reservoir inlet.	Armoring is not needed because the flow velocities will be less than about 2 ft/sec. The check dam will enable the reservoir pool in the Area 1 Reservoir to be increased to El. 2356.

2.2 Upstream Slope Protection

The previous concept included provisions to protect about the upper 7 feet of the reservoir embankments from wave erosion with a 9-inch-thick zone of riprap. This concept is marginally acceptable provided the reservoir levels were always maintained near full. However, based on the anticipated reservoir operations, reservoir levels would routinely fluctuate and could frequently be lower than 7 feet below the dam crest. If the reservoir levels were frequently lower than the level of slope protection, waves would still be generated and would erode the unprotected upstream slope. Erosion of the upstream slope below the riprap would be a significant safety issue, could result in destabilizing the upstream slope, would likely require frequent, extensive, and potentially difficult maintenance, and if unattended, could result in dam failure. In addition, the previous concept of a 9-inch-thick layer of riprap is likely too thin to provide long-term protection from the expected wave energy.

The updated concept includes protecting the entire upstream slope of the dam embankments with soil-cement. This would mitigate the potential for wave erosion of the upstream embankment.

2.3 Clay Liner

Both the previous and updated concepts included a clay liner to manage reservoir seepage. However, the reliability of the previous concept is very low. First, the previous concept had a 12-inch-thick liner that was unprotected and exposed except for the 2 feet of dead pool storage. There could be times when 2 feet of water could not be maintained and even if it were, it only would provide marginal protection. Second, there would be some variations of the liner thickness based on constructability. It is probable that in localized areas the liner would be thinner than 12 inches. Third, if only one 12-inch-thick layer of fill were placed to construct the liner, there would be a reasonable chance that sandy (more permeable) pockets of material could extend completely through the liner. This could result in excessive and unsafe seepage conditions that would lead to a piping failure. It could be difficult to construct a liner in two 6-inch-thick lifts. Fourth, according to local building codes, typical design values for frost depth are 3 feet. A moist clayey material exposed to the atmosphere would expand and contract from wet-dry and freeze-thaw cycles. This would decrease the density and increase the permeability. In addition, burrowing animals and roots from vegetation could also penetrate and compromise an exposed 12-inch-thick liner. For the previous concept, it is likely that after about 2 to 3 years, significant seepage problems would develop and, if the problems were unattended, could result in a dam breach.

The updated concept includes an 18-inch-thick clayey liner constructed in two 9-inch lifts that are covered with 3 feet of soil material to protect the critical liner.

2.4 Dam Embankments

The dam embankment included in the previous concept was not well defined. Based on the limited information presented in Olsson 2012, RJH understands that the previous concept included a homogeneous clayey dam embankment with 3H:1V upstream and downstream slopes. Based on RJH's analysis and experience, there are two issues with this concept: embankment stability and the potential for internal erosion. RJH considered that the short duration high flows (SDHF) could occur annually and would represent a rapid drawdown loading condition on the upstream slope of the embankment. A 3H:1V upstream slope consisting of clayey soils would not be appropriately stable. Unstable slopes during rapid drawdown could lead to slope failures and a dam breach.

Although homogeneous dams are acceptable for some applications, for this Project, there is a potential for minor differential settlement of the embankment because the embankment would be founded on variable alluvial soils. Some of these soils also have a low potential for collapse settlement. If there were differential settlement below the embankment, small transverse cracks could develop through the clayey embankment soils. In a homogeneous dam, there are not components to safely stop the progression of transverse cracks. If seepage goes uncontrolled through the embankment, a backwards erosion (or piping) failure can develop.

The updated concept includes 4H:1V upstream slopes comprised predominantly of sandy, permeable materials. Both the flatter slope, and the permeable (free draining) materials would provide the needed stability for the upstream slope during rapid drawdown conditions. Additionally, the updated concept includes a granular filter zone downstream of the central core to stop the progression of transverse cracks and to safely collect and discharge seepage. It is standard modern dam safety practice to include this filter zone in most dams.

2.5 Reservoir Layout, Grading, and Capacity

The previous concept located the downstream toes of the dam at approximately the limits of project development. Although it increases the reservoir area and capacity, it could preclude access to many parts of the downstream toe for maintenance or observation. It also limits flexibility in future stages of design if any facilities needed to be located on the downstream side of the dam (i.e., piezometers, controls, etc.). Also, in some cases the downstream toes of the embankments for the previous concept extended beyond the project limits or did not connect the embankment topography with the existing topography.

The updated concept located the downstream toes of the dams approximately 50 feet inside of the limits of project development. Based on our experience, it is necessary to provide space between the project limits and the downstream toe, not only to avoid the need for potentially-difficult-to-obtain easements, but to facilitate access for the long-term inspection and maintenance of the dams.

The previous concept included generally flat-bottom reservoirs. The technical issue with this concept is that the reservoir liner would be at or only a foot or 2 above the average groundwater levels across most of the site. This would result in a relatively high potential for the liner to be subject to uplift pressures. If the uplift pressures became too great on the liner, the liner could heave, crack, and become ineffective (often referred to as “blow-out”).

The updated concept includes sloped reservoirs that drain to the outlets. The slopes of the reservoir bottoms would somewhat follow the anticipated groundwater gradient at the site. Therefore across the site, the bottom of the liner typically would be situated a few feet above the historic high groundwater levels thereby reducing the potential for uplift pressures to damage the liner. It would also eliminate most of the dead storage in the reservoirs and maintain head on the outlet gates as the reservoir drains. By maintaining head on the outlet gates even during the SDHF, the outlet structures would be smaller relative to flat-bottomed reservoirs.

The previous concept provided 14,115 ac-ft of beneficial storage. This beneficial storage did not include the reservoir volume for the 2 feet of dead storage presumably intended to protect the liner from uplift pressures. The previous concept obtained that storage by:

- Setting the maximum normal water surface (MNWS) elevation in Area 1 Reservoir at El. 2354.25, which provided a total of 10,941 ac-ft of beneficial storage.
- Setting the MNWS elevation in Area 2 Reservoir at El. 2357.0, which provided a total of 3,174 ac-ft of beneficial storage.

The updated concept considered that the canal would be checked with a canal gate immediately downstream of the Area 1 inlet and therefore both reservoirs could be filled to a MNWS elevation at El. 2356.0. This MNWS and the sloped reservoir bottom provides 12,135 ac-ft of beneficial storage in Area 1 Reservoir and 3,265 ac-ft of beneficial storage in Area 2 Reservoir, for a total of 15,400 ac-ft of beneficial storage.

2.6 Exterior Embankment Protection

The previous concept did not include erosion protection for the exterior of the embankment along Plum Creek or the unnamed tributary. As discussed in RJH 2013, potentially high-flow events can occur and if unprotected, the exterior side of the embankments could erode. This erosion could result in the need for significant repairs or failure of the embankment.

The updated concept included erosion protection on the exterior of the embankment in areas potentially subjected to stream flows. For Plum Creek, which has more flow, higher velocity flow, and flow directed at the dam (i.e., the dam would turn the flow about 90 degrees), sheet piles and armored soil-cement was needed. For the unnamed tributary, well-rooted and maintained sod or a reinforced turf should be sufficient to mitigate embankment erosion because of the expected velocity.

2.7 Hydraulic Structures

The previous concept included four hydraulic structures, which is similar to the updated concept. Many of the gates were modified in the updated concept. The previous concept included three slide gates at both Area 1 and Area 2 inlet structures. The updated concept includes one slide gate and one radial gate at the Area 1 inlet. The Area 2 inlet gates were changed for the updated concept by adjusting the gate sizes from three, 12-foot-wide by 12-foot-high slide gates to three, 10-foot-high by 10-foot-wide slide gates.

The gates and locations of the outlet structures were also modified for the updated concept. The previous concept included one radial gate at each outlet. The updated concept includes both a radial gate and a slide gate at each outlet structure. This would provide better flow control for the anticipated ranges of releases. More precise flow control is needed to enable releases for the smaller target flows (less than 500 cfs) and the radial gates provide the capacity needed to release the larger SDHF (2,000 cfs for 3 days). The location of the Area 2 outlet was modified to avoid directing the large outflows at the Area 1 embankment. The updated concept locates the Area 2 outlet to direct the water into the unnamed tributary with about a 30 degree change in flow direction instead of the 90 degree change in flow direction proposed in the previous concept.

Additionally, the updated concept adds provisions such as soil-cement drop structures and sheet piles to safely discharge high flows to the Platte River. The previous concept did not include these provisions. Without erosion protection in the outlet channels, the likelihood for erosion to undermine the structures would be high.

2.8 Emergency Spillway

The previous concept did not include emergency spillways in the reservoirs. Although the reservoirs are off-stream and inflow is controlled with gates, it is prudent design to consider that equipment malfunctions or operator errors could occur. Therefore, the updated concept included radial gates that would overflow at El. 2356.0 (MNWS). The overflow gates make use of the already-included outlet channels. Although gate overflow requires more robust radial gates relative to non-overflow radial gates, RJH considered that the cost increase of the gate would be less than the cost to construct a separate spillway channel.

3 Cost Comparison

The total Project cost estimated by Olsson for the previous concept was $49.7 million. Olsson included a cost of $4.8 million for land acquisition. If the costs included for land are removed, the Olsson estimate would be $44.9 million. The total Project cost estimated by RJH for the updated concept is $62.6 million. RJH's estimate did not include land costs; therefore, the difference in total costs, without including land acquisition costs, is about $17.7 million.

Although a line-item cost comparison was not feasible for the entire project because of the differences in concepts, the primary differences in costs that account for about 80 percent of the difference between the previous and updated concepts are summarized in the Table 2. The majority of the remaining 20 percent difference is associated with the allowances (contingencies, engineering, permitting, etc.) that are based on a percentage of direct costs.

TABLE 2
SUMMARY OF PRIMARY COST DIFFERENCES

Item	Cost for Previous Concept ($, million)	Updated Concept ($, million)	Change in Cost(1) ($, million)
Capital			
Upstream Slope Protection	4.3	10.4	6.1
Clay Liner	2.7	13.8	11.1
Exterior Embankment Protection	0	2.6	2.6
Hydraulic Structures (Inlet and Outlet Structures)(2)	7.0	5.1	(1.9)
Embankment(2)	12.1	8.0	(4.1)
Annual Operations and Maintenance	0.39	0.14	(0.25)

Notes:
1. ( ) indicates updated concept is less expensive than previous.
2. Although concepts and quantities are similar, the costs differ primarily because of differences in unit prices of the various components and elements that comprise the item.

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