LAGUNA DEL CAMPO RESERVOIR

DAM REHABILITATION
ALTERNATIVES REPORT

Prepared for

New Mexico Department of Game and Fish

Prepared by

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EXECUTIVE SUMMARY

This Dam Rehabilitation Alternatives Report for Laguna Del Campo Reservoir was prepared by W. W. Wheeler & Associates Inc. (Wheeler) for the New Mexico Department of Game and Fish (NMDGF). The dam is owned and operated by NMDGF and is located in Rio Arriba County approximately 13 miles south of Chama, New Mexico. The project objective was to develop and evaluate alternatives to rehabilitate the dam and bring it into compliance with New Mexico Office of the State Engineer (NMOSE) dam safety rules and regulations. Wheeler's scope of work included a review of project records, a startup site visit, a preliminary Incremental Damage Assessment (IDA), feasibility-level spillway alternative design and opinions of probable cost to rehabilitate or decommission the dam.

The Laguna Del Campo Dam is classified as a small, high-hazard dam. The dam is a 36-foot-high, embankment dam with a normal storage capacity of approximately 100 acre-feet. The 2015 NMOSE dam inspection classified the dam as being in poor condition, primarily due to inadequate spillway capacity. In accordance with NMOSE dam safety rules and regulations, the spillway is required to pass runoff resulting from the Probable Maximum Precipitation (PMP) storm; it is currently capable of passing six percent of the PMP without overtopping the dam. A challenge with this project was that spillway improvements had to be made within the narrow confines of NMGDF property. Because easements outside of NMGDF property could not be considered, some of the more cost effective alternatives were eliminated from consideration at the beginning of the study.

Three primary alternatives were evaluated in this study: a dam breach, lowering the dam to remove it from NMOSE Jurisdiction, and providing RCC overtopping protection over the dam. The dam breach would include constructing a 100-foot wide breach in the dam and a series of wetland ponds in the basin. Lowering the dam would include lowering the dam crest by 12 feet and construction of a new spillway capable of passing runoff from the 100-year, 24-hour storm. Results from the preliminary IDA indicate a strong potential to reduce the IDF to 60 percent of the PMP. The RCC overtopping protection alternative was evaluated for both the 60 percent and 100 percent Probable Maximum Flood (PMF).

Wheeler's preferred alternative is Alternative 2, as it provides a cost effective solution to the dam safety issues while maintaining a small pond and creating a valuable wetland resource for NMDGF. Lowering the dam crest would cost approximately $2.46 million and would result in a 16.4-acre-foot storage pool. Breaching the dam would cost approximately 1.79 million and also provides a cost effective solution however, it eliminates the reservoir entirely which is undesirable to NMDGF. The 100 percent PMF, RCC spillway would require a permanent storage reduction of 26 acre feet. The 60 percent and 100 percent PMF RCC alternatives would have similar project costs of approximately $7.73 million each, and result in anticipated costs per acre-foot of approximately $77,550 and $122,610, respectively. The anticipated cost of the RCC overtopping protection is expected to significantly exceed the value of the water storage in the reservoir.

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1.0 INTRODUCTION

1.1 Project Objective

The Laguna Del Campo Reservoir, Dam Rehabilitation Alternatives project objective is to develop preliminary alternatives to bring the Laguna Del Campo Dam into compliance with the dam safety rules and regulations published by the New Mexico Office of the State Engineer (NMOSE).

1.2 Authorization

The work documented in this report was authorized by Task Order F16PX00202, Contract No. F15PC00157, between the U.S. Fish and Wildlife Service (FWS) and W.W. Wheeler and Associates Inc. (Wheeler). Laguna Del Campo Dam is owned and operated by the New Mexico Department of Game and Fish (NMDGF). The work was contracted through FWS in accordance with an agreement between the NMDGF and FWS.

1.3 Statement of Work

The Statement of Work included in the above mentioned authorization includes the following major tasks:

Task 1: Project Management and Meetings;

Task 2: Alternatives Development;

Task 3: Preliminary Cost Opinion;

Task 4: Alternatives Evaluation and Selection;

Task 5: Alternatives Workshop.

1.4 Project Location

The Laguna Del Campo Dam is located in Rio Arriba County, approximately two miles northwest of the town of Tierra Amarillo, New Mexico and 80 miles northwest of Santa Fe New Mexico. The reservoir is an off-channel facility located approximately 2,500 feet east of the Rio Chama. The reservoir is fed by gravity outflow from the Los Ojos State Fish Hatchery via a ditch system. A project location map is presented on Figure No.1.

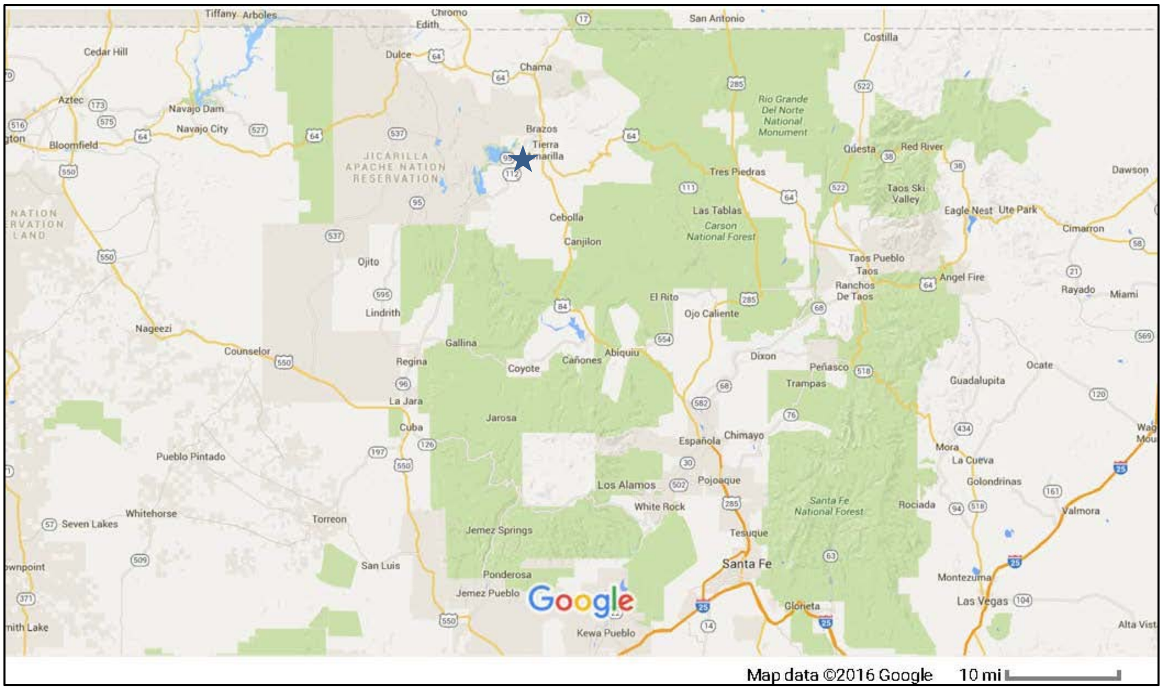

Figure 1 – Project Location Map

1.5 Project Team

Key staff responsible for the preparation of this report include:

Stephen Jamieson, P.E.	Principal-in-Charge
Todd Street, P.E., CFM	Project Manager
Todd Lewis, P.E.	Project Engineer
Ying-Kit Choi, Ph.D., P.E.	Technical Reviewer
John Treacy, P.E.	Cost Estimator
Danielle Hannes, P.E.	Calculations Review

2.0 BACKGROUND

2.1 Previous Studies

Information on the initial design and construction of Laguna Del Campo Dam is limited. A list of available design drawings and previous studies is presented below. There is no known geotechnical report addressing subsurface conditions, embankment seepage or stability for the dam. Detailed topographic site data is limited to mapping developed in the late 1930's during dam construction. Previous construction drawings are presented in Appendix A. Alternatives presented in this report were generally developed based on information obtained from the following documents:

- Drawing titled "Brood Pond No. 3, Parkview Fish Hatchery", Kenneth A. Heron, Engineer, July, 1937
- Drawing titled "Burns Canyon Dam", New Mexico Works Progress Administration, April 1938
- Drawing titled "Repairs to Brood Pond No.3 Spillway, Parkview Fish Hatchery, Rio Arriba County, New Mexico", Chambers Campbell, Isaacson, Chaplin, Inc. 1979.
- "Brood Pond Dam No.3, Rio Arriba County, NM, NM00313, Phase 1 Inspection report", Tierra Engineering Consultants Inc., September 1978.
- "Operation and Maintenance Manual, Laguna Del Campo Dam, OSE File NO. D313, Rio Arriba County, New Mexico", URS, July 2012
- "Laguna Del Campo Dam, OSE Filing No. D313, Breach Analysis, Rio Arriba County, New Mexico", URS, July 2012

2.2 Descriptions of Dam and Appurtenant Structures

The Laguna Del Campo Dam construction was completed in 1940 and the original concrete spillway was replaced in 1979. The 2015 NMOSE dam inspection classified the Dam as being in poor condition, primarily due to inadequate spillway capacity. The Laguna Del Campo Dam, also referred to as Brood Pond No.3, is classified as a small, high-hazard dam. In accordance with the NMOSE Rules and Regulations the dam spillway is required to pass runoff resulting from the Probable Maximum Precipitation (PMP) storm (NMOSE, 2010). The spillway is currently capable of passing approximately six percent of the PMP without overtopping the dam (URS, 2012).

The embankment is a zoned earth-fill structure with crest length of 500 feet and a maximum height of 36 feet. The dam embankment has an approximate 3H:1V (Horizontal: Vertical) upstream slope and 2H:1V downstream slope. The reservoir also has an approximate 1,030-foot long dike along its north side. Approximate crest elevations of both the dam and dike are 7,314[1]. feet (NAVD88).

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[1] All elevations are reported in feet above mean sea level based on the North American Vertical Datum of 1988.

At the spillway crest, the reservoir has a surface area of 10.8 acres and a storage volume of 99.6 acre-feet. The Laguna Del Campo Reservoir is separated into two pools by a dike running parallel to the dam near its upstream end. The upstream pond is significantly smaller and functions as a forebay to improve water quality of outflow from the Los Ojos Hatchery.

The dam outlet works consists of a concrete intake structure and a 150-foot-long, two-foot by two-foot square concrete outlet conduit. The outlet works is controlled by a slide gate mounted to the concrete intake. The gate operator is mounted to a 60-inch-diameter corrugated metal pipe and is accessed by boat. The outlet works gate is used infrequently and its current condition is unknown. We understand that an internal video inspection of the outlet works is scheduled to be completed by NMDGF later in 2016, however, the results of that inspection were not available for this report.

The spillway is an uncontrolled concrete structure located in the left (south) abutment of the dam and consists of an approach channel, compound weir and discharge channel. The approach channel is approximately 50-feet-long and concrete lined. The control section is a 28-foot-wide, concrete ogee weir with a crest elevation at 7,308.75. There is a four-foot-wide, low flow notch cut into the center ogee weir with crest elevation 7,308.15. The discharge channel is approximately 20 feet long and is also concrete lined.

The La Puente Ditch runs along the south side of the reservoir. Water is currently delivered to the ditch at two locations, outflow from the hatchery and a head gate located in in the reservoir spillway approach channel. The hatchery outflow is the primary source of water for the ditch. The spillway headgate is located on the left (south) side of the spillway, upstream of the spillway weir. The low flow notch in the spillway weir can be blocked with stop logs to increase flow diverted into the ditch.

An existing conditions site plan showing key features of the dam and reservoir is presented on Sheet 2 of the conceptual design drawings in Appendix B. Table No. 1, below, summarizes key data for the dam.

Table 1 – Key Laguna Del Campo Dam Data

Dam Feature	Key Data
Dam Crest Elevation	7,314
Main Dam Crest Length	500 feet
North Dike Crest Length	1030 feet
Maximum Embankment Height	36 feet
Dam Upstream Slope	3H:1V
Dam Downstream Slope	2H:1V
Dam Crest Width	13 feet
Downstream Outlet Works Invert Elevation	7,283
Outlet Works Capacity at Dam Crest	94.1 cubic feet per second
Spillway Low Flow Crest Elevation	7308.15
Spillway Outflow Weir Elevation	7308.75
Spillway Width	28 feet
Spillway Capacity at Dam Crest	1,185 cfs
Reservoir Capacity at Spillway Crest	99.6 acre-feet
Reservoir Surface Area at Spillway Crest	10.83 acres
Maximum Storage Capacity at Dam Crest	117.5 acre-feet
Reservoir Surface area at Dam Crest	19.05 acres
Drainage Area	5.75 square miles

Note: Data summarized from 2012 URS Breach Report

2.3 Existing Spillway Capacity

Spillway capacity at the dam crest elevation was estimated at 1,185 cfs in the URS breach report. A summary of the existing spillway elevation discharge relationship developed by URS is provided in Table No. 2 and Figure No. 2, as given below (URS, 2012).

Table 2 - Existing Emergency Spillway Stage-Discharge

Reservoir Stage[1] (feet)	Low Flow Discharge (cubic feet per second)	Spillway Weir Discharge (cubic feet per second)	Dam Overtopping Discharge[2] (cubic feet per second)	Total Discharge (cubic feet per second)
7308.15	0	0	0	0
7308.75	6	0	0	6
7309.00	10	11	0	21
7310.0	31	117	0	148
7311.0	59	284	0	343
7312.0	93	492	0	585
7313.0	132	736	0	868
7314.0	175	1,010	0	1,185
7315.0	221	1,313	4,627	6,161
7316.0	272	1,640	12,754	14,666
7317.0	325	1,990	24,176	26,491
7318.0	382	2,363	37,694	40,439

1) Stage discharge data from 2012 URS breach report
2) Dam overtopping discharge assumes dam does not fail due to overtopping

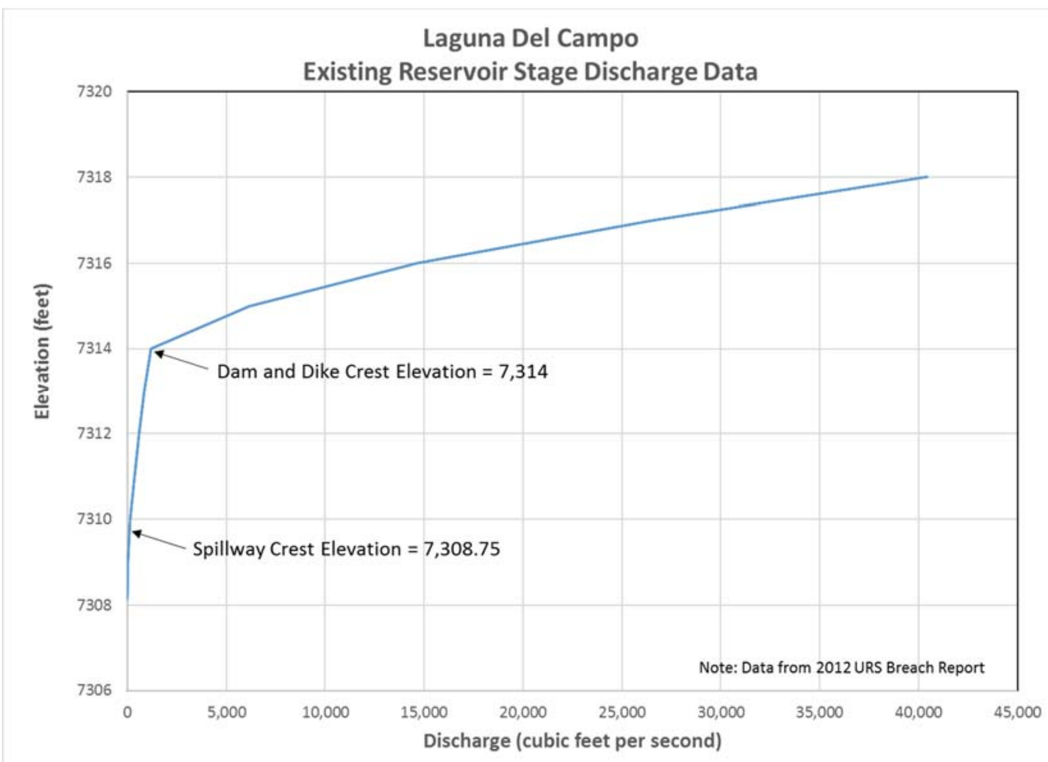

Figure 2 – Existing Spillway Discharge Curve

2.4 Reservoir Stage Storage Data

A reservoir stage-storage-area relationship based on the contours from the 1938 design drawing was developed in the URS Breach Report (URS, 2012). The stage-storage-area relationship used for Laguna Del Campo Reservoir flood routing is presented in Table No. 3 and Figure No. 3 below.

Table 3 - Reservoir Storage Data

Reservoir Elevation (Feet)	**Reservoir Area** (acres)	**Storage Volume** (acre-feet)
7283	0	0
7285	0.13	0.13
7290	1.00	2.95
7295	2.81	12.47
7300	5.13	32.33
7305	7.79	64.65
7309	10.83	99.56
7309	11.03	102.29
7314	19.05	177.49
7315	19.85	187.22
7315	20.66	197.34
7316	23.12	219.23
7320	33.00	331.48

Note: Stage-storage-area data from 2012 URS breach report

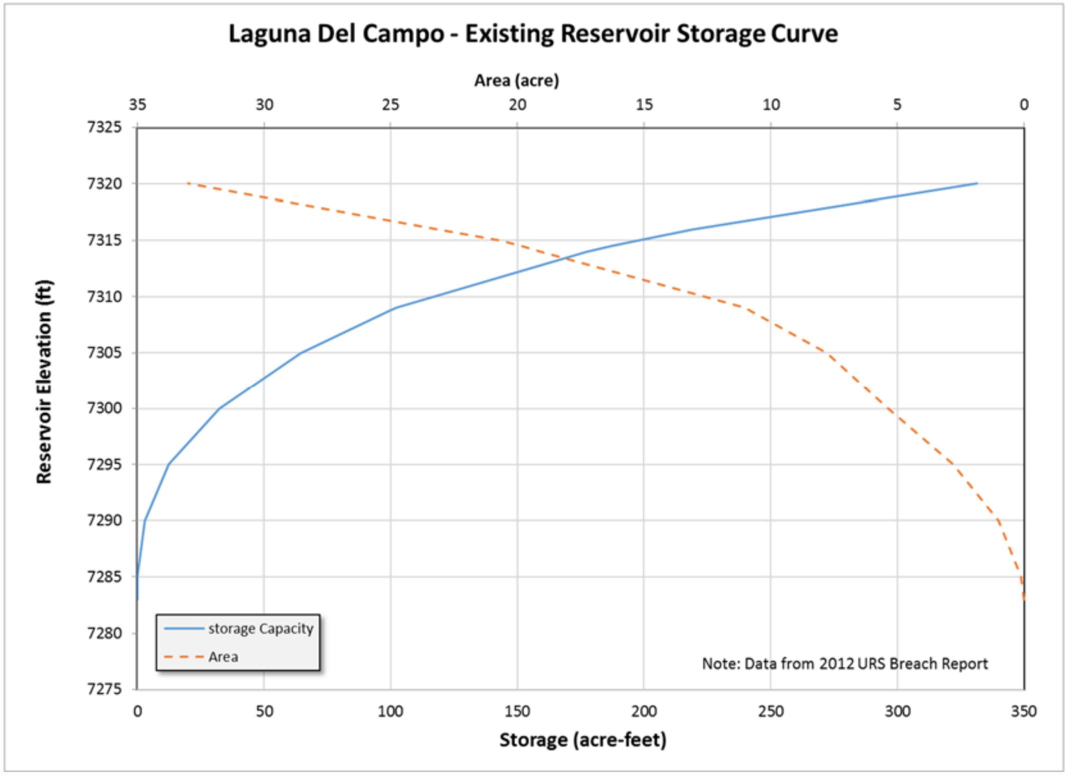

Figure 3 – Laguna Del Campo Stage-Storage-Area Cures

3.0 DATA COLLECTION

3.1 Vertical Survey Datum

A topographic site survey was not included in the current scope of work and a recent topographic site survey was not known to exist. Design drawings made in 1937, 1938 and 1973 were completed in a local site datum, placing the dam crest at local elevation 104 feet. Elevations used in this analysis are based on a converted local site datum. The conversion between the local datum and the North American Vertical Datum of 1988 (NAVD88) is: NAVD88 elevation = Local elevation + 7,210 feet. The datum conversion was determined by comparing one-third arc-second digital elevation model (DEM) of the Laguna Del Campo Dam, obtained from the United States Geological Survey (USGS), with reservoir contours taken from the 1938 “Burns Canyon Dam drawing” referenced above. Comparison of these two sources indicates the left abutment, immediately upstream of the dam, is at NAVD88 contour elevation 7,315 feet, corresponding to local datum contour elevation 105 feet.

The local site datum was converted to allow comparison of spillway tailwater calculations with dam structure elevations presented in the original design drawings. The elevations used in this analysis and report are approximate and represent the available site topographic data. Wheeler anticipates that the elevations may shift slightly when a complete topographic survey is performed as part of final design. Property boundaries shown on the drawings were provided by NMDGF.

3.2 Initial Site Visit

On March 15, 2016, Wheeler conducted a site visit to gain a better understanding of the dam and support development of rehabilitation alternatives. Wheeler staff were accompanied by staff from the NMDGF and a representative from the NMOSE. At the time of the visit, the reservoir was at the normal operating level set by the crest of the spillway weir low flow notch, approximately 7308 feet. Outflow through the reservoir notch was approximately one inch deep.

The existing spillway concrete was observed to be in very poor condition and water could be seen seeping into joints in the spillway floor. The outlet works gate was closed and NMDGF staff indicated it had not been exercised in several years. The downstream end of the outlet works was buried in sediment to the top of the outlet box. The operator and headgate leading from spillway to the La Puente Ditch was removed.

During the visit, NMDGF property boundaries and site constraints were identified in the field. The north property boundary is at the toe of the north dike and the downstream property boundary is located approximately 90 feet from the downstream toe of the dam. The south property boundary, on average, is located approximately 80 feet from the south shore of the reservoir. However, the La Puente Ditch follows the south bank in the space between the shore and property line and is separated from the reservoir by a berm. NMDGF indicated during the site visit that the proposed dam rehabilitation plan should maintain the La Puente Ditch alignment and capacity and that any improvements outside of the NMDGF property boundaries should not be considered. Based on the property boundary locations, it was determined that cost effective solutions to pass the full PMF without obtaining additional property would be limited.

It was observed that the north dike does not extend the full length of the reservoir. The dike stops approximately 600 feet from the upstream end of the reservoir. There is a low lying area at the north (right) edge of the property boundary. Based on field measurements with a hand level during the site visit, the low lying area is at an elevation of approximately 7,309, slightly higher than the spillway weir crest. The flood surcharge pool would not be contained to NMDGF property during significant storm events and may flow around the upstream end of the north dike onto private property. A photo of the low-lying area upstream of the north dike is provided on Photo 13 in Appendix F.

4.0 ANALYSIS

Analyses performed to develop dam rehabilitation alternatives are presented in the following sections. A summary of key design criteria is provided in Section 5.2 of the report.

4.1 Reservoir Inflow Hydrology

Reservoir inflow hydrology and modeling developed for the 2010 URS Breach Report was used for this study and is summarized in the following text. A complete description of hydrologic methods is presented in the 2010 URS Breach Report (URS, 2010).

The Laguna Del Campo dam watershed is approximately 5.75 square miles and is located entirely within the Tierra Amarilla Land grant. Elevations in the watershed range from 7,300 to 9,300 feet. The watershed is a mixture of undeveloped and agricultural land. Soils in the basin are predominantly Hydrological Soil Group Type D. An initial loss of zero inches and a weighted infiltration rate of 0.034 inches per hour were used in runoff calculations for all storms. A unit hydrograph was developed for the basin using methodology from the U.S. Bureau of Reclamation Flood Hydrology Manual (Cudworth, 1989). A summary of Laguna Del Campo Watershed parameters is presented in Table No. 4.

Table 4 - Laguna Del Campo Watershed Parameters

Parameter	Value
Drainage Area (square miles)	5.75
Length of Longest Watercourse (miles)	7.12
Distance to Basin Centroid (miles)	3.92
Watercourse Slope (feet / mile)	274.86
Average Weighted Manning's (K_n)	0.055
Lag Time (hours)	1.7

PMP precipitation distributions and depths were determined in the Breach Report using methods presented in HMR-55. The critical storm event for the site was determined to be the 6-hour Local PMP with a precipitation depth of 11.7 inches resulting in a peak reservoir inflow of 19,846 cfs and a storm volume of 3,588 acre-feet. The Local PMP storm was used to evaluate proposed spillway improvement alternatives considered in this report.

Only PMP storm events were evaluated in the Breach Report. Therefore, Wheeler used the existing Laguna Del Campo HEC-HMS model to determine runoff from frequency storm events to aid in evaluating potential rehabilitation alternatives and sizing ancillary structures. Precipitation depths and distributions for frequency storms were determined using procedures presented in NOAA Atlas 14 (NOAA, 2011). A summary of frequency storms and resulting runoff is presented in Table No. 5 and detailed calculations are presented in Appendix C1.

Table 5 - Summary of Frequency Storms

Recurrence Interval (years)	Duration (hours)	Depth (inches)	Peak Inflow (cubic feet per second)
2	24	1.48	1,393
10	24	2.13	2,048
50	24	2.87	2,795
100	24	3.22	3,148

4.2 Reservoir Routing and Spillway Hydraulics

4.2.1 Design Spillway Elevation Discharge

Spillway elevation discharge relationships for the alternatives were developed for broad crested and ogee weir configurations. Broad crested weirs were evaluated using the Narrow Broad Crested Weir equation presented in “Handbook of Hydraulics”, (Brater and King, 1963). Elevation discharge relationships for ogee weir configurations were calculated using equations presented in “Design of Small Dams, Third Edition”, (USBR, 1987). Discharge coefficients were calculated for each weir type based on piezometric head at the weir. Narrow broad crested weir coefficients ranged from 2.7 to 3.3 and ogee weir coefficients ranged from 3.7 to 4.0. Combined rating curves were developed for compound weirs. Spillway exit channel tailwater curves were developed in HEC-RAS V5.1 for spillway configurations including an exit channel chute. A summary of calculated spillway discharge capacity for each evaluated alternative is presented in alternative’s respective sub section of Appendix C.

4.2.2 Reservoir Routing

Reservoir routing was completed using the existing HEC-HMS Laguna Del Campo Hydrologic model developed by URS (URS, 2012). Maximum reservoir water surface elevations were calculated by replacing the existing spillway capacity curve with the capacity curve developed for each alternative and adjusting the rainfall depth and distribution to match the design storm. Basin area, runoff routing, rainfall loss, and the reservoir stage-storage relationship were left unchanged from the original HEC-HMS model. A summary of peak water surface elevations for each alternative is presented in Table No. 6. Reservoir routing calculations and HEC-HMS output for each evaluated alternative are presented in alternative’s respective sub section of Appendix C.

Table 6 - Summary of Peak Water Surface Elevations

Alternative	Peak Water Surface Elevation	Residual Freeboard (feet)	Peak Discharge (cubic feet per second)	Design Storm
Alternative 1[1]	--	--	--	N/A
Alternative 2	7301.0	1.0	3,139	100-year
Alternative 3a	7313.0	1.0	11877	60% PMP
Alternative 3b	7313.0	1.0	19875	100% PMP

1) Alternative 1 does not include a spillway

4.2.3 Energy Dissipation

Spillway stilling basins were sized for Alternative Nos. 2, 3a, and 3b using methods presented in "Hydraulic Design of Stilling Basins and Energy Dissipaters, Eight Edition", (USBR, 1984). Stilling basins were designed as Free Jump (USBR, Type I) stilling basins with an equivalent length to the overtopping section. Tailwater conditions in the downstream channel were calculated using a HEC-RAS model developed with cross-section geometry from the one-third arc second DEM topographic data referenced above in Section 3.1. Calculated sequent depths were compared to the calculated depth of tailwater in the outlet channel. If the sequent depth exceeds the tailwater depth, the stilling basin invert was lowered to create adequate tailwater depth. Stilling basin training wall height was set equal to the jump height at the peak IDF outflow. Energy dissipation calculations are presented in Appendix C4.

4.2.4 Dam Breach Calculations

For the dam breach alternative, the minimum breach width was determined using guidance published in the document "Guidance for Decommissioning U.S. Fish and Wildlife Service Low Hazard Dams", (FWS, 2015). The dam breach was extended to the natural ground elevation and was sized with a minimum width sufficient to pass the 100-year peak IDF discharge with a maximum flow depth increase of two feet upstream of the breach. Depth calculations were performed using a HEC-RAS model. Model geometry was developed using the one-third arc second DEM downstream of the dam, an assumed cross-section through the embankment, and pre-construction topographic data from the 1938 Burns Canyon Dam Drawing upstream of the dam. HEC-RAS model inputs and detailed output is presented in Appendix C2.

4.3 Preliminary Incremental Damage Assessment

A preliminary Incremental Damage Assessment (IDA) was completed to determine if reducing the reservoir Inflow Design Flood (IDF) may be possible and to determine if a complete IDA study was warranted during final design. The preliminary IDA was completed using the existing the Laguna Del Campo Breach Analysis HEC-HMS and FLO-2D models developed by URS (URS, 2012). PMP precipitation depths were reduced in 10 percent increments by scaling the distribution and the resulting reservoir inflows were determined (for each increment).

A dam breach hydrograph was developed using breach parameters presented in the 2010 URS Breach Analysis and assuming the dam would breach at the maximum water surface elevation resulting from each reduced PMP precipitation event. The resulting series of reduced PMP hydrographs was applied to the existing FLO-2D model.

The preliminary IDA compared downstream flow conditions under breach and no-breach scenarios to determine the incremental impacts of a dam breach on downstream flow conditions. Reservoir outflows were routed through the 2,500-foot-long drainage channel between the dam and the Rio Chama and approximately 13 miles downstream on the Rio Chama to El Vado Reservoir. A Rio Chama base flow of 1,450 cfs, equivalent to the peak flow from the 100-year, 24-hour storm, as reported by FEMA in the Rio Arriba County Flood Insurance Study, was used in the model (FEMA, 2012). Inflow from the Rio Brazos, which enters the Rio Chama approximately four miles downstream of the reservoir, was not considered in the evaluation. Evaluation criteria used for the preliminary IDA was to maintain less than a two-foot increase in maximum water surface elevation between breach and no-breach scenarios. The comparison was completed for each 10 percent increment of the Local PMP storm.

Results of the preliminary IDA indicate the Laguna Del Campo IDF can likely be reduced to approximately 60 percent of the local 6-hour PMP, resulting in a peak reservoir inflow of 11,860 cfs. At the 60 percent reduction there are two isolated areas within the Rio Chama that show an incremental depth increase of greater than two feet. However, these areas are generally undeveloped and are located within the Rio Chama regulatory floodplain. Under all breach scenarios, the undeveloped 2,500-foot-long drainage channel between the dam and the Rio Chama shows incremental increases of greater than 2-feet. Maps presenting the incremental depth increase for the 60-percent PMP are provided in Appendix D.

Based on this evaluation, it is Wheelers opinion that a full IDA is justified and would result in an approximate 40 percent reduction to the design storm. It should be noted that if spillway improvement were designed for the 60 percent of the PMP and a habitable structure were constructed in the 2,500-foot-long drainage immediately below the dam, the dam would again be out of compliance with NMOSE dam safety rules and regulations.

4.4 Residual Freeboard Calculations

Wave run-up calculations were completed to determine the minimum residual freeboard requirements for Laguna Del Campo. Wave run-up calculations were performed using the method published by the U.S. Bureau of Reclamation in ACER Technical Memorandum No. 2 (USBR, 1981). The resulting minimum residual freeboard requirement is 1.02 feet. A minimum of one foot of residual freeboard was used to develop alternatives presented in this report. Minimum freeboard calculations are presented in Appendix C5.

5.0 SPILLWAY REHABILITATION ALTERNATIVES

5.1 Overview of Alternatives

Laguna Del Campo Dam rehabilitation alternatives were developed through a collaborative process between NMDGF, FWS and Wheeler. Alternative development was focused primarily on correcting spillway deficiencies. Ancillary improvements, such as outlet works renovation and extension of the north dike were also considered in the alternatives analysis; however, they were not driving factors in alternative selection. Cost effective solutions for rehabilitating the spillway to pass the full PMP are limited due to the property boundary constraints and relative size of the IDF compared to the reservoir. The three primary alternatives considered to bring the Laguna Del Campo Dam into compliance with NMOSE dam safety rules and regulations are presented below:

1. Alternative No. 1 - Dam breach with constructed wetlands;
2. Alternative No. 2 - Lower the dam to remove it from NMOSE jurisdiction and provide a new spillway capable of passing the 100-year, 24-hour storm; and
3. Alternative No. 3a and 3b - Roller Compacted Concrete (RCC) overtopping spillways for both the 60 percent and 100 percent PMF.

5.2 Design Criteria

The design criteria used to develop rehabilitation alternatives were obtained from the "NMDGF Rules and Regulations Governing Dam Design, Construction and Dam Safety" (NMOSE, 2010) and through conversations with NMDGF. Key design criteria are presented below:

- The controlling Probable Maximum Flood is the Local Storm, 6 Hour PMP flood;
- Four feet of normal freeboard should be maintained between the spillway crest and dam crest;
- Maintain one foot of residual freeboard above the maximum water surface during design storm;
- Improvements must be contained within NMDGF property. Easements outside of NMDGF property should not be considered because it would be nearly impossible to identify all fo the land owners in this part of New Mexico;
- Design storm flood surcharge must be contained to NMDGF property;
- Maintain the existing La Puente Ditch capacity and alignment;
- Maintain the diversion from the reservoir to the La Puente Ditch;
- Limit any permanent normal operating pool reductions to four feet (EL. 7,304.75), where applicable; and
- Assume major rehabilitation of the outlet works.

Information relating to allowable maximum reservoir construction drawdown or maintenance of storage water rights could not be provided by NMDGF for consideration in this study.

5.3 Alternatives Eliminated from Consideration

A "No Action" Alternative was not a viable alternative for this project. The Laguna Del Campo Spillway is currently capable of passing approximately six percent of the IDF without overtopping, creating an unacceptable level of risk and causing it to be out of compliance with the NMOSE Rules and Regulations. The scope of work for this study is to develop dam rehabilitation alternative that will bring the dam into compliance with the NMOSE rules and regulations.

Alternatives removed from consideration due to cost, constructability or maintenance concerns are summarized below:

1. **Full Height Labyrinth Spillway** – A full height labyrinth spillway would meet the challenging space constraints by efficiently passing the full PMF with a minimum effective weir length and eliminating the need for a chute or stilling basin. The design could also be scaled to pass either the 60 percent or 100 percent PMP event. Initial assessments of anticipated labyrinth spillway sizes and construction costs indicated the cost would significantly exceed what is considered feasible for this project given the relatively small reservoir storage volume.

2. **Side Channel Spillway** – A side channel spillway was considered on the left (south) abutment. For the 60 percent PMP design, the spillway's lateral weir would extend approximately 350 feet upstream from the dam along the south bank. Flow would then be routed into a 180-foot-long, concrete spillway chute with a Saint Anthony Falls-type stilling basin at the bottom. Due to the length of weir required, scaling the side channel spillway up to pass the full PMP would present significant constructability challenges including channel size downstream of the lateral weir and maintaining the La Puente Ditch alignment. Additionally, this alternative could result in unacceptable chute hydraulics and require a stilling basin excavation in excess of 20 feet deep at the toe of the dam. The required 350-foot weir width, complicated chute, and stilling basin excavation would result in a project cost that exceeds what is considered feasible for the project.

3. **Fuse gates or fuse plug spillway** – Fuse gates or a fuse plug spillway were initially considered as alternatives that would meet the site's space constraints. However, both would require extensive concrete construction that was considered cost prohibitive for this project. Additionally, they would require regular maintenance and the site is relatively remote with limited maintenance budget. Consequently, fuse gates and fuse plug spillways were removed from consideration.

5.4 Evaluated Alternatives

The primary alternatives evaluated in this study are described in detail below. Drawings for each alternative are presented in Appendix B and an opinion of cost for each alternative is presented in Appendix E.

<u>Alternative 1 - Dam Breach</u> – In Alternative 1, the dam would be decommissioned by constructing a 100-foot-wide breach in the embankment and converting the reservoir to a series of constructed wetland ponds. The breach would be excavated to natural grade elevation of approximately 7,278 and extend up to the dam crest elevation of 7,314 at a 3H:1V slope. The minimum required bottom width of the breach is approximately 100 feet. A 100-foot breach width meets FWS criteria to maintain a water surface elevation increase of less than 2 feet, when compared to the estimated flow depth with no dam in place (FWS, 2015). A 15-foot-wide, two-foot-deep low-flow channel would be provided through the breach. The low-flow channel would have a slope of 0.5 percent and would be armored with soil filled riprap. Breach width calculations are provided in Appendix C2.

The existing outlet works would be removed to allow for construction of the breach. When the dam is breached the existing spillway would no longer serve a purpose. The concrete would be removed and the excavation would be backfilled with excess soil cut from the dam breach. The existing La Puente Ditch headgate, located in the existing spillway would no longer function once the dam is breached. Accommodations would need to be made to allow for the diversion upstream of the reservoir in the ditch system.

The reservoir area would be converted to a system of four constructed wetland ponds providing a total wetland area of approximately 5.3 acres. Three of the wetland ponds would be created by constructing berms in the reservoir and the fourth pond would be created by modifying the outlet of the existing forebay pond upstream of the reservoir. The berms would be constructed with excavated soil from the dam breach and within the reservoir. Berms would have 3H:1V and 4H:1V upstream and downstream slopes, respectively. Berm heights would have a maximum height of six feet upstream and 12 feet downstream. Excavation would be required within the ponds to provide a relatively level bottom, and allow a uniform water depth of approximately one foot across the wetland. Six inches of topsoil would be placed on the bottom of the wetlands to allow for establishment of vegetation. Each pond would be provided with a low-level outlet to control the water surface and provide a means to drain the wetland. Low-level outlets would consist of a stop log arrangement mounted in a concrete outlet which could be used to maintain a constant water surface elevation in the ponds. Each pond would also be provided with a 50-foot-long, three-foot-deep grouted riprap overflow spillway. Conceptual design drawings for Alternative 1 are shown on sheet nos. 5 and 6 in Appendix B.

<u>Alternative 2 – Lower the Dam</u> – In Alternative 2, the dam height would be reduced from 36 feet to 25 feet to remove it from NMOSE Jurisdiction and a new spillway capable of passing the 100-year, 24-hour storm would be provided. The NMOSE Rules and Regulations state that the dams with less than 50 acre-feet of normal storage or a height lower than 25 feet are non-jurisdictional. Although dam safety would remain a primary consideration, the dam would not be regulated by NOMSE and the spillway would no longer need to be capable of passing the full PMP storm. The maximum reservoir storage capacity at elevation 7,302, the proposed Alternative 2 dam crest elevation, is approximately 46 acre-feet.

Operational storage capacity with the new configuration would be controlled by the crest elevation of a new spillway. An 85-foot-wide spillway with crest elevation 7,296 would convey the 100-year, 24-hour storm with one foot of residual freeboard. The new spillway would be configured with a two-foot-high control sill and concrete approach and discharge channels. It would be located in approximately the same location as the existing spillway. A normal operating water surface elevation of 7,296 corresponds to a storage volume of 16.4 acre-feet.

Alternative 2 would reduce the normal operating water surface elevation and therefore require relocation of the La Puente Headgate upstream of the reservoir, similar to what would be required with Alternative 1. The condition of the outlet works is currently unknown and this report assumes that significant outlet works rehabilitation would be required. Based on available information, the anticipated outlet works rehabilitation would consist of slip lining the existing two-foot by two-foot concrete conduit with a 20-inch-diamater, HDPE pipe and grouting the annular space and replacing the existing outlet works headgate. Because Alternative 2 would reduce the normal operating water surface elevation, the outlet works gate operator and CMP riser would require modification.

The existing forebay pond at the upstream end of the reservoir would be converted to a wetland pond by adding a low-level outlet to provide control of the water surface elevation and providing an overflow spillway, similar to the concept presented with Alternative 1. Conceptual design drawings for Alternative 2 are shown on sheet nos. 7 and 8 in Appendix B.

<u>Alternative 3 – RCC Overtopping Spillway</u> – In Alternative 3, an overtopping roller compacted concrete (RCC) spillway and stilling basin would be constructed to replace the existing spillway. Overtopping spillways were evaluated for both the 60 percent PMP (Alternative 3a) and full PMP (Alternative 3b) storms.

The 60-percent PMP design (Alternative 3a) requires a 493-foot-wide, vertical faced ogee weir crest at elevation 7309.75 and provides one foot of residual freeboard above the maximum water surface. There would be a two-foot-deep, 50-foot-wide, low-flow notch at an invert elevation of 7307.75. The 60-percent PMP design permanently reduces the existing normal operational water surface elevation by one foot to 7307.75 and is 0.4 feet lower than the existing spillway stoplog notch.

The full PMP design (Alternative 3b) requires a 361-foot-wide vertical faced ogee weir crest at elevation 7306.75 and provides one foot of residual freeboard above the maximum water surface. There would be a two-foot-deep, 50-foot-wide, low-flow notch at an invert elevation of 7304.75. The full PMP design would result in a permanent four-foot reduction to the normal operating water surface, which would result in a permanent normal storage reduction of 26 acre-feet.

For both alternatives a reinforced concrete approach slab with upstream cutoff wall would be provided. RCC chutes were designed with two-foot-high, eight-foot-long RCC steps at a 2.5H:1V slope. A 24-inch-thick drain and filter layer is provided below the RCC. RCC steps would also be placed perpendicular to the dam crest at a 2.5H:1V on the spillway side slopes. The RCC spillways would require a stilling basin at the toe of the chute. Stilling basins for the 60 percent and full PMP alternatives would be 50 feet and 90 feet long, respectively. Each stilling basin would have cutoff wall at its downstream end.

Under both RCC overtopping alternatives the outlet works would be rehabilitated by slip lining the existing two-foot by two-foot concrete conduit with a 20-inch-diameter, HDPE pipe and grouting the annular space and replacing the existing outlet works headgate. The RCC alternatives would also require extending the north dike by approximately 700 feet to the upstream end of the reservoir at an elevation of 7,314. The existing La Puente headgate, located in the existing spillway, would be relocated to a point approximately 100 feet upstream of its current location. Because the full PMP alternative requires reducing the reservoir's operating water surface elevation, it may not be possible to relocate the La Puente headgate in the reservoir. Information sufficient to determine the headgate operability with a reduced water surface was not available at the time of this study. Under the full PMP configuration it may be necessary to address the La Puente Ditch diversion at a point upstream of the reservoir. Conceptual design drawings for Alternatives 3a and 3b are shown on sheet nos. 8 through 14 in Appendix B

A summary of the primary alternatives discussed above is presented in Table No. 7.

Table 7 - Summary of Primary Alternatives

Alternative	**Crest / Breach Elevation** (feet)	**Normal Operating WSEL** (feet)	**Normal Storage** (acre-feet)	**Design Storm**
Alternative 1 - Breach	7,278	N/A	N/A	N/A
Alternative 2 - Lower Crest	7,302	7,294	16.4	100-yr, 24-hr
Alternative 3a - 60% PMP RCC	7,314	7,307.75	99.6	60% PMP
Alternative 3b - 100% PMP RCC	7,314	7,304.75	63.0	100% PMP

6.0 OPINIONS OF PROBABLE COST

6.1 Cost Development Approach

Wheeler developed feasibility-level opinions of probable project cost for the three primary alternatives for rehabilitation of Laguna Del Campo Dam. Wheeler's opinions of probable project cost are reasonably conservative and considered to be equivalent to a Class 3, feasibility level budget opinion (AACE, 1997). As project planning and the final design develops the project budgets can change significantly due to the final configuration of the project and other unforeseen issues. The potential for these changes should be considered during planning and budgeting phases.

Preliminary construction quantities and a preliminary project construction bid tab and project budget opinion were developed for the three primary alternatives. These direct construction cost opinions were developed in 2016 construction dollars. Construction after 2016 is expected to increase in cost. To approximate future costs, the opinions of project cost presented in this report should be increased by a minimum of three percent annually for each year after 2016. The indirect project costs include budgets for non-construction items that are required to complete the project, such as design engineering; a construction change order contingency; permitting, legal and administrative costs; and construction administration and engineering. A summary of the opinion of probable direct construction and indirect project costs for each alternative is provided in Table No. 8. A summary of the key elements in the direct construction costs is provided in Table No. 9. A summary of the key elements in the indirect project costs are provided in Table No. 10. Additional details of Wheeler's feasibility-level opinion of probable project costs are provided in Appendix E.

Table 8 - Opinion of Primary Alternatives Probable Project Cost

Item Description	Alternative 1	Alternative 2	Alternative 3a	Alternative 3b
	Dam Breach	Lowered Dam	60% PMP RCC Overtopping	100% PMP RCC Overtopping
Direct 2016 Construction Costs	$1,305,000	$1,723,600	$5,595,500	$5,596,600
Indirect 2016 Construction Costs	$480,000	$731,000	$2,128,000	$2,128,000
Total 2016 Construction Costs	**$1,785,000**	**$2,454,600**	**$7,723,500**	**$7,724,600**

6.2 Direct Construction Opinions of Cost

The key work elements that were developed to prepare the direct construction cost opinion are summarized as follows:

1. Preparatory work including mobilization, stormwater management, clearing and grubbing, and construction dewatering;
2. Earthwork including wetland topsoil, bedding, riprap, excavation, and general fill;

3. Existing spillway demolition and reconstruction;
4. Outlet works rehabilitation or removal;
5. Miscellaneous items; and
6. Unlisted Items.

Unlisted items were estimated at 15 percent of the direct construction cost. Unlisted items are included to provide a contingency for additional design features that are typically included in the final design work scope that cannot be identified at this stage of project development. Construction contractor mobilization, bonds, general conditions administration, and insurance were estimated at approximately 10 percent of the direct construction cost. Table 7 provides a summary of the direct construction cost. A detailed listing of the anticipated construction items is provided in Appendix E. The opinions of probable direct construction costs are reported in 2016 dollars.

Table 9 – Primary Alternatives Direct Construction Costs Summary

Item Description	Alternative 1	Alternative 2	Alternative 3a	Alternative 3b
	Dam Breach	Lower Dam	60% PMP RCC Overtopping	100% PMP RCC Overtopping
Prepatory Work	$238,000	$190,600	$503,600	$507,600
Earthwork	$665,500	$102,500	$906,400	$996,000
Service Spillway	$23,000	$1,060,000	--	--
RCC Overtopping	--	--	$3,347,000	$3,254,500
Outlet Works	$15,000	$95,500	$95,500	$95,500
Miscellaneous Items	$193,500	$50,000	$13,000	$13,000
Unscheduled Items	$170,000	$225,000	$730,000	$730,000
Direct Construction Costs Subtotal	**$1,305,000**	**$1,723,600**	**$5,595,500**	**$5,596,550**

6.3 Indirect Project Opinions of Cost

A summary of the development of the indirect project cost elements is provided below.

1. **Construction Contingency -** A change order contingency equivalent to 15 percent of the opinion of probable direct construction cost total was included. This change order contingency is included to address changes to construction quantities or unexpected changes that normally occur during a large heavy civil construction project.

2. **Final Design Engineering -** Final design engineering was assumed to be eight percent of the direct construction cost and would include the preparation of detailed construction drawings, construction specifications, and a design summary report

that documents the engineering analysis completed to support the design. These design documents will require review and approval by the New Mexico Office of the State Engineer.

3. **Topographic Survey –** A budget was estimated to include a complete site topographic survey, necessary for final design. This would include topographic mapping of the site, identification of property boundaries, and installation of a site benchmark.

4. **Geotechnical Investigations -** A budget was estimated to include subsurface investigations to refine the final design. This would include geotechnical borings to better quantify embankment and foundation conditions. It would also include laboratory testing to characterize imported borrow fill materials and additional stability analysis of the dam, where required.

5. **Permitting and Administrative Costs -** A contingency equivalent to approximately five percent of the direct construction cost was included in the project budget to cover permitting costs, such as obtaining a 404 permit from the U.S. Army Corps of Engineers. This contingency also includes other required construction permits, legal costs, and other NMDGF administrative costs to complete the project.

6. **Construction Administration and Engineering -** The construction administration and engineering costs were estimated as 10 percent of the sum of the direct construction cost plus the change order contingency. This budget would include the following activities that are normally required by the New Mexico Office of the State Engineer, including:

    a. On-site resident engineering and preparation of daily construction reports;
    b. Materials testing;
    c. Routine progress meetings and preparation of meeting summaries;
    d. Monthly progress reports with photos and construction test results;
    e. Review and approval of contractor's monthly payment requests;
    f. Review of construction change orders;
    g. Responses to contractor requests for information (RFI);
    h. Preparation of a final construction report; and
    i. Preparation of Record Drawings to document the "as-built" condition of the project.

Table 10 – Primary Alternatives Indirect Project Costs Summary

Item Description	Alternative 1	Alternative 2	Alternative 3a	Alternative 3b
	Dam Breach	Lower Dam	60% PMP RCC Overtopping	100% PMP RCC Overtopping
Construction Contingency	$170,000	$225,000	$730,000	$730,000
Final Design Engineering	$104,000	$138,000	$448,000	$448,000
Final Design Subsurface Geotechnical Investigations	--	$100,000	$100,000	$100,000
Survey	$10,000	$10,000	$10,000	$10,000
Permitting and Administrative Costs	$65,000	$86,000	$280,000	$280,000
Construction Administration and Engineering	$131,000	$172,000	$560,000	$560,000
Indirect Project Costs	**$480,000**	**$731,000**	**$2,128,000**	**$2,128,000**

7.0 ALTERNATIVE COMPARISON

It is Wheeler's opinion that breaching the dam, Alternative 1 addresses the dam safety concerns at Laguna Del Campo by simply breaching the dam. Alternative 2, lowering the dam, would result in a 16.4-acre-foot reservoir. Because Alternative 2 requires constructing a new spillway to convey the 100-year, 24-hour storm, it is still a relatively expensive rehabilitation alternative. The Alternative 2 cost per acre-foot is approximately $149,650. Alternative 3 provides the most cost effective option to pass the full IDF. However, the costs for both Alternative 3 RCC configurations may significantly exceed the value of water stored in the reservoir. The cost per acre foot for Alternatives 3a and 3b are approximately $77,550 and $122,610 respectively. A comparison of the primary alternatives is presented in Table No. 10.

Table 11 – Primary Alternatives Comparison

Parameter	Alternative 1	Alternative 2	Alternative 3a	Alternative 3b
Maintains Existing Storage Capacity			X	
Permanently Reduced Storage Capacity		X		X
No Storage	X			
Pass the full PMF				X
Created Wetlands	X	X		
Remove / Abandon Existing Spillway	X	X	X	X
Outlet Works Rehabilitation		X	X	X
Relocate La Puente Ditch Headgate in Reservoir			X	X
Relocate La Puente Ditch Diversion Upstream of Reservoir	X	X		
Upstream Dike Extension			X	X
Remove Dam from NMOSE Jurisdiction	X	X		

During the alternatives draft report review workshop, NMDGF indicated they prefer Alternative 2, lowering the dam. While the Alternative 2 cost per-acre-foot is relatively high, Laguna Del Campo is highly valued by the local community as a recreational resource and it is one of the few restricted use fishing ponds in the state. The cost per acre-foot of water storage may not reflect the entire value of the reservoir to NMDGF. Maintaining angling opportunities for youth and senior citizens at Laguna Del Campo is a priority for NMDGF. Alternative 2 would maintain a fishing pond while allowing for the creation of some wetland ponds.

8.0 DESIGN AND CONSTRUCTION CONSIDERATIONS

8.1 Design Considerations

The analyses and alternative designs for this study were performed with limited data and site information. Reasonably conservative assumptions were made regarding topographic data, subsurface soil conditions, material characteristics, existing ground topography under the reservoir, and as-constructed configurations of the dam and appurtenant structures. For final design, additional data will be needed. The following is a list of key issues that should be addressed during final design:

1. **Subsurface conditions –** Geotechnical data was not available for the site. A site subsurface investigation should be conducted to determine the depth to bedrock, depth to natural grade below the embankment, embankment / foundation material properties and general site subsurface conditions. Geotechnical laboratory testing should be conducted on samples obtained from the geotechnical borings.

2. **Topographic Survey –** Reliable topographic data is not available for the site. Designs presented in this report are generally based on hand drawn contours from the 1938 dam design drawings and USGS one-third arc-second DEM topography. A detailed site topographic survey should be completed prior to initiating final design.

3. **Water Rights –** Breaching the dam would have an impact on water rights associated with the Laguna Del Campo Reservoir and potentially the La Puente Ditch. A water rights assessment was not included in the scope of work for this study. Water rights of the reservoir and the impact of a breach should be fully understood prior to initiating final design of a dam breach.

4. **La Puente Ditch Diversion –** Alternatives 1, Alternative 2, and potentially Alternative 3b, would render the existing La Puente Ditch diversion inoperable due to the lower reservoir water surface elevations. The diversion would need to be relocated to a point upstream of the reservoir in the ditch system.

5. **RCC Batch Plant** – Alternative 3 would require producing large quantities of RCC and an RCC batch plant would likely be required. The batch plant could likely be set up at the nearby gravel pit located approximately 0.5 mile from the site.

6. **Wetland Mitigation Credits –** A strong potential exists to obtain wetland mitigation credits for creation of wetlands at the Laguna Del Campo site. The wetland credits could be used to offset wetland disturbance by NMDGF at other sites. An assessment should be competed in advance of the project to determine additional requirements and how to maximize the potential wetland mitigation credits.

7. **Wetland delineation –** The area near the natural channel at the toe of the dam appears to contain wetlands that would likely be impacted by construction of a breach and the RCC overtopping alternatives. A wetland delineation should be completed for the site and included in the site topographic survey.

8.2 Construction Considerations

1. **Staging and Stockpile Area –** Limited space exists on site for material staging and stockpiles. However, the Los Ojos Fish Hatchery is located approximately 0.5-miles north of the dam. A nearby staging area should be identified on property owned by NMDGF.

2. **Sediment Management –** One of the key construction considerations for a dam breach will be sediment management. A sediment management plan should be developed prior to construction.

3. **Construction Timing –** Time should be allowed between reservoir dewatering and construction to allow saturated soils and sediment in the bottom of the reservoir to dry to a workable state.

9.0 LIMITATIONS

This Dam Safety Rehabilitation Alternatives Report for Laguna Del Campo Dam is based on generally accepted civil engineering practices in this area and is for the exclusive use of New Mexico Department of Game and Fish for Laguna Del Campo Dam. The analysis, cost opinions, conclusions, and recommendations documented in this report are based, in-part, on incomplete design and construction records, anecdotal information, analysis, and hydrologic modeling prepared by others. The information in this report may not reflect subsurface variations or actual conditions in the foundation, embankment, abutments, or along the outlet works system at Laguna Del Campo Dam. Construction cost opinions can be influenced by market forces, weather conditions, and other issues that are outside of our control. As a result, there is no expressed or implied warranty or guarantee of the information provided in this report. The members of the Wheeler engineering team are also not responsible for the liability associated with the interpretation of the information presented in this report by others.

10.0 REFERENCES

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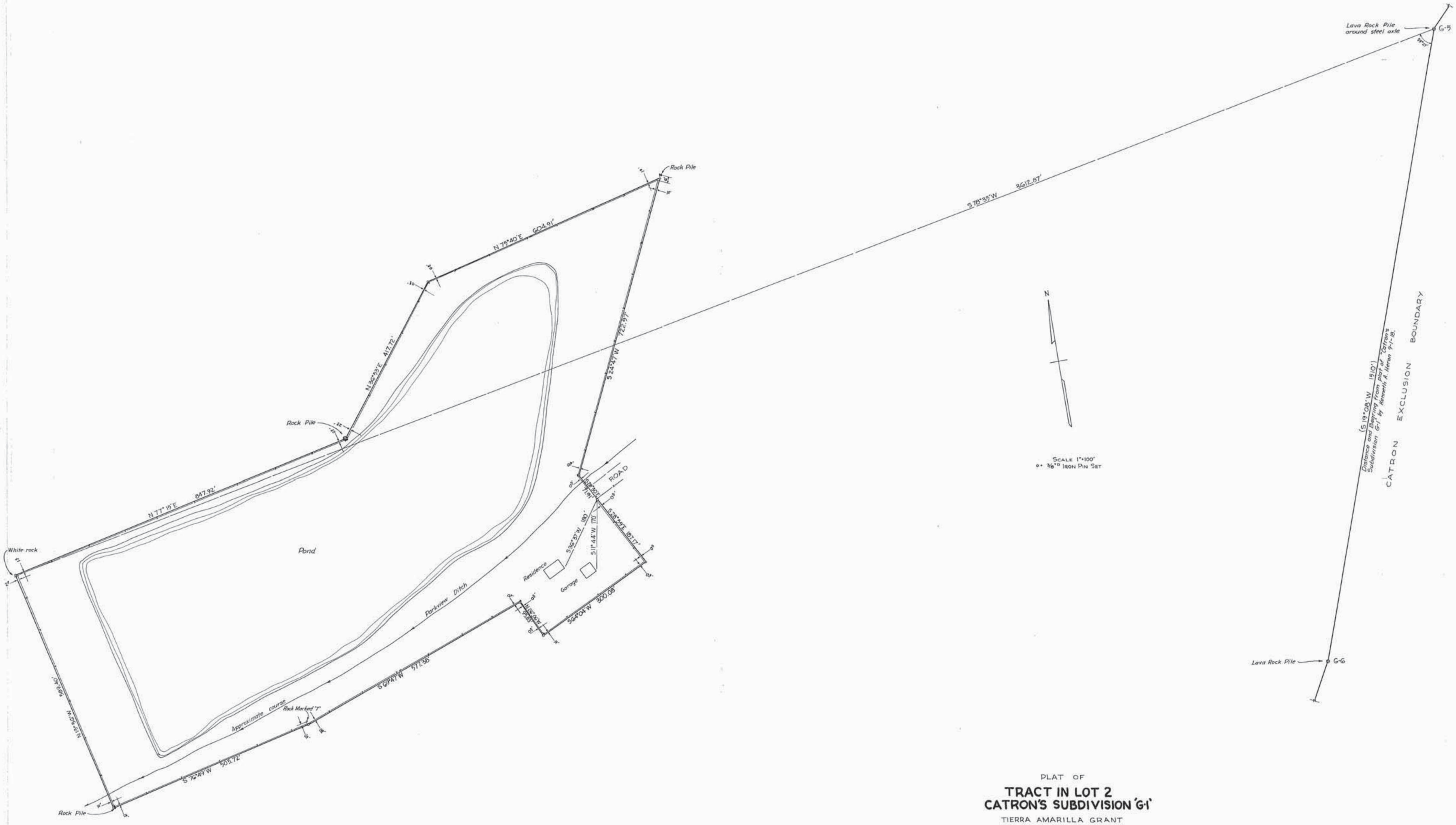
Appendix A

Previous Construction Drawings



PLAT OF

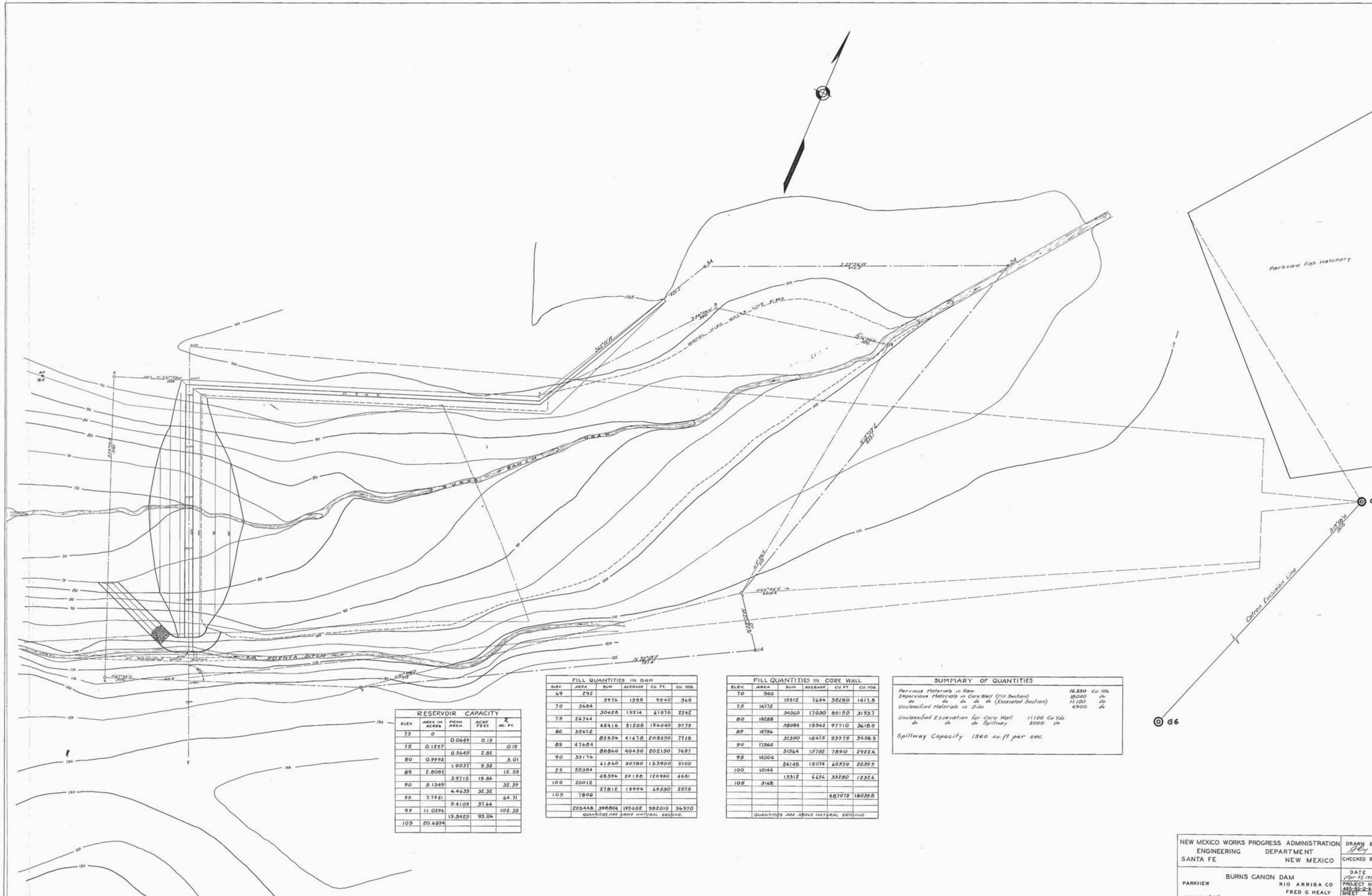
TRACT IN LOT 2
CATRON'S SUBDIVISION 'G-1'

TIERRA AMARILLA GRANT
RIO ARRIBA COUNTY, N.M.
CONTAINING 22.3691 A.

I hereby certify that I am a registered Professional Engineer and Land Surveyor and that this plat was prepared from notes of an actual field survey made under my direction and is true and correct to the best of my knowledge and belief.

[signature]

N.M. REG. NO. 162



RESERVOIR CAPACITY				
ELEV.	AREA IN ACRES	MEAN AREA	ACRE FEET	Σ AC. FT.
73	0			
		0.0649	0.19	
75	0.1297			0.19
		0.5645	2.82	
80	0.9992			3.01
		1.9037	9.52	
85	2.8082			12.53
		3.9715	19.86	
90	5.1349			32.39
		6.4635	32.32	
95	7.7921			64.71
		9.4109	37.64	
99	11.0296			102.35
		15.8425	95.06	
105	20.6554			

FILL QUANTITIES IN DAM					
ELEV.	AREA	SUM	AVERAGE	CU. FT.	CU. YDS.
69	292				
		3976	1988	9940	368
70	3684				
		30428	15214	61070	2262
75	26744				
		62416	31208	156040	5779
80	35672				
		83356	41678	208390	7718
85	47684				
		80860	40430	202150	7487
90	33176				
		61560	30780	153900	5700
95	28384				
		48396	24198	120990	4481
100	20012				
		27812	13906	69530	2575
105	7800				
	203448	398804	199402	982010	36370
	QUANTITIES ARE ABOVE NATURAL GROUND.				

FILL QUANTITIES IN CORE WALL					
ELEV.	AREA	SUM	AVERAGE	CU. FT.	CU. YDS.
70	540				
		15312	7656	38280	1417.8
75	14772				
		34060	17030	85150	3153.7
80	19288				
		38084	19542	97710	3618.9
85	19796				
		37350	18675	93375	3458.3
90	17560				
		31564	15782	78910	2922.6
95	14004				
		24148	12074	60370	2235.9
100	10144				
		13312	6656	33280	1232.6
105	3168				
				487075	18039.8
	QUANTITIES ARE ABOVE NATURAL GROUND				

SUMMARY OF QUANTITIES

Pervious Materials in Dam — 16330 Cu Yds.
Impervious Materials in Core Wall (Fill Section) — 18040 do
do do do do do (Excavated Section) — 11100 do
Unclassified Materials in Dike — 4500 do

Unclassified Excavation for Core Wall — 11100 Cu Yds.
do do do Spillway — 2000 do

Spillway Capacity 1360 cu. ft. per sec.

NEW MEXICO WORKS PROGRESS ADMINISTRATION
ENGINEERING DEPARTMENT
SANTA FE NEW MEXICO

BURNS GANON DAM
PARKVIEW RIO ARRIBA CO
FRED G HEALY
ADMINISTRATOR
SCALE 1"=50'

DRAWN BY Gley
CHECKED BY
DATE Apr 27, 1938
PROJECT NO 465-85-2-64
SHEET NO 1

F.P.-No.PV-8

APPLICATION No. 2181
RECEIVED
JULY 27, 1937
OFFICE OF STATE ENGINEER
SANTA FE, NEW MEXICO

CLAIMANT'S CERTIFICATE

STATE OF NEW MEXICO
COUNTY OF SANTA FE } ss:
I, Elliott S. Barker, being first duly sworn upon my oath state that I am the Secretary of the State Game Commission, duly organized under the laws of the State of New Mexico, that the foregoing map and statements were made under authority of the State Game Commission, and that I, in their behalf, have read and examined the foregoing statements and representations thereon and state that the same are true to the best of my knowledge and belief.

STATE GAME COMMISSION
Claimant.
By Elliott S. Barker
Secretary.

Subscribed and sworn to before me this 24th day of July, 1937
Minnie B. Carter
Notary Public
My commission expires June 3, 1939

ENGINEER'S CERTIFICATE

STATE OF NEW MEXICO
COUNTY OF RIO ARRIBA } ss:
I, Kenneth A. Heron, being first duly sworn upon my oath, state that I am the engineer who made the map of the Brood Pond No. 3, Parkview Fish Hatchery, and that such map was made from field notes taken from actual bona fide surveys made in the field byme, and from plans furnished by Geo. M. Neel, and that the same true and correct to the best of my knowledge and belief.

Kenneth A. Heron
Engineer.

Subscribed and sworn to before me this 20th day of July, 1937.
A.J. Barr
Notary Public.
My commission expires 2-1-40

STATE ENGINEER'S CERTIFICATE

STATE OF NEW MEXICO
COUNTY OF SANTA FE } ss:
I hereby certify that the above map and statements have been examined by me, and were duly accepted for filing on the 27 day of July 1937.
Thos. M. McClure
State Engineer.

The claimant, the State Game Commission, has caused to be located by a competent surveyor and engineer, the works shown hereon and makes these several statements relative thereto, and offers this map and statements for acceptance and for filing in compliance with the laws of the State of New Mexico:

1. The "6G" corner on the boundary of the Parkview Mesa Tract, Catron Exclusions, Tierra Amarilla Grant, bears N85°E 2450' from Sta. 6+50 on the ℄ of the proposed dam.

2. All of the lands shown hereon are on the Tierra Amarilla Grant, Rio Arriba County, N.M.

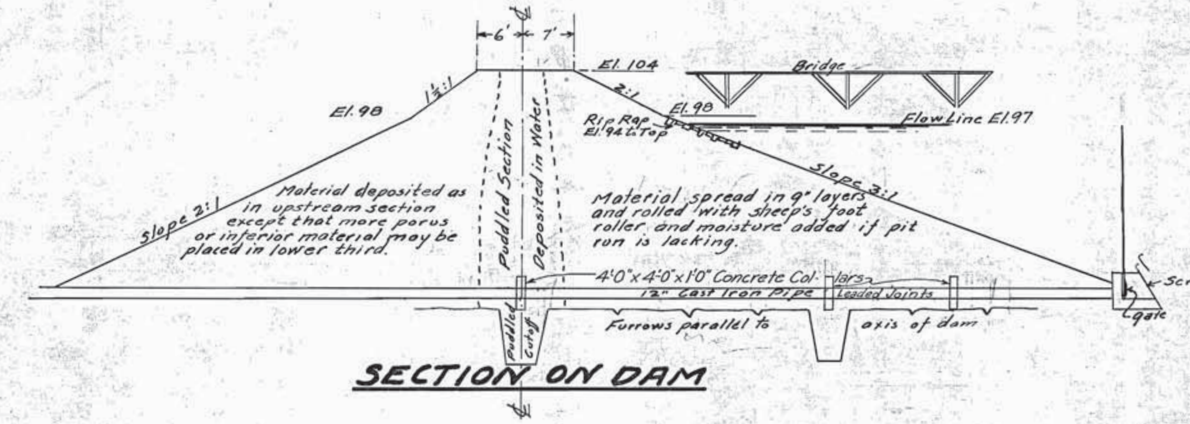
3. Maximum height of dam is 36.0';
Length of dam is 500';
Top of dam is 13.0 wide; bottom 190' wide;
Dam to be an earth fill;
Slopes to be as shown hereon;

4. Maximum storage capacity of 96.7 acre feet is hereby claimed continously, when there is an unappropriated supply of water to fill the reservoir.

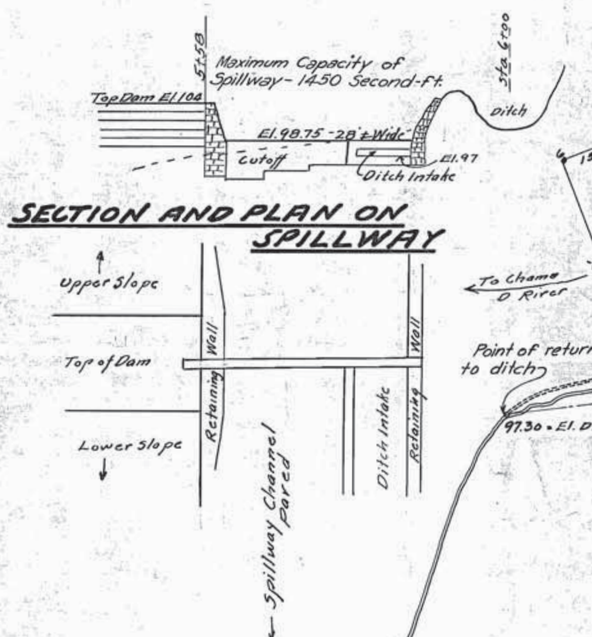
5. The cost of the works is estimated at $30,000.00;

6. Drain ditches 4' wide and 2' deep are proposed as shown hereon.

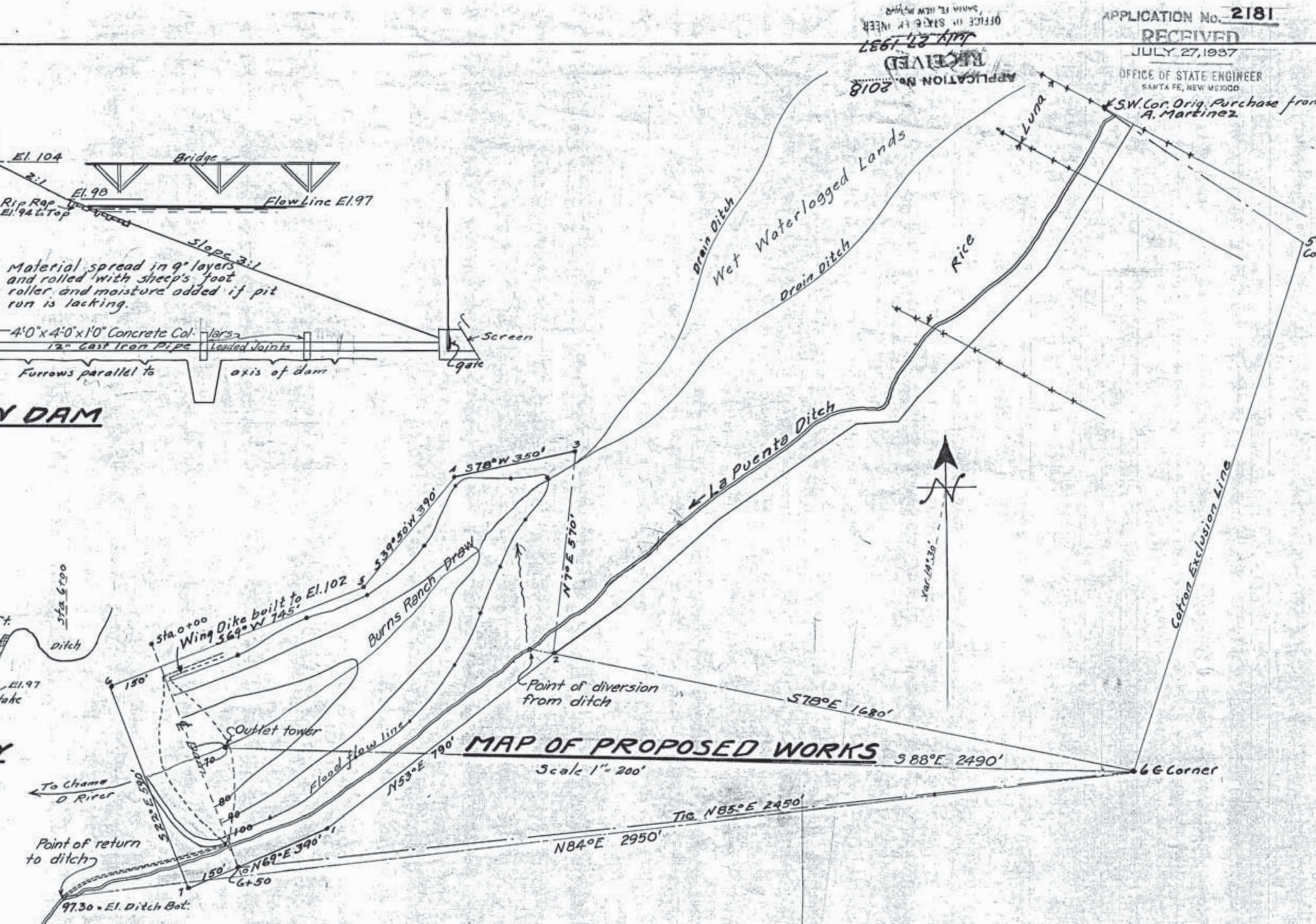
7. The pond or reservoir is to be used for fish breeding purposes.



SECTION ON DAM

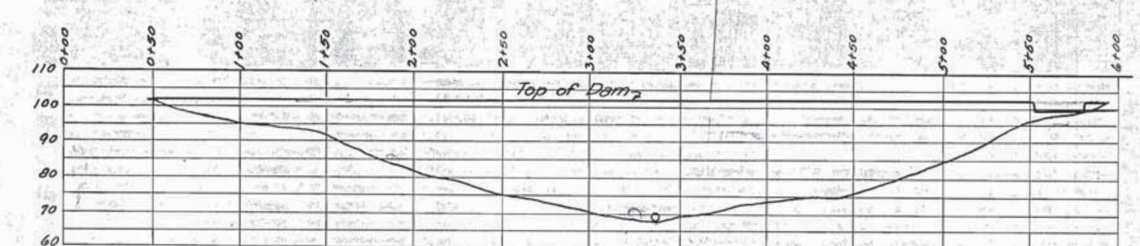


SECTION AND PLAN ON SPILLWAY



MAP OF PROPOSED WORKS

Scale 1" = 200'



PROFILE ON DAMSITE

Looking Upstream

8. The reservoir tract is to be acquired from the present owner, T. D. Burns.

9. Surplus water to the amount of 6.0 c.f.s. originating on the property of the claimant one half mile Northeast of the proposed pond is wasted into La Puenta Ditch. It is proposed to divert this into the pond and divert all surplus water back into the La Puenta Ditch.

10. Soil on Midsection of dam site is surface gravel underlaid at 2 ft depth with tight impervious clay. Walls of canyon mostly clay with some gravel imbedded in clay matrix.

APPLICATION No. 2181
RECEIVED
JULY 27, 1937
OFFICE OF STATE ENGINEER
SANTA FE, NEW MEXICO

Reservoir Contents

Elev.	Area acres	M.A.	Contents a.f.	Total Contents a.f.
70	0.2			
		1.1	11.0	
80	2.0			11.0
		3.8	38.0	
90	5.6			49.0
		6.8	47.7	
97	8.0			96.7
		8.8	26.3	
100	9.5			123.0

Map of
BROOD POND No. 3, PARKVIEW FISH HATCHERY
-of-
STATE GAME COMMISSION, APPLICANT
Located in Rio Arriba County, N. M.

Scale as Shown
July 20, 1937

Kenneth A. Heron
Engineer

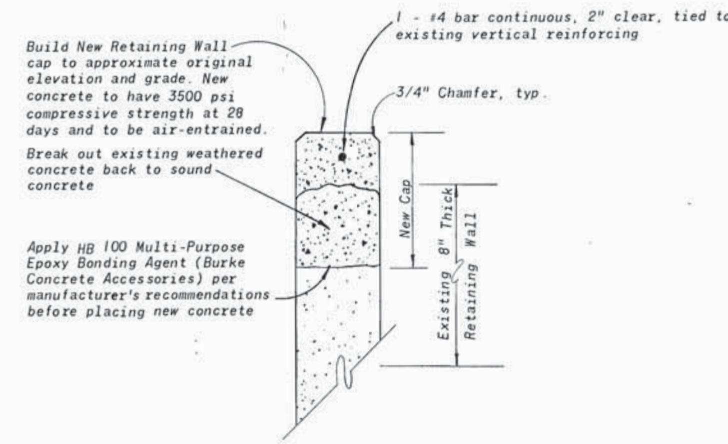
REPAIRS TO BROOD POND NO. 3 SPILLWAY

PARKVIEW FISH HATCHERY — RIO ARRIBA COUNTY, N.M.

NOTE: Fish Screen not shown.

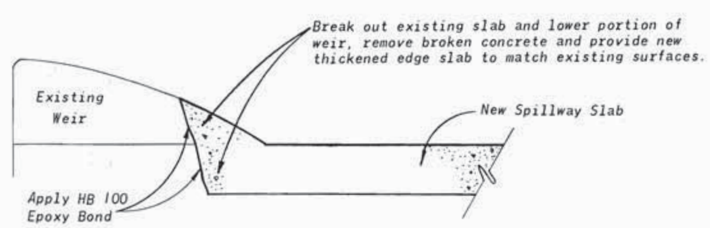
SCHEDULE OF QUANTITIES

Spillway Slab Concrete	12 cubic yards
Epoxy	60 gallons
Welded Wire Mesh	440 square feet
Expansion Joint Dowels	11 each



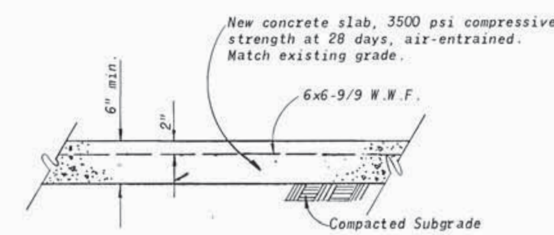
NEW RETAINING WALL CAP

1 1/2" = 1'-0"



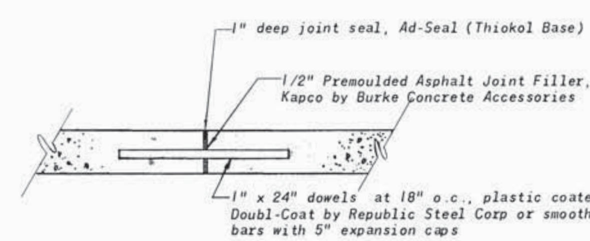
NEW SPILLWAY SLAB AT WEIR

No Scale



NEW SPILLWAY SLAB

1" = 1'-0"

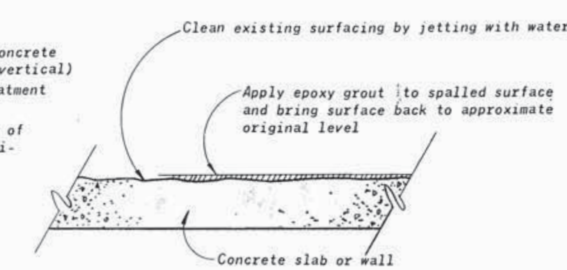


TYPE 'A' EXPANSION JOINT DETAIL

1" = 1'-0"

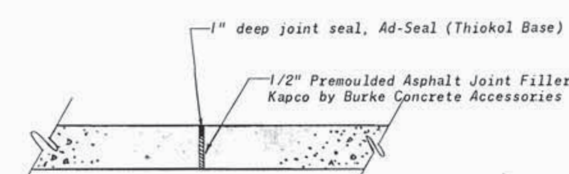
NOTES:

1. All existing distressed concrete surfaces (horizontal and vertical) shall receive surface treatment application.
2. Epoxy grout shall consist of Hunt Process, HB 100 Multi-Purpose Epoxy Bonding Agent mixed with sand with a minimum ratio of adhesive (epoxy) to aggregate of 1:4 by volume.



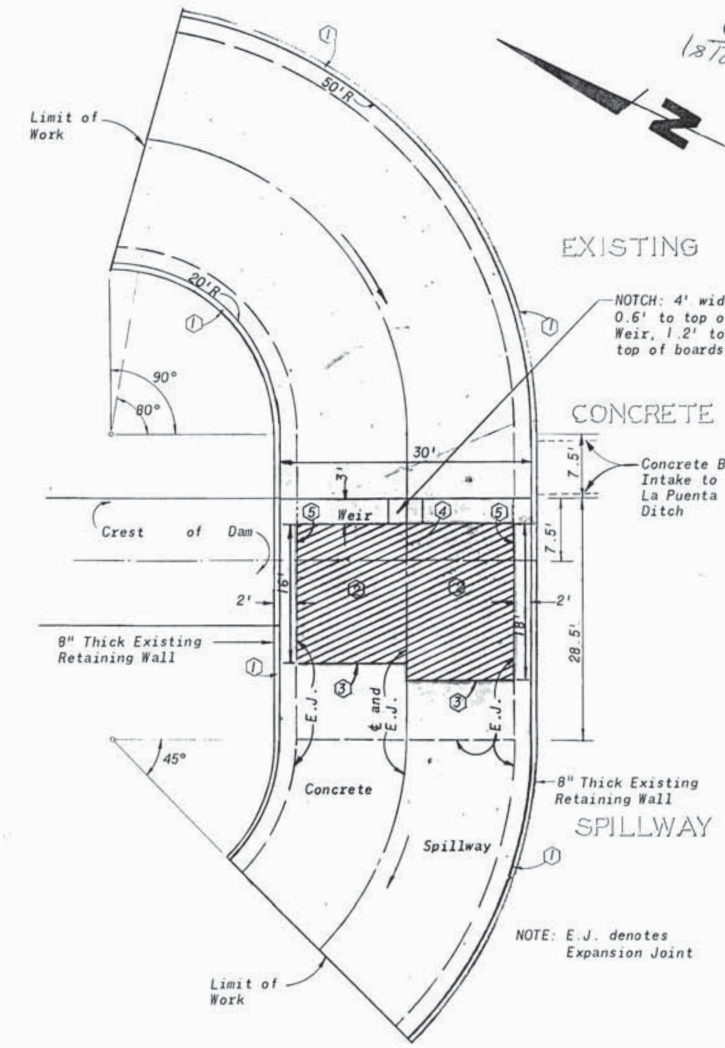
SURFACE TREATMENT DETAIL

No Scale



TYPE 'B' EXPANSION JOINT DETAIL

1" = 1'-0"



NOTE: E.J. denotes Expansion Joint

PLAN OF SPILLWAY

1" = 10'

1. Build new retaining wall cap - see detail this sheet.
2. Cross-hatched area indicates concrete slab to be removed and re-constructed per details this sheet.
3. Existing mortar filled construction joint to be westerly limits of new concrete slab.
4. Build Type 'A' Expansion Joint along spillway ℄.
5. Build Type 'B' Expansion Joint along retaining wall footing.

ENGINEER'S CERTIFICATE

STATE OF NEW MEXICO
COUNTY OF BERNALILLO

I, Thomas O. Isaacson, being first duly sworn upon my oath, state that I am a registered professional engineer, qualified in civil engineering and that the accompanying plans and specifications consisting of one sheet of plans was prepared under my supervision and direction.

License No. 3895

Thomas O. Isaacson
Registered Professional Engineer

Subscribed and sworn to before me this 9th day of July, 1979.
My commission expires: 11-22-81

Notary Public

CCIC Chambers Campbell Isaacson Chaplin, Inc.

JOB NO 379-4
DATE JUNE 1979
SHEET 1 OF 1

Appendix B

Conceptual Laguna Del Campo Rehabilitation Drawings

LAGUNA DEL CAMPO DAM

DAM REHABILITATION ALTERNATIVES

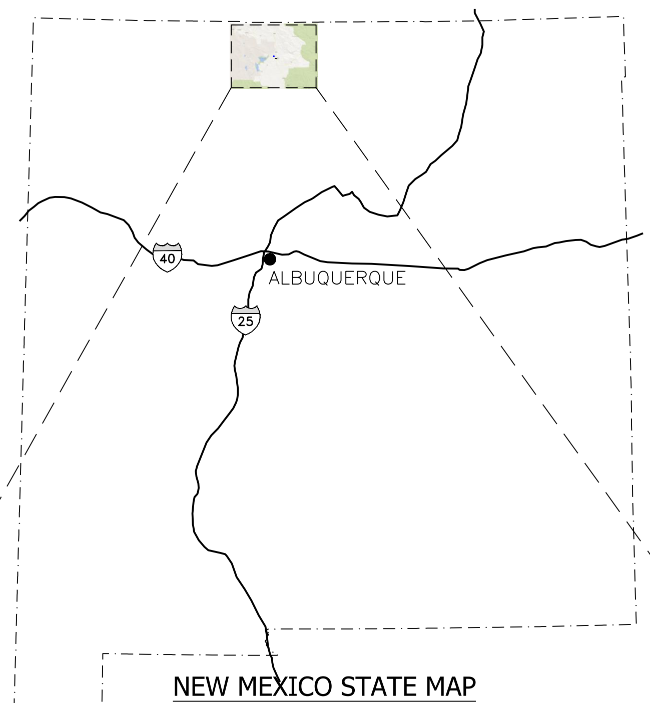
LOS OJOS FISH HATCHERY
RIO ARRIBA COUNTY, NEW MEXICO

PREPARED FOR:
NEW MEXICO DEPARTMENT OF GAME AND FISH
SANTE FE, NEW MEXICO

PREPARED BY:
W. W. WHEELER AND ASSOCIATES, INC.
3700 SOUTH INCA STREET
ENGLEWOOD, COLORADO 80110
(303) 761-4130

DRAWING INDEX

SHEET NO.	TITLE
1	COVER SHEET AND LIST OF DRAWINGS
2	EXISTING CONDITIONS SITE PLAN
3	EXISTING DAM PROFILE AND SECTION
4	OUTLET WORKS REHABILITATION
5	ALTERNATIVE 1 - DAM BREACH PLAN
6	ALTERNATIVE 1 - DAM BREACH PROFILE AND CROSS-SECTIONS
7	ALTERNATIVE 2 - REDUCED DAM CREST PLAN AND PROFILE
8	ALTERNATIVE 2 - REDUCED DAM CREST SPILLWAY PROFILE AND DAM SECTIONS
9	ALTERNATIVE 3A - 60% PMF RCC SPILLWAY SITE PLAN
10	ALTERNATIVE 3A - 60% PMF RCC SPILLWAY PLAN AND PROFILE
11	ALTERNATIVE 3A - 60% PMF RCC SPILLWAY SECTIONS AND DETAILS
12	ALTERNATIVE 3B - 100% PMF RCC SPILLWAY SITE PLAN
13	ALTERNATIVE 3B - 100% PMF RCC SPILLWAY PLAN AND PROFILE
14	ALTERNATIVE 3B - 100% PMF RCC SPILLWAY SECTIONS AND DETAILS



NEW MEXICO STATE MAP
(N.T.S.)

LOCATION MAP

0 2 5 10
Scale in Miles

DAM LOCATION MAP

0 1000 2000 4000
Scale in Feet

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NO.	DATE	MADE	CHECKED	REMARKS

REVISIONS

SHEET NO.	DRAWING NO.	TITLE

REFERENCE

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W. W. WHEELER & ASSOCIATES, INC
Water Resources Engineers
3700 S. INCA STREET | ENGLEWOOD, CO 80110-3405
303-761-4130 | FAX 303-761-2802

LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
COVER SHEET
AND LIST OF DRAWINGS

CLIENT: NEW MEXICO DEPT. OF GAME AND FISH			
DESIGN	TSS	05/16	WHEELER NO. 1772.16.00
DRAWN	SAA	05/16	
CHECK	SLJ	05/16	SHEET NO. 1 OF 14
PLOT DATE 05/24/2016	X		DRAWING NO. 11X17

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Reference Sheet No.	Drawing No.	Title

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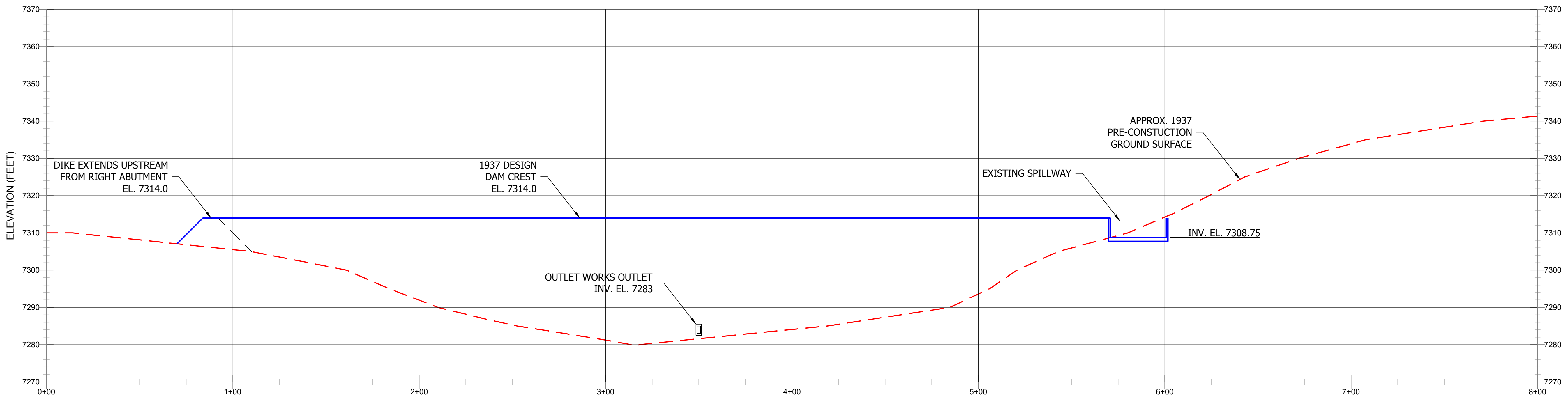
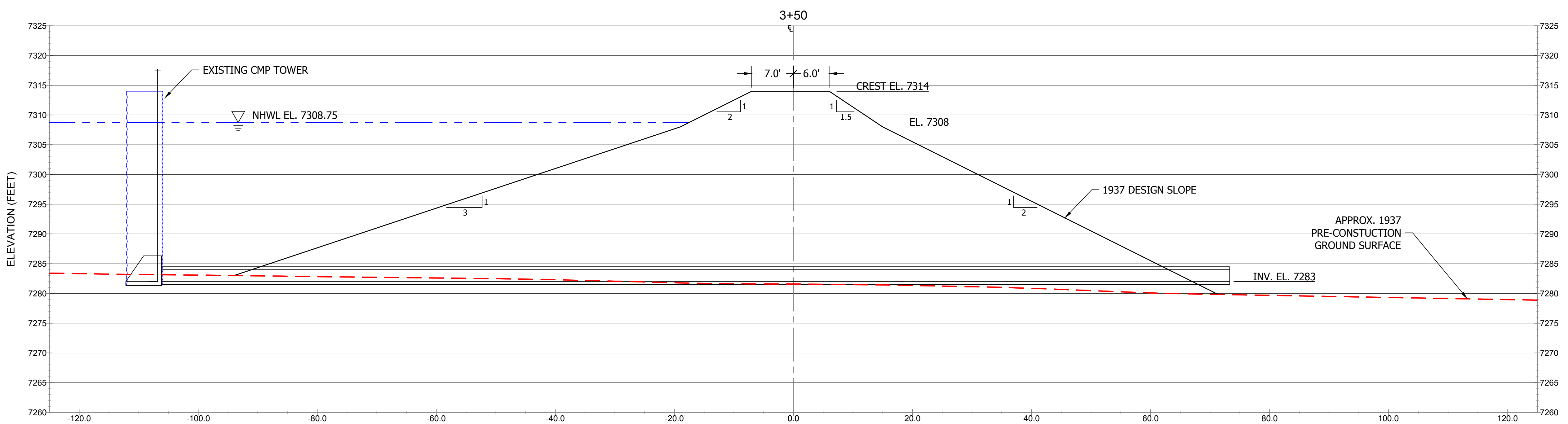
Water Resources Engineers
3700 S. Inca Street | Englewood, CO 80110-3405
303-761-4130 | Fax 303-761-2802

LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
EXISTING CONDITIONS
SITE PLAN

Client	NEW MEXICO DEPT. OF GAME AND FISH		
Design	TSS	05/16	Wheeler No. 1772.16.00
Drawn	SAA	05/16	Sheet No. 2 OF 14
Check	SLJ	05/16	
Plot Date	06/02/2016		Drawing No. SHEET 2



PROFILE VIEW OF EMBANKMENT ALIGNMENT



CROSS-SECTION THROUGH OUTLET WORKS

NOTES:
EMBANKMENT SECTION BASED ON 1937 AS-LET DRAWINGS.

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REVISIONS No.	Date	Made	Checked	Remarks

REFERENCE Sheet No.	Drawing No.	Title

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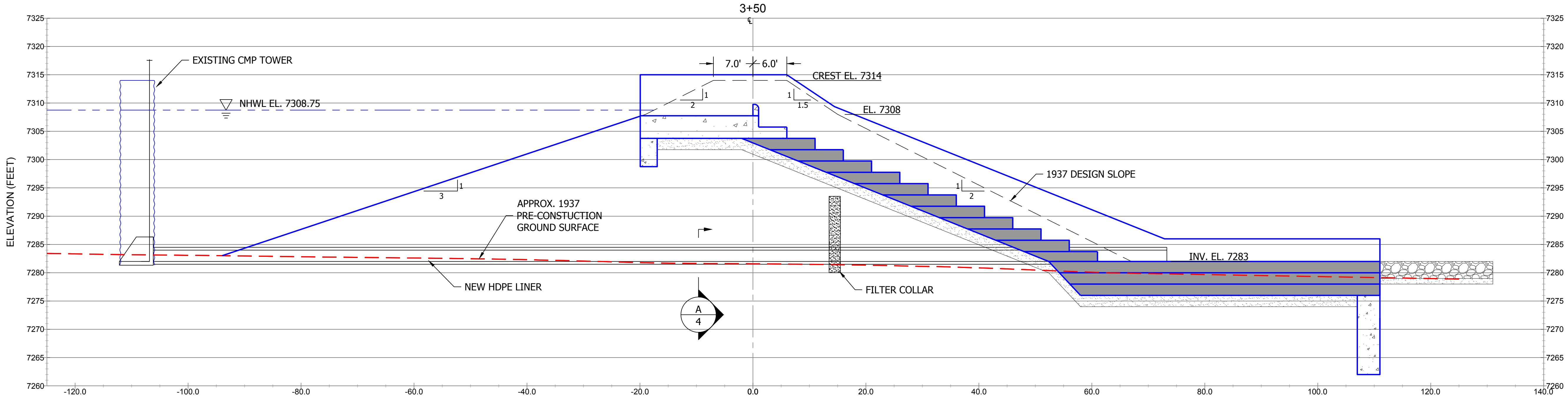
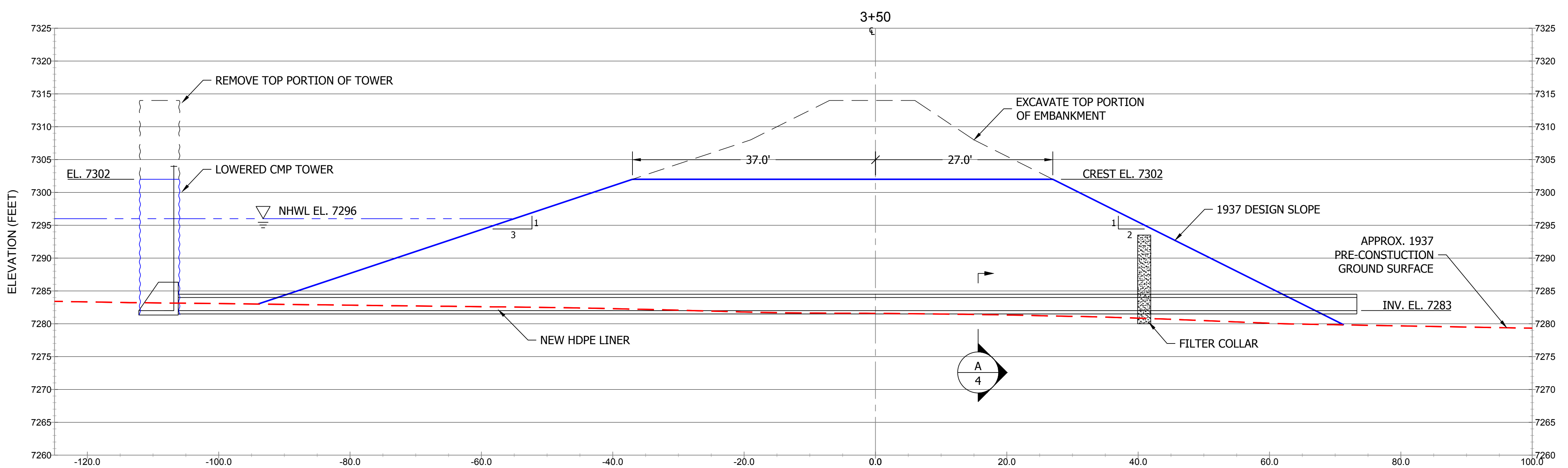
303-761-4130 | Fax 303-761-2802

LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
EXISTING DAM
PROFILE AND SECTION

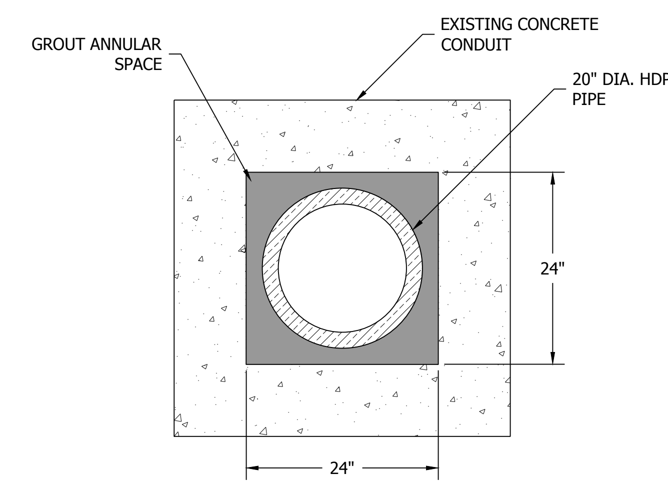
Client	NEW MEXICO DEPT. OF GAME AND FISH		
Design	TSS	05/16	Wheeler No. 1772.16.00
Drawn	SAA	05/16	Sheet No. 3 OF 14
Check	SLJ	05/16	
Plot Date 06/02/2016			Drawing No. SHEET 3



CROSS-SECTION THROUGH OUTLET WORKS - ALTERNATIVE 3



CROSS-SECTION THROUGH OUTLET WORKS



OUTLET WORKS PIPE
SECTION
A
4

0 ½ 1 2 3
Scale in Feet

NOTES:
1. EMBANKMENT SECTION BASED ON 1937 AS-LET DRAWINGS.
2. ALTERNATIVE 3A SHOWN ON RCC CROSS-SECTION. ALTERNATIVE 3B WILL VARY.

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Reference Sheet No.	Drawing No.	Title

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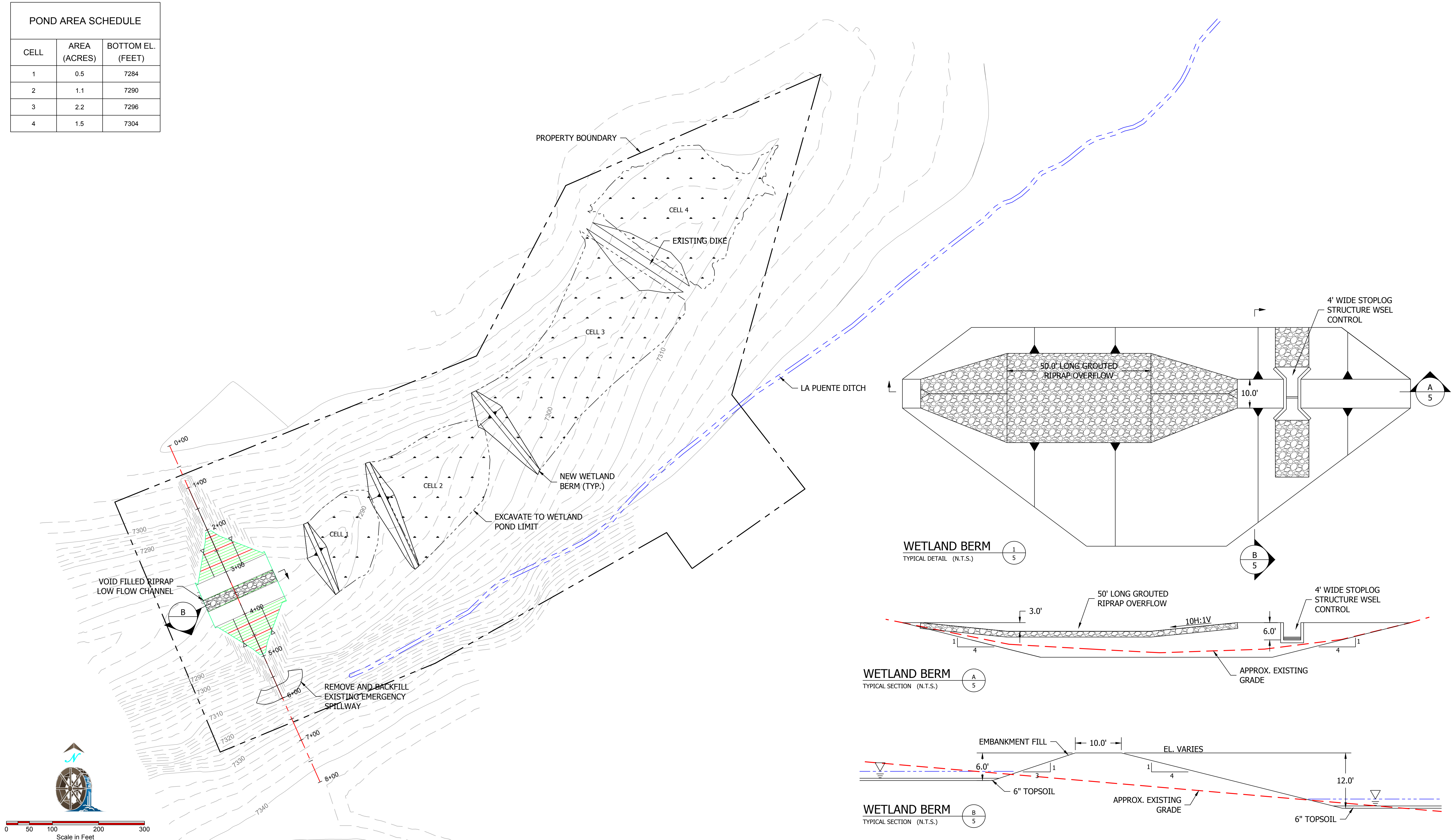
303-761-4130 | Fax 303-761-2802

LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
OUTLET WORKS REHABILITATION
CROSS-SECTIONS

Client	NEW MEXICO DEPT. OF GAME AND FISH		
Design	TSS	05/16	Wheeler No. 1772.16.00
Drawn	SAA	05/16	Sheet No. 4 OF 14
Check	SLJ	05/16	
Plot Date	06/02/2016	X	Drawing No. SHEET 4

POND AREA SCHEDULE

CELL	AREA (ACRES)	BOTTOM EL. (FEET)
1	0.5	7284
2	1.1	7290
3	2.2	7296
4	1.5	7304



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No.	Date	Made	Checked	Remarks

REVISIONS

Sheet No.	Drawing No.	Title

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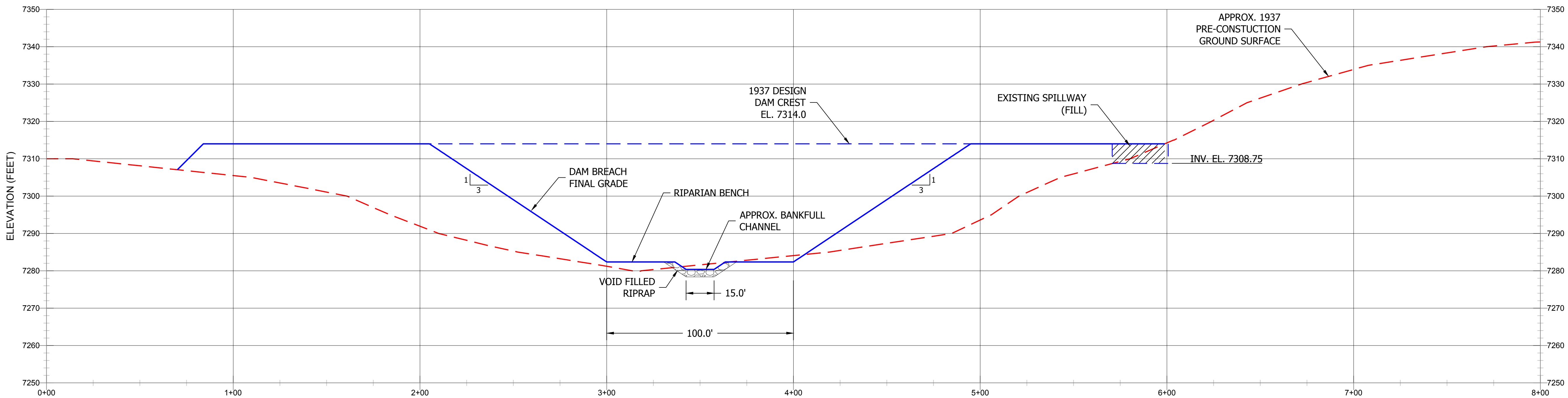
303-761-4130 | Fax 303-761-2802

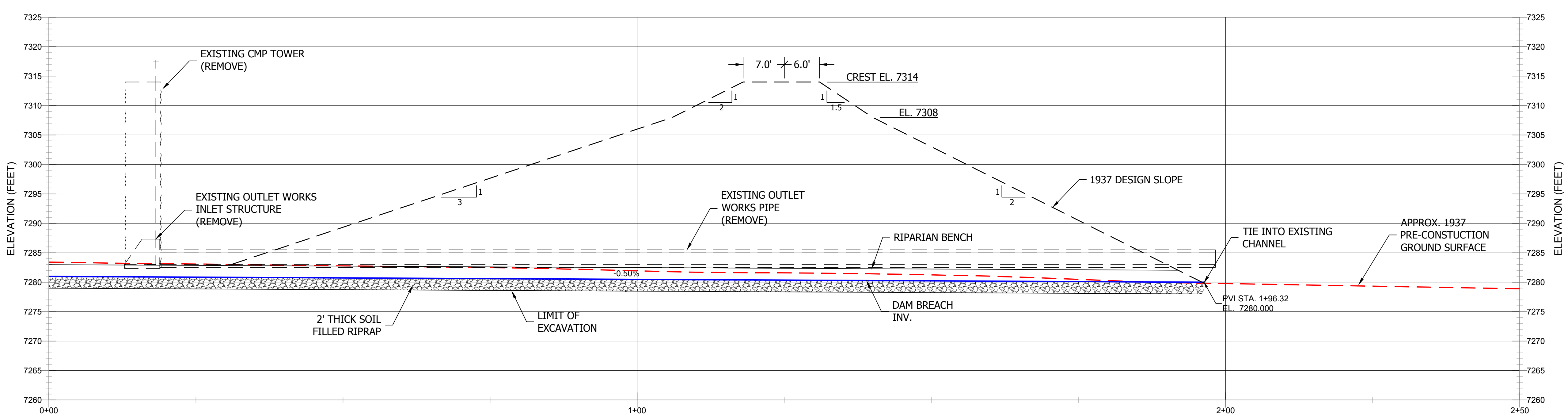
LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
ALTERNATIVE 1
DAM BREACH
SITE PLAN

Client: NEW MEXICO DEPT. OF GAME AND FISH

Design	TSS	05/16	Wheeler No.	1772.16.00
Drawn	SAA	05/16	Sheet No.	5 OF 14
Check	SLJ	05/16		
Plot Date	06/02/2016		Drawing No.	SHEET 5



PROFILE VIEW OF EMBANKMENT ALIGNMENT



CROSS-SECTION THROUGH OUTLET WORKS

NOTES:
EMBANKMENT SECTION BASED ON 1937 AS-LET DRAWINGS.

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REVISIONS	NO.	DATE	MADE	CHECKED	REMARKS

REFERENCE	SHEET NO.	DRAWING NO.	TITLE

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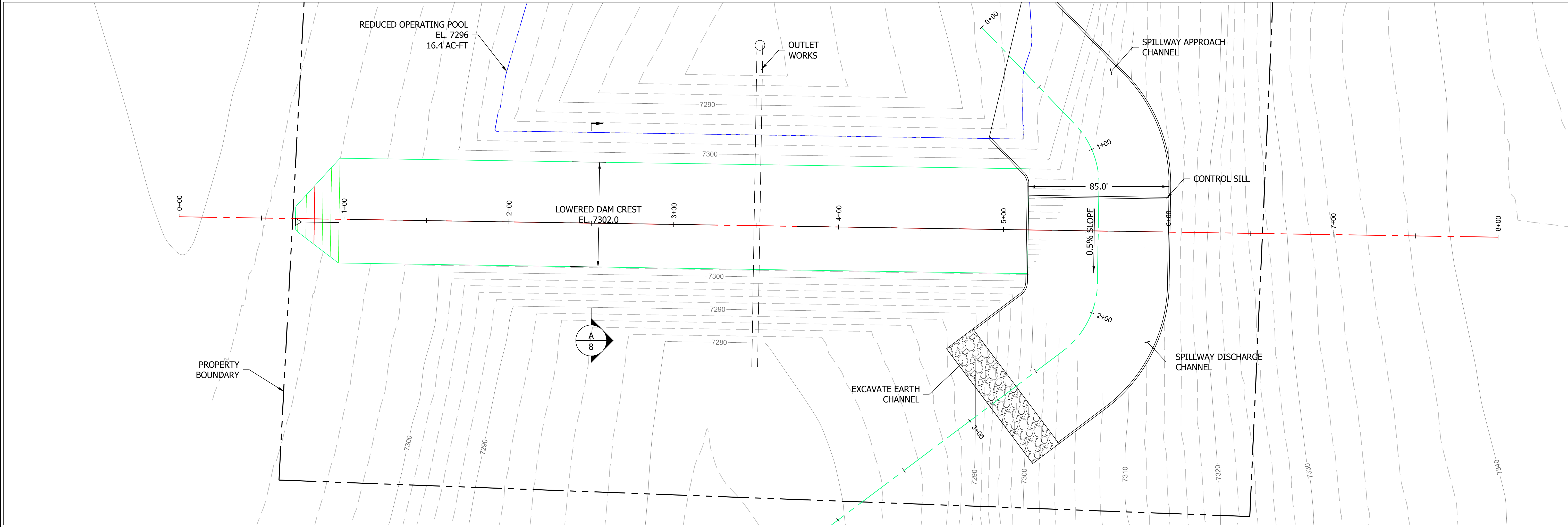
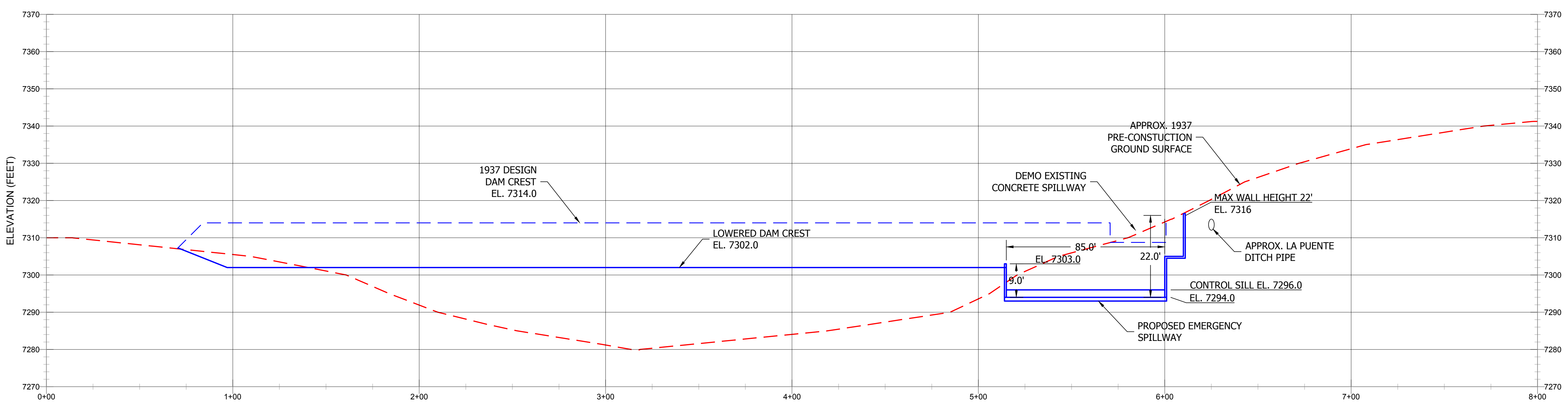
303-761-4130 | FAX 303-761-2802

LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
ALTERNATIVE 1
DAM BREACH
PROFILE AND CROSS-SECTION

CLIENT: NEW MEXICO DEPT. OF GAME AND FISH			
DESIGN	TSS	05/16	WHEELER NO. 1772.16.00
DRAWN	SAA	05/16	SHEET NO. 6 OF 14
CHECK	SLJ	05/16	
PLOT DATE 06/02/2016			DRAWING NO. SHEET 6





PROFILE VIEW OF EMBANKMENT ALIGNMENT

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No.	Date	Made	Checked	Remarks

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Sheet No.	Drawing No.	Title

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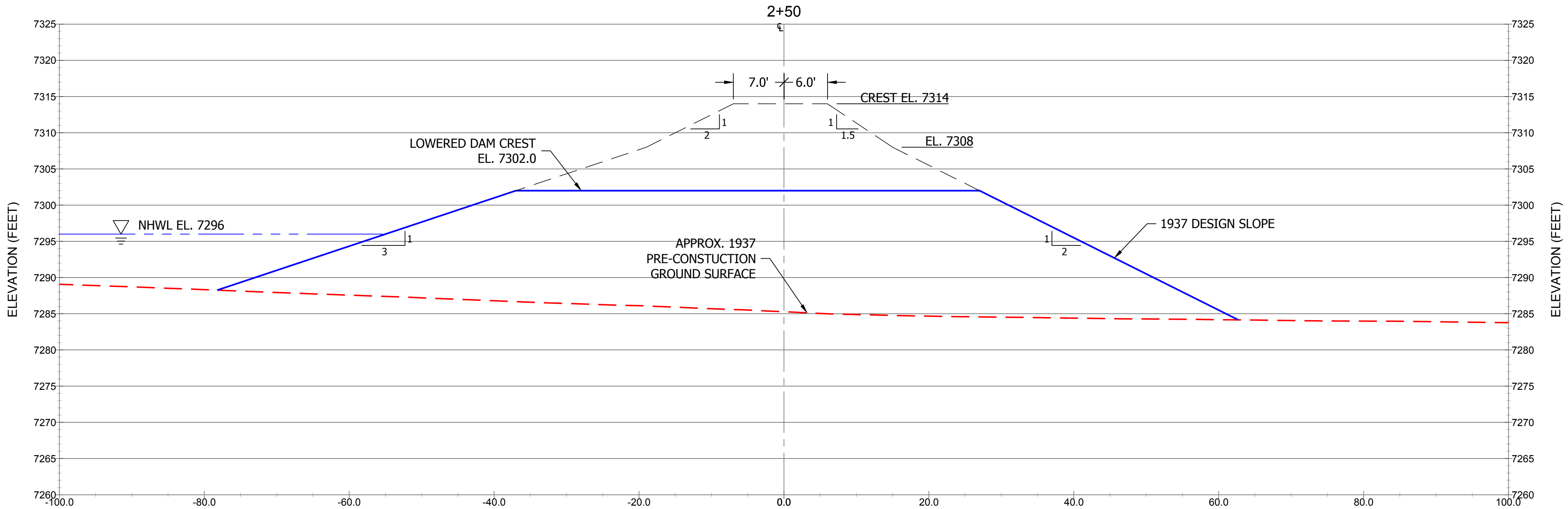
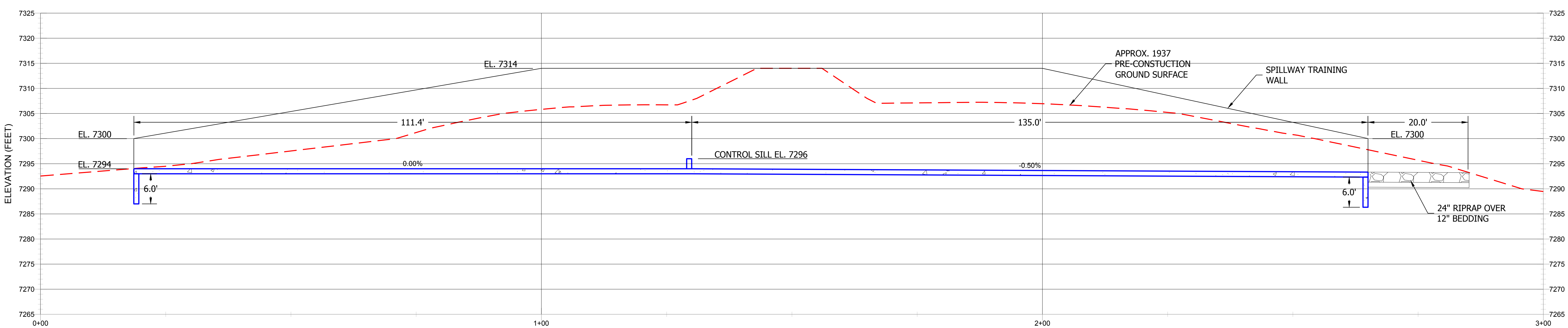
303-761-4130 | Fax 303-761-2802

LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
ALTERNATIVE 2
REDUCED DAM CREST
PLAN AND PROFILE

Client	NEW MEXICO DEPT. OF GAME AND FISH		
Design	TSS	05/16	Wheeler No. 1772.16.00
Drawn	SAA	05/16	
Check	SLJ	05/16	Sheet No. 7 OF 14
Plot Date	06/02/2016		Drawing No. SHEET 7



CROSS-SECTION A



PROFILE THROUGH LOWERED
EMERGENCY SPILLWAY

NOTES:
EMBANKMENT SECTION BASED ON 1937 AS-LET DRAWINGS.

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No.	Date	Made	Checked	Remarks

REVISIONS

Sheet No.	Drawing No.	Title

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Water Resources Engineers
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303-761-4130 | fax 303-761-2802

LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
ALTERNATIVE 2
REDUCED DAM CREST
DAM SECTION AND SPILLWAY PROFILE

CLIENT: NEW MEXICO DEPT. OF GAME AND FISH

DESIGN	TSS	05/16	WHEELER NO. 1772.16.00
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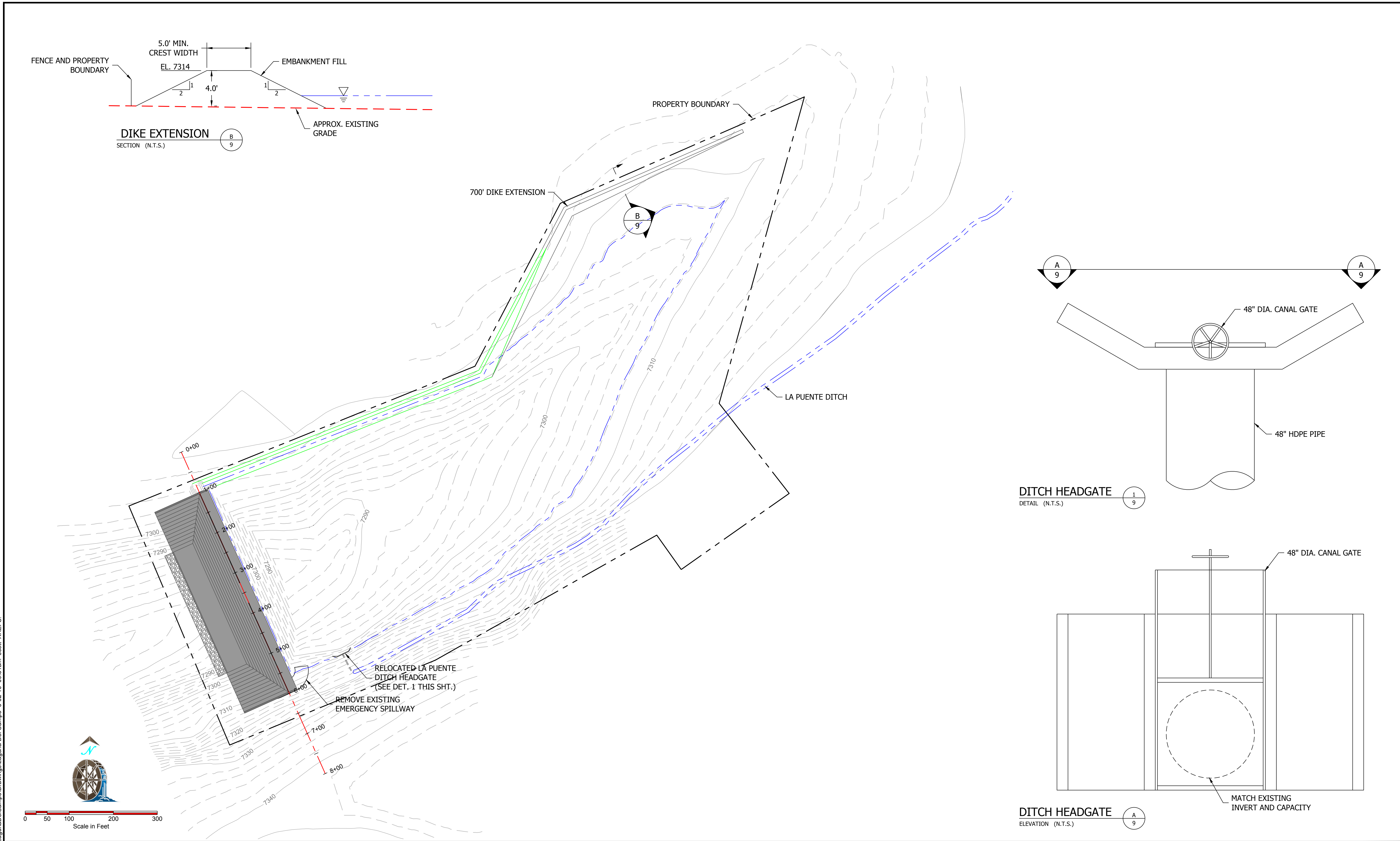
CHECK	SLJ	05/16	SHEET NO. 8 OF 14
PLOT DATE	06/02/2016	X	DRAWING NO. SHEET 8



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REFERENCE Sheet No.	Drawing No.	Title

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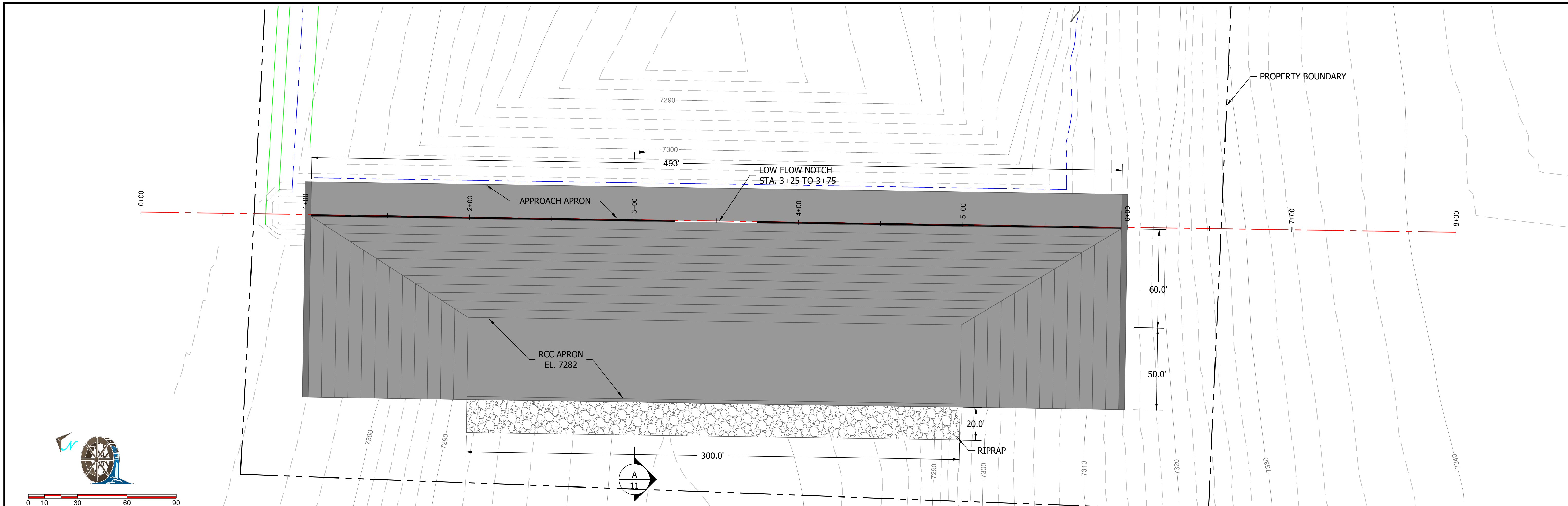
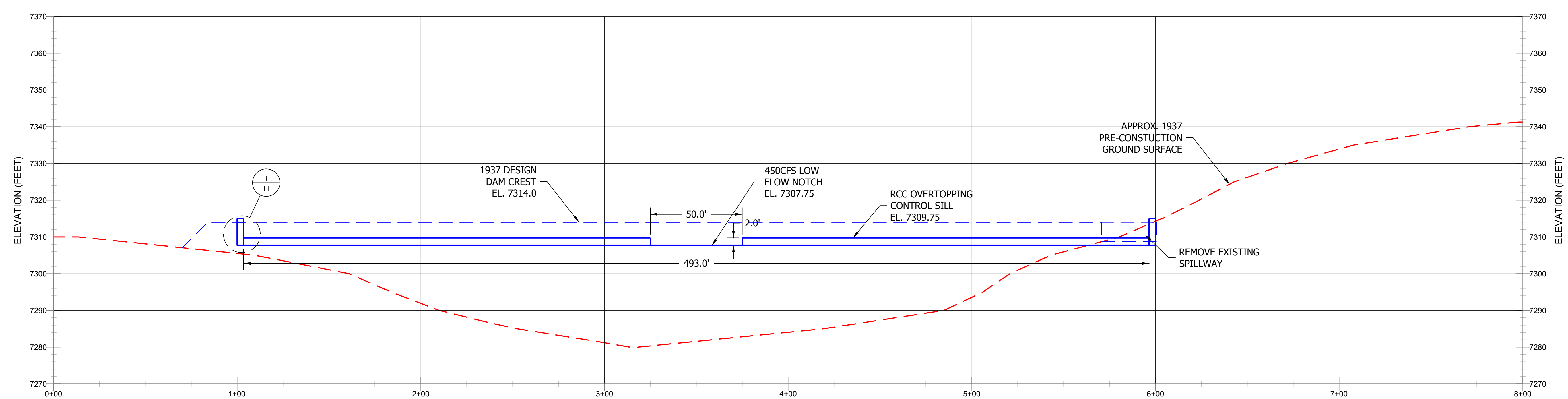
303-761-4130 | Fax 303-761-2802

LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
ALTERNATIVE 3A
60% PMF RCC SPILLWAY
SITE PLAN

Client: NEW MEXICO DEPT. OF GAME AND FISH		
Design: TSS	05/16	Wheeler No.: 1772.16.00
Drawn: SAA	05/16	Sheet No.: 9 OF 14
Check: SLJ	05/16	
Plot Date: 06/02/2016	X	Drawing No.: SHEET 9



PLAN VIEW OF RCC SPILLWAY



PROFILE VIEW OF EMBANKMENT ALIGNMENT

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REVISIONS NO.	DATE	MADE	CHECKED	REMARKS

REFERENCE SHEET NO.	DRAWING NO.	TITLE

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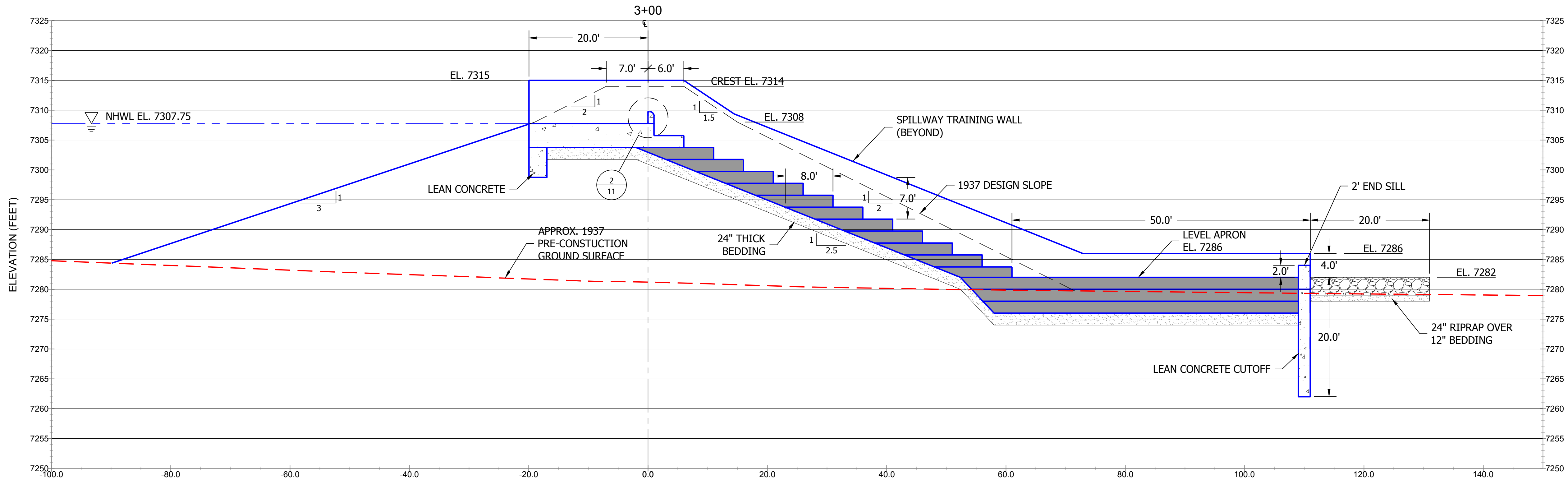
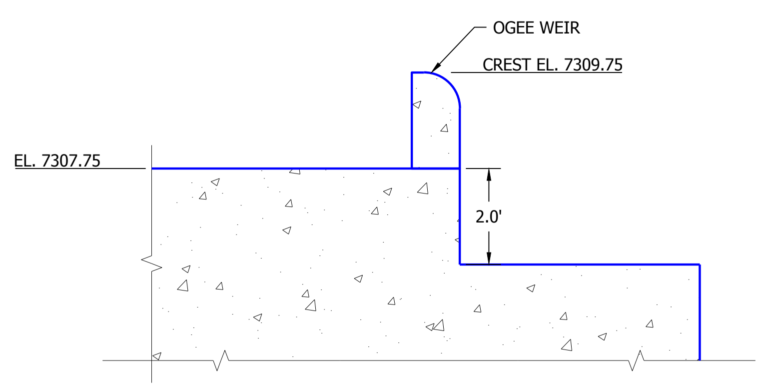
Water Resources Engineers
3700 S. Inca Street | Englewood, CO 80110-3405
303-761-4130 | Fax 303-761-2802

LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
ALTERNATIVE 3A
60% PMF RCC SPILLWAY
PLAN AND PROFILE

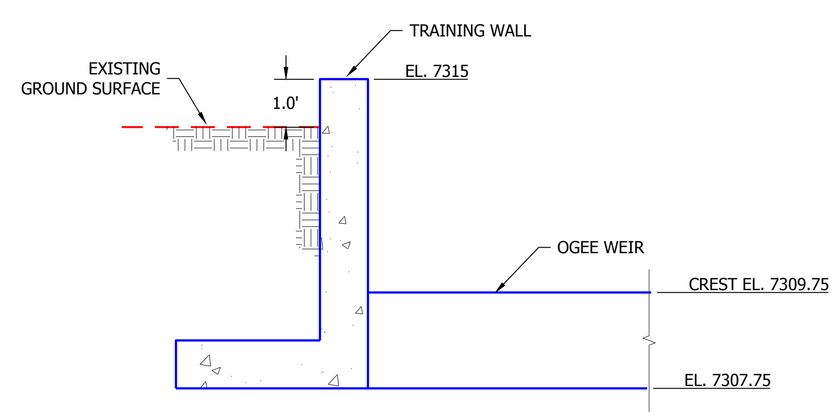
CLIENT	NEW MEXICO DEPT. OF GAME AND FISH	
DESIGN	TSS	05/16
DRAWN	SAA	05/16
CHECK	SLJ	05/16
WHEELER NO.	1772.16.00	
SHEET NO.	10 OF 14	
PLOT DATE	06/02/2016	
DRAWING NO.	SHEET 10	



CROSS-SECTION A



CONTROL SILL (2/11)
DETAIL
Scale in Feet: 0 1 2 4 6



TRAINING WALL (1/10)
DETAIL
Scale in Feet: 0 1 2 4 6

NOTES:
EMBANKMENT SECTION BASED ON 1937 AS-LET DRAWINGS.

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REFERENCE Sheet No.	Drawing No.	Title

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& ASSOCIATES, INC
Water Resources Engineers
3700 S. Inca Street | Englewood, CO 80110-3405
303-761-4130 | Fax 303-761-2802

LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
ALTERNATIVE 3A
60% PMF RCC SPILLWAY
CROSS-SECTION AND DETAILS

Client	NEW MEXICO DEPT. OF GAME AND FISH		
Design	TSS	05/16	Wheeler No. 1772.16.00
Drawn	SAA	05/16	Sheet No. 11 OF 14
Check	SLJ	05/16	
Plot Date 06/02/2016	X		Drawing No. SHEET 11

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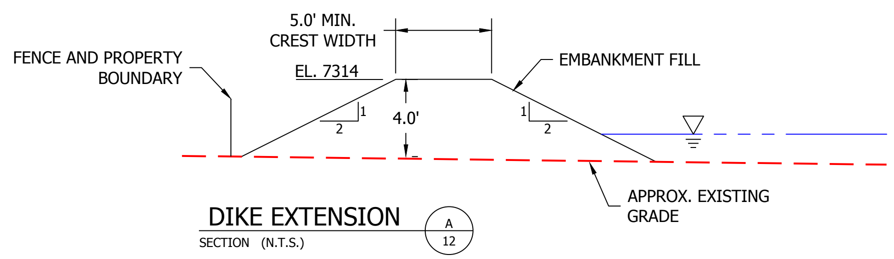

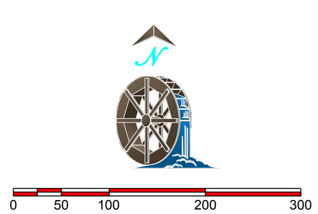

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REVISIONS

Sheet No.	Drawing No.	Title

REFERENCE

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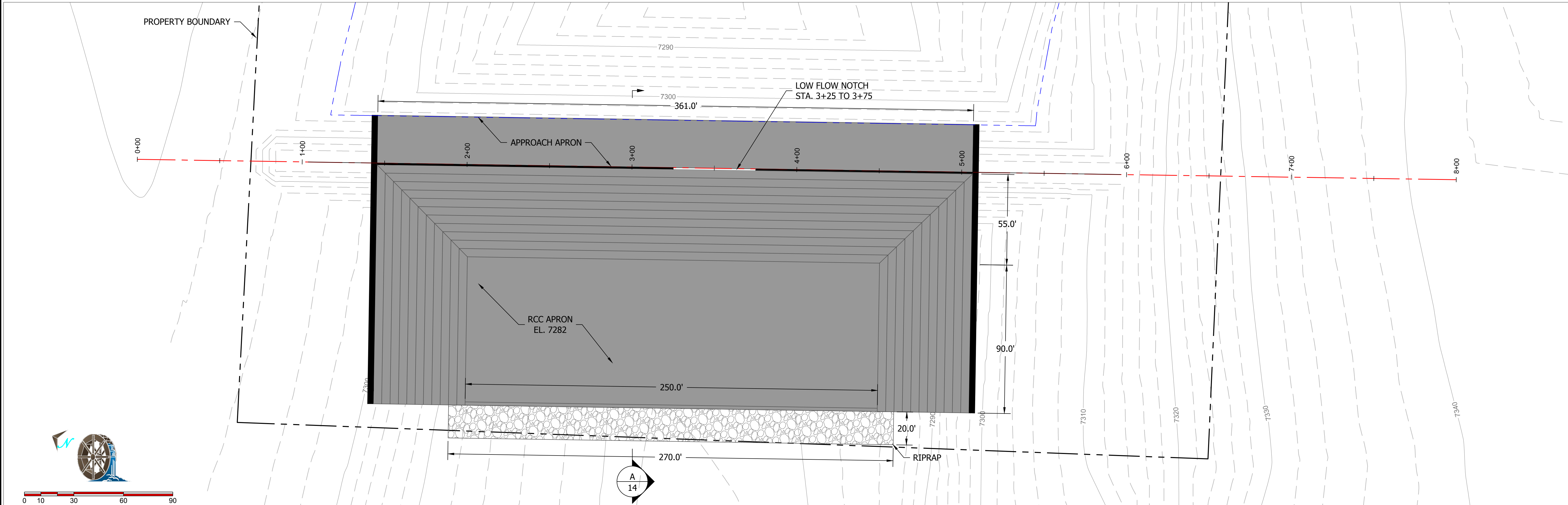
W. W. WHEELER & ASSOCIATES, INC
Water Resources Engineers
3700 S. Inca Street | Englewood, CO 80110-3405
303-761-4130 | Fax 303-761-2802

LAGUNA DEL CAMPO DAM

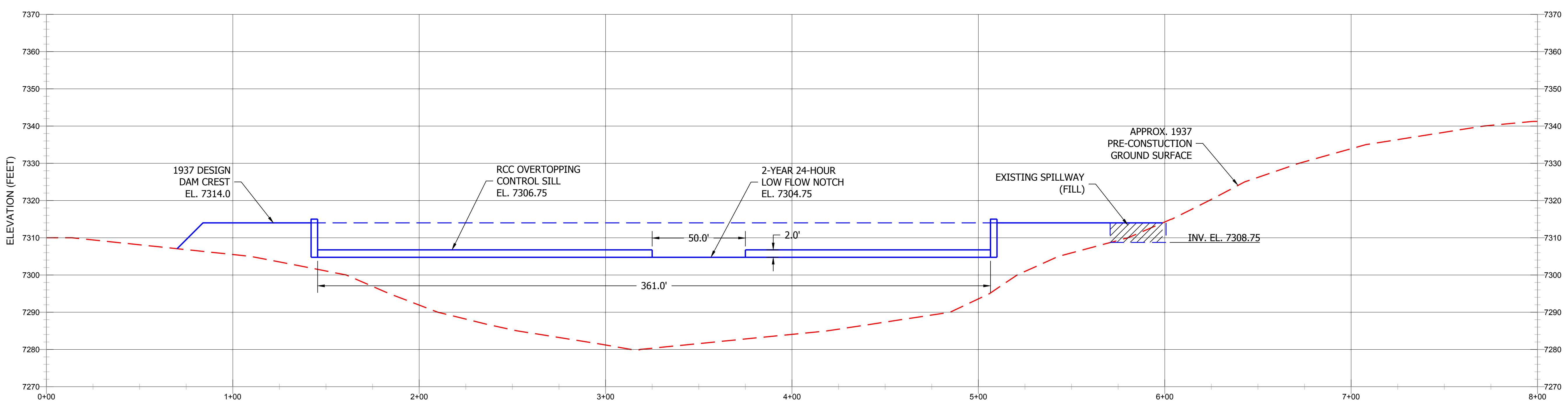
DAM REHABILITATION ALTERNATIVES
ALTERNATIVE 3B
100% PMF RCC SPILLWAY
SITE PLAN

Client: NEW MEXICO DEPT. OF GAME AND FISH

Design	TSS	05/16	Wheeler No. 1772.16.00
Drawn	SAA	05/16	Sheet No. 12 OF 14
Check	SLJ	05/16	Drawing No. SHEET 12
Plot Date 06/02/2016			



PLAN VIEW OF RCC SPILLWAY



PROFILE VIEW OF EMBANKMENT ALIGNMENT

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REVISIONS No.	Date	Made	Checked	Remarks

REFERENCE Sheet No.	Drawing No.	Title

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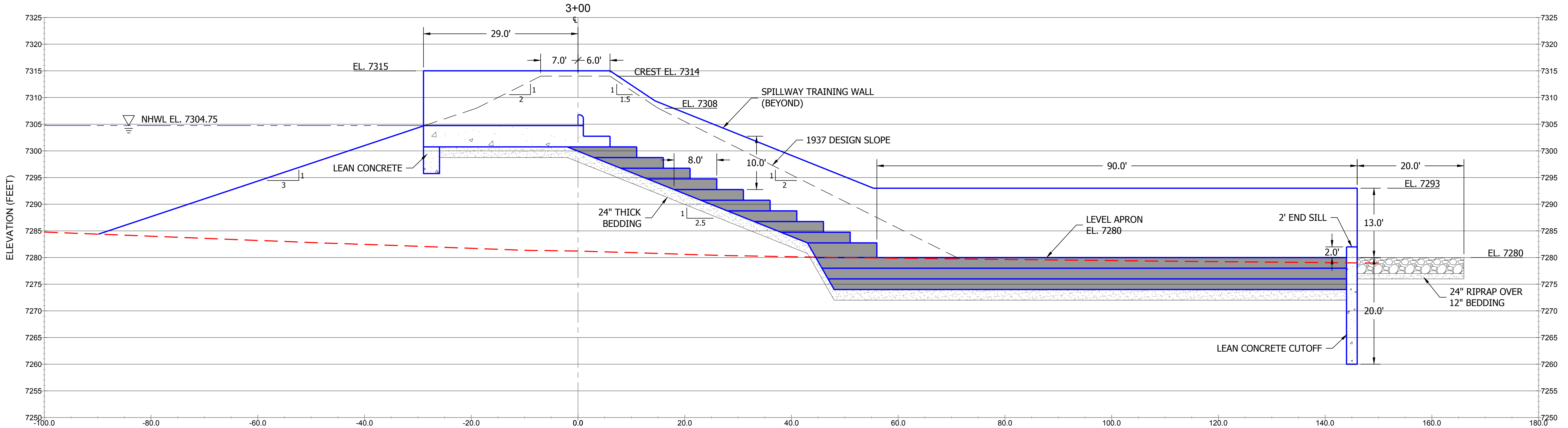
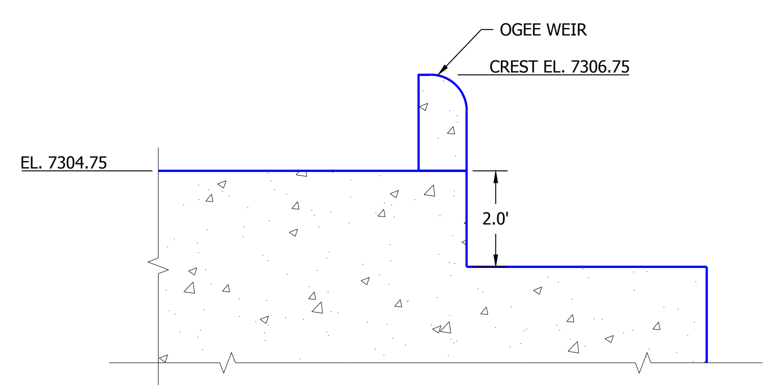
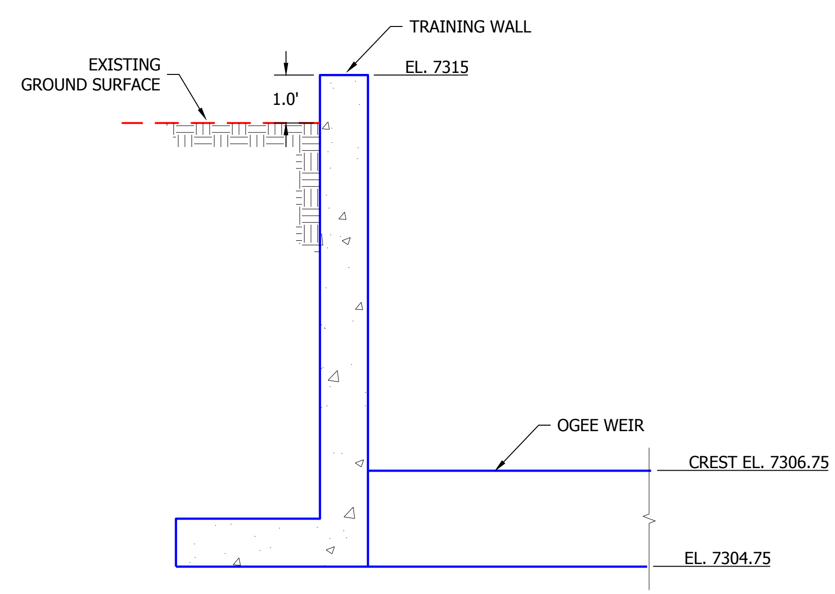
LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
ALTERNATIVE 3B
100% PMF RCC SPILLWAY
PLAN AND PROFILE

Client	NEW MEXICO DEPT. OF GAME AND FISH		
Design	TSS	05/16	Wheeler No. 1772.16.00
Drawn	SAA	05/16	Sheet No. 13 OF 14
Check	SLJ	05/16	
Plot Date	06/02/2016	X	Drawing No. SHEET 13





CONTROL SILL (2/11)
DETAIL
Scale in Feet



TRAINING WALL (1/10)
DETAIL
Scale in Feet

NOTES:
EMBANKMENT SECTION BASED ON 1937 AS-LET DRAWINGS.

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No.	Date	Made	Checked	Remarks

REVISIONS

Sheet No.	Drawing No.	Title

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LAGUNA DEL CAMPO DAM
DAM REHABILITATION ALTERNATIVES
ALTERNATIVE 3B
100% PMF RCC SPILLWAY
PROFILE AND CROSS-SECTION

Client: NEW MEXICO DEPT. OF GAME AND FISH

Design	TSS	05/16	Wheeler No. 1772.16.00
Drawn	SAA	05/16	Sheet No. 14 OF 14
Check	SLJ	05/16	
Plot Date 06/02/2016			Drawing No. SHEET 14

Appendix C

Calculations

Appendix C1 – Design Storms

Appendix C2 – Alternative No. 1 Calculations

Appendix C3 – Alternative No. 2 Calculations

Appendix C4 – Alternative Nos. 3 and 4 Calculations

Appendix C5 – Residual Freeboard Calculations

Appendix C1

Design Storms

OBJECTIVE:

Document the sources of (and calculations involved in) establishing the design precipitation events (storms) used in the Laguna Del Campo Dam spillway alternatives evaluation.

METHOD:

The inflow design flood (IDF) for the Laguna Del Campo Dam is the 6-hour duration, 100% probable maximum precipitation (PMP) storm, as described in "Laguna Del Campo Dam OSE Filing No. D313 Breach Analysis Report – Rio Arriba County, New Mexico" (URS, 2012). The magnitude of this storm was determined (by URS) using the methods described in "Hydrometeorological Report No. 55A – Probable Maximum Precipitation Estimates – United States Between the Continental Divide and the 103rd Meridian" (US Dept. of Commerce, 1988). Further, temporal distribution of the 6-hour duration, 100% PMP storm was accomplished (by URS) using the methods described in "Standard Project Flood Determinations, Civil Engineer Bulletin No. 52-8" (US Dept. of the Army, 1965).

Twenty four hour duration frequency storms (both magnitudes and temporal distributions) of various average recurrence intervals (ARI) were derived by W.W. Wheeler and Associates (Wheeler) using methods taken from "NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 1, Version 5.0: Semiarid Southwest (Arizona, Southeast California, Nevada, New Mexico & Utah)" (NOAA, 2011).

ASSUMPTIONS:

The following assumptions were employed:

- The centroid of the watershed contributing runoff to the Laguna Del Campo Dam was determined using Google Earth Pro through comparison to Figure 1 of Appendix F, page F-10 of (URS, 2012):
  - Latitude 36.7062° N,
  - Longitude 106.5356° W, and
  - Elevation 7,628 feet.
- Laguna Del Campo Dam is located in Semiarid Southwest Region 2 (Convective Precipitation Zone). Table A.1.1 of (NOAA, 2011) shows that first quartile (Q1) storms occur most commonly in this area, therefore, Wheeler assumes that all frequency storms employed at this site will be Q1 storms.
- For temporally distributing storms of a given quartile, (NOAA, 2011) provides dimensionless patterns for various percentage occurrence. Wheeler conservatively assumes that all frequency storms employed at this site will be distributed using the 10% occurrence probability temporal distribution for Q1 storms.
- As the area of the Laguna Del Campo watershed (5.75 square miles) is less than 10 square miles, areal reduction factors for point precipitation values do not apply.

CALCULATIONS:

The Laguna Del Campo Dam watershed centroid location was input into the NOAA precipitation frequency server at http://hdsc.nws.noaa.gov/hdsc/pfds and tabulated values of point precipitation storm depths for various frequencies and durations at that location were downloaded. Then, the 24-hour duration total storm depths for the 2-year, 10-year, 50-year and 100-year ARI storms were used with the appropriate 10% occurrence probability Q1 storm temporal pattern to derive design hyetographs for use in HEC-HMS modeling.

CONCLUSIONS/RESULTS:

The 6-hour duration, 100% PMP design storm magnitude is 11.7 inches and is temporally distributed following the pattern given in EM-1110-2-1411 (US Dept. of the Army, 1965).

The frequency storms developed for this site were temporally distributed using the 10% occurrence probability, Q1 pattern and have the following magnitudes:

- 2-year ARI, 24-hour duration magnitude is 1.48 inches,
- 10-year ARI, 24-hour duration magnitude is 2.13 inches,
- 50-year ARI, 24-hour duration magnitude is 2.87 inches, and
- 100-year ARI, 24-hour duration magnitude is 3.22 inches.

The various frequency storm calculations are included as Attachment 1.

REFERENCES:

1. National Oceanic and Atmospheric Administration (NOAA), *“NOAA Atlas 14, Precipitation-Frequency Atlas of the United States, Volume 1, Version 5.0: Semiarid Southwest (Arizona, Southeast California, Nevada, New Mexico & Utah)”*, 2004 (revised 2011). Silver Spring, MD.

2. URS, *“Laguna Del Campo Dam OSE Filing No. D313 Breach Analysis Report – Rio Arriba County, New Mexico”*, Design report prepared for the New Mexico Department of Game and Fish, July, 2012. Denver, CO.

3. United States Department of the Army, *“Standard Project Flood Determinations, Civil Engineer Bulletin No. 52-8”*, Document No. EM-1110-2-1411, March, 1952 (revised March, 1965). Washington, DC.

4. United States Department of Commerce, et. al., *“Hydrometeorological Report No. 55A – Probable Maximum Precipitation Estimates – United States Between the Continental Divide and the 103rd Meridian”*, June, 1988. Silver Spring, MD.

ATTACHMENT 1

FREQUENCY STORM CALCULATIONS

NOAA Atlas 14, Volume 1, Version 5 - Point Precipitation Frequency Estimates for Laguna Del Campo Reservoir HEC-HMS Model (Expected Values)

Source for precipitation frequency data: http://hdsc.nws.noaa.goc/hdsc/pfds/

Selected Location Information

Latitude (°): 36.7062 **Name:** Los Ojos, New Mexico

Longitude (°): -106.5356 **Elevation (ft):** 7,628

Precipitation Frequency Estimates of Point Rainfall (inches) based on analysis of partial duration series (Expected Values)												
Duation			Average Recurrence Interval (years)									
(min)	(hr)	(d)	1	2	5	10	25	50	100	200	500	1000
5	0.083	0.0035	0.182	0.234	0.317	0.384	0.477	0.556	0.638	0.728	0.857	0.966
10	0.167	0.0069	0.276	0.356	0.483	0.584	0.727	0.844	0.971	1.11	1.30	1.47
15	0.25	0.0104	0.343	0.442	0.599	0.724	0.901	1.05	1.20	1.37	1.62	1.82
30	0.5	0.0208	0.461	0.595	0.807	0.974	1.21	1.41	1.62	1.85	2.18	2.45
60	1	0.0417	0.571	0.737	0.998	1.21	1.50	1.74	2.01	2.29	2.69	3.04
120	2	0.0833	0.664	0.851	1.13	1.36	1.69	1.96	2.26	2.58	3.04	3.43
180	3	0.125	0.733	0.927	1.21	1.44	1.78	2.06	2.36	2.67	3.14	3.53
360	6	0.25	0.846	1.06	1.36	1.60	1.96	2.25	2.56	2.90	3.38	3.78
720	12	0.5	0.994	1.24	1.55	1.82	2.19	2.50	2.83	3.18	3.67	4.07
1,440	24	1	1.19	1.48	1.84	2.13	2.55	2.87	3.22	3.57	4.06	4.44
2,880	48	2	1.37	1.70	2.10	2.42	2.86	3.21	3.57	3.94	4.45	4.84
4,320	72	3	1.52	1.88	2.32	2.67	3.16	3.54	3.94	4.34	4.89	5.31
5,760	96	4	1.67	2.07	2.54	2.93	3.46	3.87	4.30	4.74	5.33	5.79
10,080	168	7	2.04	2.52	3.07	3.52	4.11	4.56	5.02	5.48	6.08	6.54
14,400	240	10	2.32	2.86	3.48	3.96	4.61	5.10	5.59	6.08	6.72	7.20
28,800	480	20	3.12	3.85	4.65	5.28	6.11	6.73	7.35	7.96	8.74	9.32
43,200	720	30	3.87	4.77	5.72	6.44	7.36	8.04	8.70	9.34	10.10	10.70
64,800	1,080	45	4.82	5.93	7.05	7.91	8.97	9.73	10.50	11.10	12.00	12.50
86,400	1,440	60	5.65	6.95	8.23	9.20	10.40	11.30	12.10	12.80	13.70	14.30

NOAA Atlas 14, Volume 1, Version 5 - Temporal Distributions for Laguna Del Campo Reservoir HEC-HMS Model (Introduction)

Source for precipitation frequency data: http://hdsc.nws.noaa.goc/hdsc/pfds/

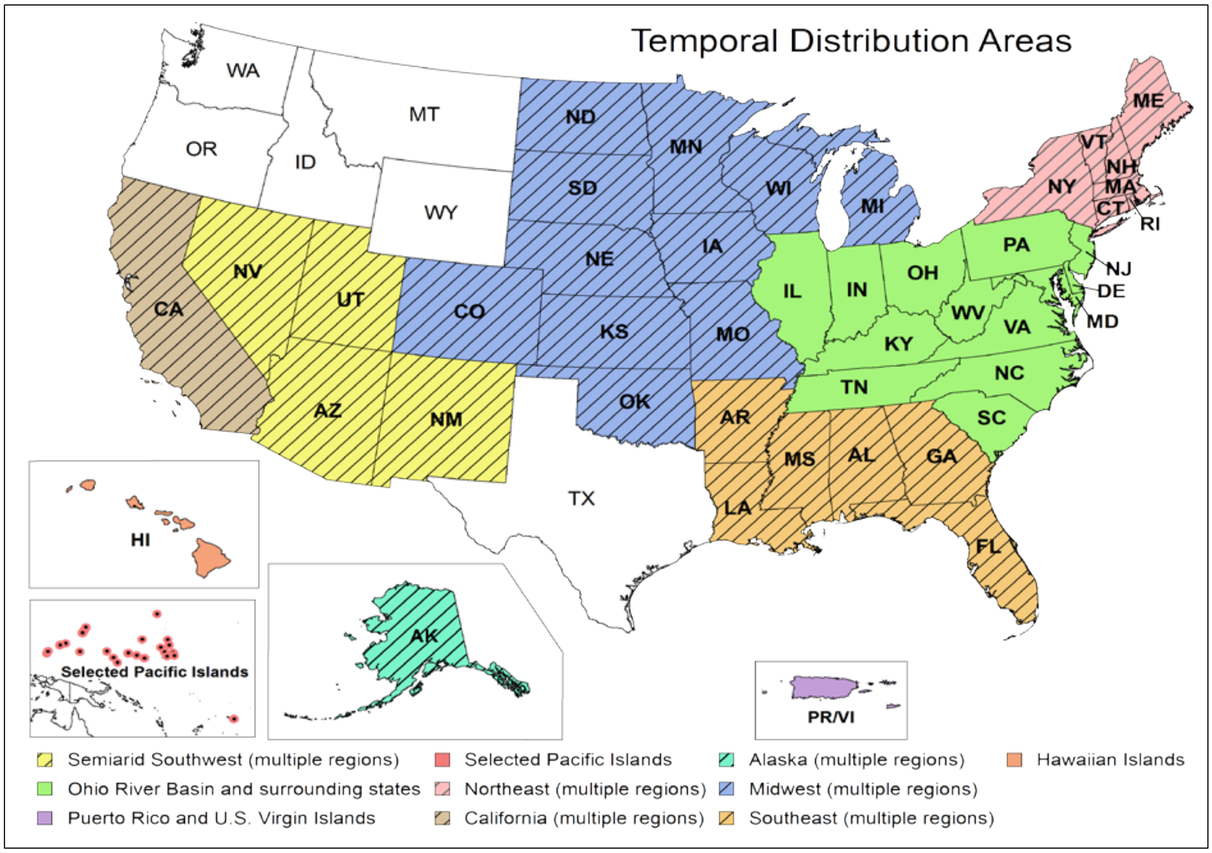
(Note that this location lies within Semiarid Southwest Region 2.)

Selected Location Information

Latitude (°): 36.7062 **Name:** Los Ojos, New Mexico

Longitude (°): -106.5356 **Elevation (ft):** 7,628

First, start by selecting the appropriate Temporal Distribution Area for the site in question.



NOAA Atlas 14, Volume 1, Version 5 - Temporal Distributions for Laguna Del Campo Reservoir HEC-HMS Model (Introduction)

Source for precipitation frequency data: http://hdsc.nws.noaa.goc/hdsc/pfds/

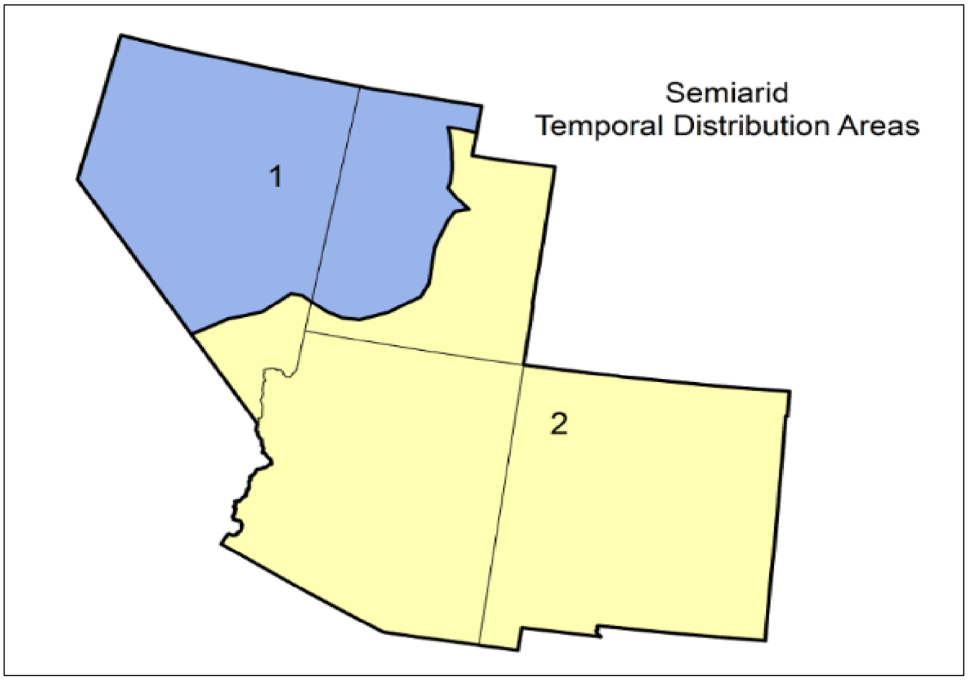
(Note that this location lies within Semiarid Southwest Region 2.)

Selected Location Information

Latitude (°): 36.7062 **Name:** Los Ojos, New Mexico

Longitude (°): -106.5356 **Elevation (ft):** 7,628

Two (sub)regions exist within the Semiarid Southwest. Looking at New Mexico, one zone applies. Laguna Del Campo Reservoir is in Semiarid Southwest Region 2.



From the Precipitation Frequency Data Server, regional temporal distribution data are available in a tabular form for selected locations under the "Supplementary information" tab or through the temporal distribution web page (http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_temporal.html). For 6-, 12- and 24-hour durations, temporal distribution data area provided in 0.5-hour increments and for 96-hour durations in hourly increments.

Table A.1.1 can be used to determine which storm quartile temporal distribution is most likely for a given duration and location - see below:
(In this case, the most likely storm quartile (Q1) for all storm durations in Semiarid Southwest Region 2 is highlighted.)

Table A.1.1 - # of Precipitation Cases by Storm Quartile for Each Climate Region in the Semiarid Southwest: (1) General Precipitation & (2) Convective Precipitation

Duration			Region	Total	First Quartile (Q1)		Second Quartile (Q2)		Third Quartile (Q3)		Fourth Quartile (Q4)	
(min)	(hr)	(d)		# of Cases	# of cases	% of storms	# of cases	% of storms	# of cases	% of storms	# of cases	% of storms
360	6	0.25	1	1,851	669	36%	471	25%	468	25%	243	13%
			2	3,216	1,679	52%	744	23%	509	16%	284	9%
720	12	0.50	1	1,807	596	33%	465	26%	469	26%	277	15%
			2	3,443	1,753	51%	769	22%	567	16%	354	10%
1440	24	1	1	1,728	630	36%	442	26%	380	22%	276	16%
			2	3,459	1,751	51%	645	19%	571	17%	492	14%
5760	96	4	1	1,829	841	46%	376	21%	292	16%	320	17%
			2	3,716	1,952	53%	707	19%	530	14%	527	14%

NOAA Atlas 14, Volume 1, Version 5 - Temporal Distributions for Laguna Del Campo Reservoir HEC-HMS Model (24-hour Duration Storms)

Source for precipitation frequency data: http://hdsc.nws.noaa.goc/hdsc/pfds/

(Note that this location lies within Semiarid Southwest Region 2.)

Selected Location Information

Latitude (°): 36.7062
Longitude (°): -106.5356
Name: Los Ojos, New Mexico
Elevation (ft): 7,628

Cumulative Percentages of Total Precipitation for First-Quartile Storms											
Elapsed Time			Percentage of Occurrence								
(min)	(hr)	(d)	90%	80%	70%	60%	50%	40%	30%	20%	10%
0	0.0	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.5	0.021	2.31	3.49	4.74	6.17	8.01	10.49	13.03	15.69	17.80
60	1.0	0.042	4.62	6.98	9.49	12.35	16.01	20.98	26.05	31.38	35.59
90	1.5	0.063	6.93	10.47	14.23	18.52	24.02	31.48	39.08	47.06	53.39
120	2.0	0.083	9.25	13.96	18.97	24.68	31.99	41.89	52.00	62.60	70.99
150	2.5	0.104	12.48	17.82	23.38	29.72	37.47	47.79	58.25	68.67	76.83
180	3.0	0.125	15.70	21.68	27.79	34.77	42.95	53.69	64.50	74.75	82.66
210	3.5	0.146	18.92	25.54	32.19	39.81	48.44	59.59	70.75	80.82	88.49
240	4.0	0.167	22.15	29.40	36.60	44.86	53.92	65.49	77.00	86.90	94.33
270	4.5	0.188	25.88	33.68	41.24	49.86	59.06	70.56	81.77	91.03	97.80
300	5.0	0.208	30.22	38.45	46.16	54.80	63.81	74.64	84.78	92.85	98.47
330	5.5	0.229	34.56	43.23	51.08	59.75	68.55	78.72	87.79	94.68	99.13
360	6.0	0.250	38.90	48.00	56.00	64.70	73.30	82.80	90.80	96.50	99.80
390	6.5	0.271	41.21	50.61	58.71	67.31	75.78	84.68	91.93	97.03	99.83
420	7.0	0.292	43.52	53.22	61.42	69.92	78.27	86.57	93.06	97.55	99.85
450	7.5	0.313	45.83	55.83	64.13	72.53	80.75	88.45	94.19	98.08	99.88
480	8.0	0.333	48.12	58.42	66.82	75.12	83.22	90.32	95.31	98.60	99.90
510	8.5	0.354	49.51	59.86	68.34	76.66	84.66	91.28	95.88	98.78	99.93
540	9.0	0.375	50.90	61.30	69.85	78.20	86.10	92.25	96.45	98.95	99.95
570	9.5	0.396	52.29	62.74	71.36	79.74	87.54	93.22	97.02	99.12	99.97
600	10.0	0.417	53.68	64.18	72.88	81.28	88.98	94.18	97.59	99.30	100.00
630	10.5	0.438	55.03	65.39	74.04	82.39	89.89	94.74	97.87	99.37	100.00
660	11.0	0.458	56.39	66.59	75.19	83.49	90.79	95.30	98.15	99.45	100.00
690	11.5	0.479	57.74	67.80	76.35	84.60	91.70	95.85	98.42	99.52	100.00
720	12.0	0.500	59.10	69.00	77.50	85.70	92.60	96.40	98.70	99.60	100.00
750	12.5	0.521	60.33	70.23	78.73	86.70	93.23	96.78	98.85	99.65	100.00
780	13.0	0.542	61.56	71.46	79.96	87.71	93.86	97.15	99.00	99.70	100.00
810	13.5	0.563	62.79	72.69	81.19	88.71	94.48	97.53	99.15	99.75	100.00
840	14.0	0.583	64.02	73.92	82.42	89.71	95.11	97.90	99.30	99.80	100.00
870	14.5	0.604	65.26	75.19	83.58	90.61	95.60	98.15	99.40	99.83	100.00
900	15.0	0.625	66.50	76.45	84.75	91.50	96.10	98.40	99.50	99.85	100.00
930	15.5	0.646	67.74	77.71	85.92	92.39	96.60	98.65	99.60	99.87	100.00
960	16.0	0.667	68.98	78.98	87.08	93.29	97.09	98.90	99.70	99.90	100.00
990	16.5	0.688	70.56	80.41	88.19	94.02	97.45	99.05	99.75	99.92	100.00
1,020	17.0	0.708	72.14	81.84	89.29	94.74	97.80	99.20	99.80	99.95	100.00
1,050	17.5	0.729	73.72	83.27	90.40	95.47	98.15	99.35	99.85	99.97	100.00
1,080	18.0	0.750	75.30	84.70	91.50	96.20	98.50	99.50	99.90	100.00	100.00
1,110	18.5	0.771	77.21	86.21	92.58	96.75	98.75	99.60	99.93	100.00	100.00
1,140	19.0	0.792	79.12	87.71	93.66	97.30	99.00	99.70	99.95	100.00	100.00
1,170	19.5	0.813	81.02	89.22	94.74	97.86	99.25	99.80	99.98	100.00	100.00
1,200	20.0	0.833	82.93	90.72	95.81	98.41	99.50	99.90	100.00	100.00	100.00
1,230	20.5	0.854	85.04	92.04	96.53	98.73	99.60	99.93	100.00	100.00	100.00
1,260	21.0	0.875	87.15	93.35	97.25	99.05	99.70	99.95	100.00	100.00	100.00
1,290	21.5	0.896	89.26	94.66	97.97	99.37	99.80	99.97	100.00	100.00	100.00
1,320	22.0	0.917	91.37	95.98	98.69	99.69	99.90	100.00	100.00	100.00	100.00
1,350	22.5	0.938	93.52	96.99	99.02	99.77	99.92	100.00	100.00	100.00	100.00
1,380	23.0	0.958	95.68	97.99	99.35	99.85	99.95	100.00	100.00	100.00	100.00
1,410	23.5	0.979	97.84	99.00	99.67	99.92	99.97	100.00	100.00	100.00	100.00
1,440	24.0	1.000	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Subject New Mexico Department of Game & Fish	Made by TML	Job No. 1772.16.00
	Laguna Del Campo Dam	Checked DTH	Date 5/20/2016
	Spillway Evaluation - Design Storms	Approved TSS	

NOAA Atlas 14, Volume 1, Version 5 - Hyetographs for Laguna Del Campo Reservoir HEC-HMS Model (2-year ARI, 24-hour Duration Storms)

Source for precipitation frequency data: http://hdsc.nws.noaa.goc/hdsc/pfds/
(Note that this location lies within Semiarid Southwest Region 2.)

Selected Location Information

Latitude (°): 36.7062 **Name:** Los Ojos, New Mexico
Longitude (°): -106.5356 **Elevation (ft):** 7,628

2-yr, 24-h Storm point depth =	**1.48**	in
Areal Reduction Factor =	**1.000**	
2-yr, 24-h Storm factored depth =	**1.48**	in

Elapsed Time (hr)	Percentage of Occurance for Selected Storm Classification: First-Quartile Storms 90%	80%	70%	60%	50%	40%	30%	20%	10%
0.0	0.00	0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.000
0.5	0.03	0.05	0.07	0.09	0.119	0.16	0.19	0.23	0.263
1.0	0.07	0.10	0.14	0.18	0.237	0.31	0.39	0.46	0.527
1.5	0.10	0.15	0.21	0.27	0.356	0.47	0.58	0.70	0.790
2.0	0.14	0.21	0.28	0.37	0.473	0.62	0.77	0.93	1.051
2.5	0.18	0.26	0.35	0.44	0.555	0.71	0.86	1.02	1.137
3.0	0.23	0.32	0.41	0.51	0.636	0.79	0.95	1.11	1.223
3.5	0.28	0.38	0.48	0.59	0.717	0.88	1.05	1.20	1.310
4.0	0.33	0.44	0.54	0.66	0.798	0.97	1.14	1.29	1.396
4.5	0.38	0.50	0.61	0.74	0.874	1.04	1.21	1.35	1.447
5.0	0.45	0.57	0.68	0.81	0.944	1.10	1.25	1.37	1.457
5.5	0.51	0.64	0.76	0.88	1.015	1.17	1.30	1.40	1.467
6.0	0.58	0.71	0.83	0.96	1.085	1.23	1.34	1.43	1.477
6.5	0.61	0.75	0.87	1.00	1.122	1.25	1.36	1.44	1.477
7.0	0.64	0.79	0.91	1.03	1.158	1.28	1.38	1.44	1.478
7.5	0.68	0.83	0.95	1.07	1.195	1.31	1.39	1.45	1.478
8.0	0.71	0.86	0.99	1.11	1.232	1.34	1.41	1.46	1.479
8.5	0.73	0.89	1.01	1.13	1.253	1.35	1.42	1.46	1.479
9.0	0.75	0.91	1.03	1.16	1.274	1.37	1.43	1.46	1.479
9.5	0.77	0.93	1.06	1.18	1.296	1.38	1.44	1.47	1.480
10.0	0.79	0.95	1.08	1.20	1.317	1.39	1.44	1.47	1.480
10.5	0.81	0.97	1.10	1.22	1.330	1.40	1.45	1.47	1.480
11.0	0.83	0.99	1.11	1.24	1.344	1.41	1.45	1.472	1.480
11.5	0.85	1.00	1.13	1.25	1.357	1.42	1.46	1.473	1.480
12.0	0.87	1.02	1.15	1.27	1.370	1.43	1.46	1.474	1.480
12.5	0.89	1.04	1.17	1.28	1.380	1.43	1.46	1.475	1.480
13.0	0.91	1.06	1.18	1.30	1.389	1.44	1.47	1.476	1.480
13.5	0.93	1.08	1.20	1.31	1.398	1.44	1.47	1.476	1.480
14.0	0.95	1.09	1.22	1.33	1.408	1.45	1.47	1.477	1.480
14.5	0.97	1.11	1.24	1.34	1.415	1.45	1.47	1.477	1.480
15.0	0.98	1.13	1.25	1.35	1.422	1.46	1.47	1.478	1.480
15.5	1.00	1.15	1.27	1.37	1.430	1.46	1.47	1.478	1.480
16.0	1.02	1.17	1.29	1.38	1.437	1.46	1.48	1.479	1.480
16.5	1.04	1.19	1.31	1.39	1.442	1.47	1.476	1.479	1.480
17.0	1.07	1.21	1.32	1.40	1.447	1.47	1.477	1.479	1.480
17.5	1.09	1.23	1.34	1.41	1.453	1.47	1.478	1.480	1.480
18.0	1.11	1.25	1.35	1.42	1.458	1.47	1.479	1.480	1.480
18.5	1.14	1.28	1.37	1.43	1.462	1.47	1.479	1.480	1.480
19.0	1.17	1.30	1.39	1.44	1.465	1.476	1.479	1.480	1.480
19.5	1.20	1.32	1.40	1.45	1.469	1.477	1.480	1.480	1.480
20.0	1.23	1.34	1.42	1.46	1.473	1.479	1.480	1.480	1.480
20.5	1.26	1.36	1.43	1.46	1.474	1.479	1.480	1.480	1.480
21.0	1.29	1.38	1.44	1.47	1.476	1.479	1.480	1.480	1.480
21.5	1.32	1.40	1.45	1.47	1.477	1.480	1.480	1.480	1.480
22.0	1.35	1.42	1.46	1.48	1.478	1.480	1.480	1.480	1.480
22.5	1.38	1.44	1.47	1.48	1.479	1.480	1.480	1.480	1.480
23.0	1.42	1.45	1.47	1.48	1.479	1.480	1.480	1.480	1.480
23.5	1.45	1.47	1.48	1.479	1.480	1.480	1.480	1.480	1.480
24.0	1.48	1.48	1.48	1.480	1.480	1.480	1.480	1.480	1.480

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Subject: New Mexico Department of Game & Fish	Made by: TML	Job No.: 1772.16.00
	Laguna Del Campo Dam	Checked: DTH	Date: 5/20/2016
	Spillway Evaluation - Design Storms	Approved: TSS	

NOAA Atlas 14, Volume 1, Version 5 - Hyetographs for Laguna Del Campo Reservoir HEC-HMS Model (10-year ARI, 24-hour Duration Storms)

Source for precipitation frequency data: http://hdsc.nws.noaa.goc/hdsc/pfds/
(Note that this location lies within Semiarid Southwest Region 2.)

Selected Location Information

Latitude (°): 36.7062 **Name:** Los Ojos, New Mexico
Longitude (°): -106.5356 **Elevation (ft):** 7,628

10-yr, 24-h Storm point depth =	2.13	in
Areal Reduction Factor =	1.000	
10-yr, 24-h Storm factored depth =	2.13	in

Elapsed Time (hr)	Percentage of Occurance for Selected Storm Classification: First-Quartile Storms 90%	80%	70%	60%	50%	40%	30%	20%	10%
0.0	0.00	0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.000
0.5	0.05	0.07	0.10	0.13	0.171	0.22	0.28	0.33	0.379
1.0	0.10	0.15	0.20	0.26	0.341	0.45	0.55	0.67	0.758
1.5	0.15	0.22	0.30	0.39	0.512	0.67	0.83	1.00	1.137
2.0	0.20	0.30	0.40	0.53	0.681	0.89	1.11	1.33	1.512
2.5	0.27	0.38	0.50	0.63	0.798	1.02	1.24	1.46	1.636
3.0	0.33	0.46	0.59	0.74	0.915	1.14	1.37	1.59	1.761
3.5	0.40	0.54	0.69	0.85	1.032	1.27	1.51	1.72	1.885
4.0	0.47	0.63	0.78	0.96	1.148	1.39	1.64	1.85	2.009
4.5	0.55	0.72	0.88	1.06	1.258	1.50	1.74	1.94	2.083
5.0	0.64	0.82	0.98	1.17	1.359	1.59	1.81	1.98	2.097
5.5	0.74	0.92	1.09	1.27	1.460	1.68	1.87	2.02	2.112
6.0	0.83	1.02	1.19	1.38	1.561	1.76	1.93	2.06	2.126
6.5	0.88	1.08	1.25	1.43	1.614	1.80	1.96	2.07	2.126
7.0	0.93	1.13	1.31	1.49	1.667	1.84	1.98	2.08	2.127
7.5	0.98	1.19	1.37	1.54	1.720	1.88	2.01	2.09	2.127
8.0	1.03	1.24	1.42	1.60	1.773	1.92	2.03	2.10	2.128
8.5	1.05	1.28	1.46	1.63	1.803	1.94	2.04	2.10	2.128
9.0	1.08	1.31	1.49	1.67	1.834	1.96	2.05	2.11	2.129
9.5	1.11	1.34	1.52	1.70	1.865	1.99	2.07	2.11	2.129
10.0	1.14	1.37	1.55	1.73	1.895	2.01	2.08	2.12	2.130
10.5	1.17	1.39	1.58	1.75	1.915	2.02	2.08	2.12	2.130
11.0	1.20	1.42	1.60	1.78	1.934	2.03	2.09	2.118	2.130
11.5	1.23	1.44	1.63	1.80	1.953	2.04	2.10	2.120	2.130
12.0	1.26	1.47	1.65	1.83	1.972	2.05	2.10	2.121	2.130
12.5	1.29	1.50	1.68	1.85	1.986	2.06	2.11	2.123	2.130
13.0	1.31	1.52	1.70	1.87	1.999	2.07	2.11	2.124	2.130
13.5	1.34	1.55	1.73	1.89	2.012	2.08	2.11	2.125	2.130
14.0	1.36	1.57	1.76	1.91	2.026	2.09	2.12	2.126	2.130
14.5	1.39	1.60	1.78	1.93	2.036	2.09	2.12	2.126	2.130
15.0	1.42	1.63	1.81	1.95	2.047	2.10	2.12	2.127	2.130
15.5	1.44	1.66	1.83	1.97	2.057	2.10	2.12	2.127	2.130
16.0	1.47	1.68	1.85	1.99	2.068	2.11	2.12	2.128	2.130
16.5	1.50	1.71	1.88	2.00	2.076	2.11	2.125	2.128	2.130
17.0	1.54	1.74	1.90	2.02	2.083	2.11	2.126	2.129	2.130
17.5	1.57	1.77	1.93	2.03	2.091	2.12	2.127	2.129	2.130
18.0	1.60	1.80	1.95	2.05	2.098	2.12	2.128	2.130	2.130
18.5	1.64	1.84	1.97	2.06	2.103	2.12	2.128	2.130	2.130
19.0	1.69	1.87	1.99	2.07	2.109	2.124	2.129	2.130	2.130
19.5	1.73	1.90	2.02	2.08	2.114	2.126	2.129	2.130	2.130
20.0	1.77	1.93	2.04	2.10	2.119	2.128	2.130	2.130	2.130
20.5	1.81	1.96	2.06	2.10	2.121	2.128	2.130	2.130	2.130
21.0	1.86	1.99	2.07	2.11	2.124	2.129	2.130	2.130	2.130
21.5	1.90	2.02	2.09	2.12	2.126	2.129	2.130	2.130	2.130
22.0	1.95	2.04	2.10	2.12	2.128	2.130	2.130	2.130	2.130
22.5	1.99	2.07	2.11	2.13	2.128	2.130	2.130	2.130	2.130
23.0	2.04	2.09	2.12	2.13	2.129	2.130	2.130	2.130	2.130
23.5	2.08	2.11	2.12	2.128	2.129	2.130	2.130	2.130	2.130
24.0	2.13	2.13	2.13	2.130	2.130	2.130	2.130	2.130	2.130

NOAA Atlas 14, Volume 1, Version 5 - Hyetographs for Laguna Del Campo Reservoir HEC-HMS Model (50-year ARI, 24-hour Duration Storms)

Source for precipitation frequency data: http://hdsc.nws.noaa.goc/hdsc/pfds/
(Note that this location lies within Semiarid Southwest Region 2.)

Selected Location Information

Latitude (°): 36.7062 **Name:** Los Ojos, New Mexico
Longitude (°): -106.5356 **Elevation (ft):** 7,628

50-yr, 24-h Storm point depth = 2.87 in
Areal Reduction Factor = 1.000
50-yr, 24-h Storm factored depth = 2.87 in

Elapsed Time (hr)	Percentage of Occurance for Selected Storm Classification: First-Quartile Storms								
	90%	80%	70%	60%	50%	40%	30%	20%	10%
0.0	0.00	0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.000
0.5	0.07	0.10	0.14	0.18	0.230	0.30	0.37	0.45	0.511
1.0	0.13	0.20	0.27	0.35	0.460	0.60	0.75	0.90	1.022
1.5	0.20	0.30	0.41	0.53	0.689	0.90	1.12	1.35	1.532
2.0	0.27	0.40	0.54	0.71	0.918	1.20	1.49	1.80	2.038
2.5	0.36	0.51	0.67	0.85	1.075	1.37	1.67	1.97	2.205
3.0	0.45	0.62	0.80	1.00	1.233	1.54	1.85	2.15	2.372
3.5	0.54	0.73	0.92	1.14	1.390	1.71	2.03	2.32	2.540
4.0	0.64	0.84	1.05	1.29	1.547	1.88	2.21	2.49	2.707
4.5	0.74	0.97	1.18	1.43	1.695	2.03	2.35	2.61	2.807
5.0	0.87	1.10	1.32	1.57	1.831	2.14	2.43	2.66	2.826
5.5	0.99	1.24	1.47	1.71	1.968	2.26	2.52	2.72	2.845
6.0	1.12	1.38	1.61	1.86	2.104	2.38	2.61	2.77	2.864
6.5	1.18	1.45	1.69	1.93	2.175	2.43	2.64	2.78	2.865
7.0	1.25	1.53	1.76	2.01	2.246	2.48	2.67	2.80	2.866
7.5	1.32	1.60	1.84	2.08	2.318	2.54	2.70	2.81	2.866
8.0	1.38	1.68	1.92	2.16	2.389	2.59	2.74	2.83	2.867
8.5	1.42	1.72	1.96	2.20	2.430	2.62	2.75	2.83	2.868
9.0	1.46	1.76	2.00	2.24	2.471	2.65	2.77	2.84	2.869
9.5	1.50	1.80	2.05	2.29	2.512	2.68	2.78	2.84	2.869
10.0	1.54	1.84	2.09	2.33	2.554	2.70	2.80	2.85	2.870
10.5	1.58	1.88	2.12	2.36	2.580	2.72	2.81	2.85	2.870
11.0	1.62	1.91	2.16	2.40	2.606	2.73	2.82	2.854	2.870
11.5	1.66	1.95	2.19	2.43	2.632	2.75	2.82	2.856	2.870
12.0	1.70	1.98	2.22	2.46	2.658	2.77	2.83	2.859	2.870
12.5	1.73	2.02	2.26	2.49	2.676	2.78	2.84	2.860	2.870
13.0	1.77	2.05	2.29	2.52	2.694	2.79	2.84	2.861	2.870
13.5	1.80	2.09	2.33	2.55	2.712	2.80	2.85	2.863	2.870
14.0	1.84	2.12	2.37	2.57	2.730	2.81	2.85	2.864	2.870
14.5	1.87	2.16	2.40	2.60	2.744	2.82	2.85	2.865	2.870
15.0	1.91	2.19	2.43	2.63	2.758	2.82	2.86	2.866	2.870
15.5	1.94	2.23	2.47	2.65	2.772	2.83	2.86	2.866	2.870
16.0	1.98	2.27	2.50	2.68	2.787	2.84	2.86	2.867	2.870
16.5	2.02	2.31	2.53	2.70	2.797	2.84	2.863	2.868	2.870
17.0	2.07	2.35	2.56	2.72	2.807	2.85	2.864	2.869	2.870
17.5	2.12	2.39	2.59	2.74	2.817	2.85	2.866	2.869	2.870
18.0	2.16	2.43	2.63	2.76	2.827	2.86	2.867	2.870	2.870
18.5	2.22	2.47	2.66	2.78	2.834	2.86	2.868	2.870	2.870
19.0	2.27	2.52	2.69	2.79	2.841	2.861	2.869	2.870	2.870
19.5	2.33	2.56	2.72	2.81	2.849	2.864	2.869	2.870	2.870
20.0	2.38	2.60	2.75	2.82	2.856	2.867	2.870	2.870	2.870
20.5	2.44	2.64	2.77	2.83	2.859	2.868	2.870	2.870	2.870
21.0	2.50	2.68	2.79	2.84	2.861	2.869	2.870	2.870	2.870
21.5	2.56	2.72	2.81	2.85	2.864	2.869	2.870	2.870	2.870
22.0	2.62	2.75	2.83	2.86	2.867	2.870	2.870	2.870	2.870
22.5	2.68	2.78	2.84	2.86	2.868	2.870	2.870	2.870	2.870
23.0	2.75	2.81	2.85	2.87	2.869	2.870	2.870	2.870	2.870
23.5	2.81	2.84	2.86	2.868	2.869	2.870	2.870	2.870	2.870
24.0	2.87	2.87	2.87	2.870	2.870	2.870	2.870	2.870	2.870

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Subject New Mexico Department of Game & Fish	Made by TML	Job No. 1772.16.00
	Laguna Del Campo Dam	Checked DTH	Date 5/20/2016
	Spillway Evaluation - Design Storms	Approved TSS	

NOAA Atlas 14, Volume 1, Version 5 - Hyetographs for Laguna Del Campo Reservoir HEC-HMS Model (100-year ARI, 24-hour Duration Storms)

Source for precipitation frequency data: http://hdsc.nws.noaa.goc/hdsc/pfds/
(Note that this location lies within Semiarid Southwest Region 2.)

Selected Location Information

Latitude (°): 36.7062 **Name:** Los Ojos, New Mexico
Longitude (°): -106.5356 **Elevation (ft):** 7,628

100-yr, 24-h Storm point depth = 3.22 in
Areal Reduction Factor = 1.000
100-yr, 24-h Storm factored depth = 3.22 in

Elapsed Time (hr)	Percentage of Occurance for Selected Storm Classification: First-Quartile Storms								
	90%	80%	70%	60%	50%	40%	30%	20%	10%
0.0	0.00	0.00	0.00	0.00	0.000	0.00	0.00	0.00	0.000
0.5	0.07	0.11	0.15	0.20	0.258	0.34	0.42	0.51	0.573
1.0	0.15	0.22	0.31	0.40	0.516	0.68	0.84	1.01	1.146
1.5	0.22	0.34	0.46	0.60	0.773	1.01	1.26	1.52	1.719
2.0	0.30	0.45	0.61	0.79	1.030	1.35	1.67	2.02	2.286
2.5	0.40	0.57	0.75	0.96	1.207	1.54	1.88	2.21	2.474
3.0	0.51	0.70	0.89	1.12	1.383	1.73	2.08	2.41	2.662
3.5	0.61	0.82	1.04	1.28	1.560	1.92	2.28	2.60	2.849
4.0	0.71	0.95	1.18	1.44	1.736	2.11	2.48	2.80	3.037
4.5	0.83	1.08	1.33	1.61	1.902	2.27	2.63	2.93	3.149
5.0	0.97	1.24	1.49	1.76	2.055	2.40	2.73	2.99	3.171
5.5	1.11	1.39	1.64	1.92	2.207	2.53	2.83	3.05	3.192
6.0	1.25	1.55	1.80	2.08	2.360	2.67	2.92	3.11	3.214
6.5	1.33	1.63	1.89	2.17	2.440	2.73	2.96	3.12	3.214
7.0	1.40	1.71	1.98	2.25	2.520	2.79	3.00	3.14	3.215
7.5	1.48	1.80	2.07	2.34	2.600	2.85	3.03	3.16	3.216
8.0	1.55	1.88	2.15	2.42	2.680	2.91	3.07	3.18	3.217
8.5	1.59	1.93	2.20	2.47	2.726	2.94	3.09	3.18	3.218
9.0	1.64	1.97	2.25	2.52	2.772	2.97	3.11	3.19	3.218
9.5	1.68	2.02	2.30	2.57	2.819	3.00	3.12	3.19	3.219
10.0	1.73	2.07	2.35	2.62	2.865	3.03	3.14	3.20	3.220
10.5	1.77	2.11	2.38	2.65	2.894	3.05	3.15	3.20	3.220
11.0	1.82	2.14	2.42	2.69	2.924	3.07	3.16	3.202	3.220
11.5	1.86	2.18	2.46	2.72	2.953	3.09	3.17	3.205	3.220
12.0	1.90	2.22	2.50	2.76	2.982	3.10	3.18	3.207	3.220
12.5	1.94	2.26	2.54	2.79	3.002	3.12	3.18	3.209	3.220
13.0	1.98	2.30	2.57	2.82	3.022	3.13	3.19	3.210	3.220
13.5	2.02	2.34	2.61	2.86	3.042	3.14	3.19	3.212	3.220
14.0	2.06	2.38	2.65	2.89	3.062	3.15	3.20	3.214	3.220
14.5	2.10	2.42	2.69	2.92	3.078	3.16	3.20	3.214	3.220
15.0	2.14	2.46	2.73	2.95	3.094	3.17	3.20	3.215	3.220
15.5	2.18	2.50	2.77	2.98	3.110	3.18	3.21	3.216	3.220
16.0	2.22	2.54	2.80	3.00	3.126	3.18	3.21	3.217	3.220
16.5	2.27	2.59	2.84	3.03	3.138	3.19	3.212	3.218	3.220
17.0	2.32	2.64	2.88	3.05	3.149	3.19	3.214	3.218	3.220
17.5	2.37	2.68	2.91	3.07	3.160	3.20	3.215	3.219	3.220
18.0	2.42	2.73	2.95	3.10	3.172	3.20	3.217	3.220	3.220
18.5	2.49	2.78	2.98	3.12	3.180	3.21	3.218	3.220	3.220
19.0	2.55	2.82	3.02	3.13	3.188	3.210	3.218	3.220	3.220
19.5	2.61	2.87	3.05	3.15	3.196	3.214	3.219	3.220	3.220
20.0	2.67	2.92	3.09	3.17	3.204	3.217	3.220	3.220	3.220
20.5	2.74	2.96	3.11	3.18	3.207	3.218	3.220	3.220	3.220
21.0	2.81	3.01	3.13	3.19	3.210	3.218	3.220	3.220	3.220
21.5	2.87	3.05	3.15	3.20	3.214	3.219	3.220	3.220	3.220
22.0	2.94	3.09	3.18	3.21	3.217	3.220	3.220	3.220	3.220
22.5	3.01	3.12	3.19	3.21	3.218	3.220	3.220	3.220	3.220
23.0	3.08	3.16	3.20	3.22	3.218	3.220	3.220	3.220	3.220
23.5	3.15	3.19	3.21	3.218	3.219	3.220	3.220	3.220	3.220
24.0	3.22	3.22	3.22	3.220	3.220	3.220	3.220	3.220	3.220

Appendix C2

Alternative 1 Calculations

OBJECTIVE:

Document the calculations involved in determining the breach width to be used as Laguna Del Campo Dam spillway Alternative 1. Also document the derivation of the tailwater rating curve to be used for sizing stilling basins as part of Alternatives 3a and 3b.

METHOD:

A one-dimensional steady flow model of the Laguna Del Campo Dam stream reach starting 140 feet upstream of the dam and extending 19,700 downstream of the dam was constructed using HEC-RAS 5.0.1 software (USACE, 2016). Two versions of the model were created: one without the dam embankment and one with the dam embankment including a full height trapezoidal breach with a 100 foot bottom width and 3 H:1V side slopes.

The two versions of the HEC-RAS model were run with the peak inflow from a 100-year average recurrence interval (ARI), 24-hour frequency storm. (Derivation of the 100-year ARI, 24-hour storm is discussed in the Design Storms Appendix and calculation of the peak inflow from this storm using a HEC-HMS version 4.1 hydrologic model (USACE, 2015) of the Laguna Del Campo watershed is discussed in the Alternative 2 Calculations Appendix.) The resulting water surface elevations at a location immediately upstream of the dam were then compared in order to quantify the impact of the breached dam on pre-dam conditions.

The first version of the HEC-RAS model was also executed with a range of flow rates. The tailwater flow depths downstream of the dam were computed for each flow rate and a tailwater rating curve was assembled from the results.

ASSUMPTIONS:

The following assumptions were employed:

- Digital topography of the Laguna Del Campo Dam stream reach was obtained from the United States Geological Survey (USGS). A 1/3 arc-second digital elevation model (DEM) was downloaded from the national elevation database (see Figure 1) and converted to the New Mexico State Plane, Central Zone projection using the North American Vertical Datum of 1988 (NAVD88). Cross sections were obtained from this topography at a maximum 100 foot spacing to form the topographic basis for the HEC-RAS models downstream of the dam. Upstream of the dam, topography was assembled by combining the USGS DEM information with reservoir contours taken from a scanned design drawing of Laguna Del Campo Dam, included as Figure A-2 in Appendix A of "Laguna Del Campo Dam OSE Filing No. D313 Breach Analysis Report – Rio Arriba County, New Mexico" (URS, 2012).
- Derived cross sections were augmented with interpolated cross sections at a 10 foot maximum spacing using the three-dimensional interpolation function within HEC-RAS for greater computational accuracy.
- Channel roughness (Manning's n) values were assumed using photographs of the reach in question, overhead satellite imagery from Google Earth and tabulated values taken from "Open Channel Hydraulics" (Chow, 1959):
  - Main channel, n = 0.030.
  - Flood plains (overbank areas with no trees), n = 0.035, and
  - Flood plains (overbank areas with trees), n = 0.060.

- Expansion and contraction coefficient values were left at their respective default values:
  - Contraction coefficient, C_C = 0.10 and
  - Expansion coefficient, C_E = 0.30.
- Upstream and downstream initial water surface boundary conditions were computed by HEC-RAS as normal depth, assuming that the slopes of the energy grade lines at those two locations can be approximated as the ground slopes measured from the assembled model topography:
  - Upstream slope, S_{US} = 0.020 ft/ft and
  - Downstream slope, S_{DS} = 0.023 ft/ft.
- Inflow to Laguna Del Campo Dam from a 100-yr ARI, 24-hr duration storm is 3,148 ft^3/s.

CALCULATIONS:

Once the two HEC-RAS models were assembled and executed, the results were inspected and collected for use in the Laguna Del Campo Dam spillway alternatives evaluation.

CONCLUSIONS/RESULTS:

The HEC-RAS water surface profile results for the “No Dam” and “Dam with 100 foot Breach” scenarios with the comparison location at the upstream dam toe highlighted are included in Tables 1 and 2, respectively. Cross section plots illustrating the differences in both topography and resulting water surface elevation are provided as Attachment 1. Comparing the peak water surface elevation results, there is a 1.4 foot raise in the upstream water surface caused by the 100 foot dam breach, which complies with New Mexico Office of the State Engineer guidelines.

The HEC-RAS water surface profile results for the tailwater scenario are included in Table 3 and illustrated on Figure 2. These results are used in sizing stilling basins as part of Alternatives 3a and 3b.

REFERENCES:

1. Chow, V.T., *“Open-Channel Hydraulics”*, 1959. Caldwell, NJ.

2. URS, *“Laguna Del Campo Dam OSE Filing No. D313 Breach Analysis Report – Rio Arriba County, New Mexico”*, Design report prepared for the New Mexico Department of Game and Fish, July, 2012. Denver, CO.

3. United States Army Corps of Engineers (USACE), *“HEC-HMS Hydrologic Modeling System, Version 4.1”*, Computer software, July, 2015. Davis, CA.

4. United States Army Corps of Engineers (USACE), *“HEC-RAS River Analysis System, Version 5.0.1”*, Computer software, April, 2016. Davis, CA.

TABLES

Table 1: Laguna Del Campo Dam HEC-RAS Model Results, No Dam Scenario

Plan: LDC_BR_NONE **Geometry File:** LDC_TW **Steady Flow File:** Frequency Storm Flows **Selected Profile:** 3148 cfs (100-yr, 24-hr)

River	Reach	HEC-RAS Cross Section (ft)	Channel Station (ft)	Peak Outflow (ft^3/s)	Channel Invert (ft)	Peak WS Elevation (ft)	Critical WS Elevation (ft)	EGL Elevation (ft)	EGL Slope (ft/ft)	Channel Velocity (ft/s)	Flow Area (ft^2)	Top Width (ft)	Froude Number	Peak Flow Depth (ft)	Flow Regime
Laguna_Del_Campo	Natural_Channel	2000.0	0+00.0	3148.00	7291.21	7293.63	7294.09	7295.27	0.020293	10.60	321.58	213.46	1.38	2.42	Supercritical
Laguna_Del_Campo	Natural_Channel	1900.0	1+00.0	3148.00	7288.99	7290.94	7291.45	7292.72	0.026264	11.19	306.02	211.75	1.54	1.95	Supercritical
Laguna_Del_Campo	Natural_Channel	1859.5	1+40.5	3148.00	7287.88	7289.99	7290.50	7291.75	0.021978	10.98	314.93	222.67	1.43	2.11	Supercritical
Laguna_Del_Campo	Natural_Channel	1800.0	2+00.0	3148.00	7286.67	7288.99	7289.43	7290.61	0.018258	10.47	326.12	209.22	1.32	2.32	Supercritical
Laguna_Del_Campo	Natural_Channel	1754.8	2+45.2	3148.00	7285.75	7289.58	7288.71	7290.04	0.002978	5.85	623.01	256.30	0.58	3.83	Subcritical
Laguna_Del_Campo	Natural_Channel	1739.9	2+60.1	3148.00	7285.45	7289.65	7288.23	7289.96	0.001624	4.86	763.59	264.90	0.44	4.20	Subcritical
Laguna_Del_Campo	Natural_Channel	1700.0	3+00.0	3148.00	7284.64	7289.69	7287.49	7289.88	0.000855	3.94	952.14	272.16	0.33	5.05	Subcritical
Laguna_Del_Campo	Natural_Channel	1664.8	3+35.2	3148.00	7283.93	7288.22	7288.22	7289.66	0.009033	9.68	331.52	118.23	0.99	4.29	Subcritical
Laguna_Del_Campo	Natural_Channel	1600.0	4+00.0	3148.00	7282.61	7285.06	7285.97	7288.06	0.028120	14.05	234.31	127.50	1.67	2.45	Supercritical
Laguna_Del_Campo	Natural_Channel	1500.0	5+00.0	3148.00	7280.55	7285.49	7285.49	7287.02	0.006866	10.85	355.76	120.94	0.92	4.94	Subcritical
Laguna_Del_Campo	Natural_Channel	1400.0	6+00.0	3148.00	7278.08	7282.59	7283.52	7285.58	0.016017	14.77	252.27	102.39	1.37	4.51	Supercritical
Laguna_Del_Campo	Natural_Channel	1300.0	7+00.0	3148.00	7274.72	7278.04	7279.38	7282.34	0.042111	17.42	207.07	101.46	1.83	3.32	Supercritical
Laguna_Del_Campo	Natural_Channel	1200.0	8+00.0	3148.00	7271.69	7274.81	7276.05	7278.75	0.029874	16.51	212.65	106.04	1.78	3.12	Supercritical
Laguna_Del_Campo	Natural_Channel	1100.0	9+00.0	3148.00	7268.86	7273.12	7274.17	7276.40	0.018774	15.75	247.49	106.41	1.47	4.26	Supercritical
Laguna_Del_Campo	Natural_Channel	1000.0	10+00.0	3148.00	7264.70	7268.61	7270.15	7273.53	0.033671	18.70	193.02	87.37	1.92	3.91	Supercritical
Laguna_Del_Campo	Natural_Channel	900.0	11+00.0	3148.00	7263.03	7266.43	7267.59	7270.20	0.028523	15.85	211.77	99.50	1.73	3.40	Supercritical
Laguna_Del_Campo	Natural_Channel	800.0	12+00.0	3148.00	7260.89	7265.51	7266.09	7267.92	0.012069	13.91	313.34	114.08	1.21	4.62	Supercritical
Laguna_Del_Campo	Natural_Channel	700.0	13+00.0	3148.00	7259.43	7263.11	7263.90	7265.79	0.022563	13.63	267.80	120.45	1.36	3.68	Supercritical
Laguna_Del_Campo	Natural_Channel	600.0	14+00.0	3148.00	7257.45	7261.71	7262.28	7264.01	0.012857	12.95	285.23	114.87	1.22	4.26	Supercritical
Laguna_Del_Campo	Natural_Channel	500.0	15+00.0	3148.00	7255.34	7260.06	7260.76	7262.65	0.012966	13.92	274.31	104.88	1.24	4.72	Supercritical
Laguna_Del_Campo	Natural_Channel	400.0	16+00.0	3148.00	7252.93	7257.94	7259.18	7261.14	0.015463	15.68	247.81	92.83	1.37	5.01	Supercritical
Laguna_Del_Campo	Natural_Channel	300.0	17+00.0	3148.00	7252.52	7255.55	7256.48	7258.62	0.023987	14.27	231.51	107.18	1.58	3.03	Supercritical
Laguna_Del_Campo	Natural_Channel	200.0	18+00.0	3148.00	7249.82	7253.40	7254.37	7256.54	0.018698	14.95	239.45	98.42	1.45	3.58	Supercritical
Laguna_Del_Campo	Natural_Channel	100.0	19+00.0	3148.00	7247.84	7251.11	7252.07	7254.32	0.024226	14.53	225.15	100.74	1.59	3.27	Supercritical
Laguna_Del_Campo	Natural_Channel	0.0	20+00.0	3148.00	7245.41	7248.15	7249.18	7251.53	0.029415	14.89	218.65	106.71	1.72	2.74	Supercritical

Table 2: Laguna Del Campo Dam HEC-RAS Model Results, Dam with 100 ft Breach Scenario

Plan: LDC_BR_100 **Geometry File:** LDC_BR_100 **Steady Flow File:** Frequency Storm Flows **Selected Profile:** 3148 cfs (100-yr, 24-hr)

River	Reach	HEC-RAS Cross Section (ft)	Channel Station (ft)	Peak Outflow (ft^3/s)	Channel Invert (ft)	Peak WS Elevation (ft)	Critical WS Elevation (ft)	EGL Elevation (ft)	EGL Slope (ft/ft)	Channel Velocity (ft/s)	Flow Area (ft^2)	Top Width (ft)	Froude Number	Peak Flow Depth (ft)	Flow Regime
Laguna_Del_Campo	Natural_Channel	2000.0	0+00.0	3148.00	7291.21	7293.63	7294.09	7295.27	0.020293	10.60	321.58	213.46	1.38	2.42	Supercritical
Laguna_Del_Campo	Natural_Channel	1900.0	1+00.0	3148.00	7288.99	7293.96	7291.45	7294.12	0.000643	3.51	1024.93	265.04	0.29	4.97	Subcritical
Laguna_Del_Campo	Natural_Channel	1859.5	1+40.5	3148.00	7288.95	7291.41	7291.98	7293.61	0.019110	11.89	264.65	114.79	1.38	2.46	Supercritical
Laguna_Del_Campo	Natural_Channel	1800.0	2+00.0	3148.00	7286.78	7291.31	7289.80	7291.89	0.002388	6.11	515.59	127.23	0.53	4.53	Subcritical
Laguna_Del_Campo	Natural_Channel	1754.8	2+45.2	3148.00	7287.19	7290.22	7290.22	7291.63	0.009535	9.54	330.00	118.15	1.01	3.03	Supercritical
Laguna_Del_Campo	Natural_Channel	1739.9	2+60.1	3148.00	7285.85	7287.91	7288.88	7291.12	0.034896	14.38	218.96	112.37	1.82	2.06	Supercritical
Laguna_Del_Campo	Natural_Channel	1700.0	3+00.0	3148.00	7284.64	7286.78	7287.68	7289.80	0.030401	14.01	227.48	112.83	1.72	2.14	Supercritical
Laguna_Del_Campo	Natural_Channel	1664.8	3+35.2	3148.00	7283.93	7286.25	7286.97	7288.79	0.023603	13.02	249.07	113.97	1.53	2.32	Supercritical
Laguna_Del_Campo	Natural_Channel	1600.0	4+00.0	3148.00	7282.61	7286.66	7285.97	7287.49	0.003950	7.58	465.92	170.44	0.69	4.05	Subcritical
Laguna_Del_Campo	Natural_Channel	1500.0	5+00.0	3148.00	7280.55	7285.49	7285.49	7287.02	0.006866	10.85	355.76	120.94	0.92	4.94	Subcritical
Laguna_Del_Campo	Natural_Channel	1400.0	6+00.0	3148.00	7278.08	7282.59	7283.52	7285.58	0.016017	14.77	252.27	102.39	1.37	4.51	Supercritical
Laguna_Del_Campo	Natural_Channel	1300.0	7+00.0	3148.00	7274.72	7278.04	7279.38	7282.34	0.042111	17.42	207.07	101.46	1.83	3.32	Supercritical
Laguna_Del_Campo	Natural_Channel	1200.0	8+00.0	3148.00	7271.69	7274.81	7276.05	7278.75	0.029874	16.51	212.65	106.04	1.78	3.12	Supercritical
Laguna_Del_Campo	Natural_Channel	1100.0	9+00.0	3148.00	7268.86	7273.12	7274.17	7276.40	0.018774	15.75	247.49	106.41	1.47	4.26	Supercritical
Laguna_Del_Campo	Natural_Channel	1000.0	10+00.0	3148.00	7264.70	7268.61	7270.15	7273.53	0.033671	18.70	193.02	87.37	1.92	3.91	Supercritical
Laguna_Del_Campo	Natural_Channel	900.0	11+00.0	3148.00	7263.03	7266.43	7267.59	7270.20	0.028523	15.85	211.77	99.50	1.73	3.40	Supercritical
Laguna_Del_Campo	Natural_Channel	800.0	12+00.0	3148.00	7260.89	7265.51	7266.09	7267.92	0.012069	13.91	313.34	114.08	1.21	4.62	Supercritical
Laguna_Del_Campo	Natural_Channel	700.0	13+00.0	3148.00	7259.43	7263.11	7263.90	7265.79	0.022563	13.63	267.80	120.45	1.36	3.68	Supercritical
Laguna_Del_Campo	Natural_Channel	600.0	14+00.0	3148.00	7257.45	7261.71	7262.28	7264.01	0.012857	12.95	285.23	114.87	1.22	4.26	Supercritical
Laguna_Del_Campo	Natural_Channel	500.0	15+00.0	3148.00	7255.34	7260.06	7260.76	7262.65	0.012966	13.92	274.31	104.88	1.24	4.72	Supercritical
Laguna_Del_Campo	Natural_Channel	400.0	16+00.0	3148.00	7252.93	7257.94	7259.18	7261.14	0.015463	15.68	247.81	92.83	1.37	5.01	Supercritical
Laguna_Del_Campo	Natural_Channel	300.0	17+00.0	3148.00	7252.52	7255.55	7256.48	7258.62	0.023987	14.27	231.51	107.18	1.58	3.03	Supercritical
Laguna_Del_Campo	Natural_Channel	200.0	18+00.0	3148.00	7249.82	7253.40	7254.37	7256.54	0.018698	14.95	239.45	98.42	1.45	3.58	Supercritical
Laguna_Del_Campo	Natural_Channel	100.0	19+00.0	3148.00	7247.84	7251.11	7252.07	7254.32	0.024226	14.53	225.15	100.74	1.59	3.27	Supercritical
Laguna_Del_Campo	Natural_Channel	0.0	20+00.0	3148.00	7245.41	7248.15	7249.18	7251.53	0.029415	14.89	218.65	106.71	1.72	2.74	Supercritical

Table 3: Laguna Del Campo Dam HEC-RAS Model Results, Tailwater Rating Curve Scenario

Plan: LDC_TWR
Steady Flow File: Tailwater Rating Flows
Geometry File: LDC_TW
Selected Profile: 100 cfs - 20000 cfs

River	Reach	HEC-RAS Cross Section (ft)	Channel Station (ft)	Peak Outflow (ft^3/s)	Channel Invert (ft)	Peak WS Elevation (ft)	Froude Number	Tailwater Depth (ft)	Flow Regime
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	100	7281.99	7282.62	0.91	0.63	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	200	7281.99	7282.76	1.20	0.77	Supercritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	300	7281.99	7282.99	1.10	1.00	Supercritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	400	7281.99	7283.29	0.90	1.30	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	500	7281.99	7283.45	0.90	1.46	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	600	7281.99	7283.61	0.88	1.62	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	700	7281.99	7283.76	0.87	1.77	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	800	7281.99	7283.91	0.85	1.92	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	900	7281.99	7284.06	0.83	2.07	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	1000	7281.99	7284.21	0.81	2.22	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	1100	7281.99	7284.35	0.79	2.36	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	1200	7281.99	7284.48	0.78	2.49	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	1300	7281.99	7284.62	0.76	2.63	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	1400	7281.99	7284.75	0.75	2.76	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	1500	7281.99	7284.88	0.74	2.89	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	1600	7281.99	7284.99	0.73	3.00	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	1700	7281.99	7285.10	0.73	3.11	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	1800	7281.99	7285.22	0.72	3.23	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	1900	7281.99	7285.32	0.72	3.33	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	2000	7281.99	7285.43	0.71	3.44	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	2100	7281.99	7285.54	0.71	3.55	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	2200	7281.99	7285.65	0.70	3.66	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	2300	7281.99	7285.74	0.70	3.75	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	2400	7281.99	7285.84	0.69	3.85	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	2500	7281.99	7285.94	0.69	3.95	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	2600	7281.99	7286.04	0.68	4.05	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	2700	7281.99	7286.13	0.68	4.14	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	2800	7281.99	7286.23	0.67	4.24	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	2900	7281.99	7286.32	0.67	4.33	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	3000	7281.99	7286.41	0.67	4.42	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	3100	7281.99	7286.50	0.66	4.51	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	3200	7281.99	7286.59	0.66	4.60	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	3300	7281.99	7286.67	0.66	4.68	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	3400	7281.99	7286.76	0.65	4.77	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	3500	7281.99	7286.84	0.65	4.85	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	3600	7281.99	7286.93	0.65	4.94	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	3700	7281.99	7287.02	0.64	5.03	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	3800	7281.99	7287.10	0.64	5.11	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	3900	7281.99	7287.19	0.64	5.20	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	4000	7281.99	7287.26	0.63	5.27	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	4100	7281.99	7287.35	0.63	5.36	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	4200	7281.99	7287.44	0.63	5.45	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	4300	7281.99	7287.52	0.62	5.53	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	4400	7281.99	7287.60	0.62	5.61	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	4500	7281.99	7287.67	0.62	5.68	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	4600	7281.99	7287.75	0.62	5.76	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	4700	7281.99	7287.82	0.61	5.83	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	4800	7281.99	7287.90	0.61	5.91	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	4900	7281.99	7287.96	0.61	5.97	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	5000	7281.99	7288.03	0.61	6.04	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	5100	7281.99	7288.11	0.61	6.12	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	5200	7281.99	7288.17	0.61	6.18	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	5300	7281.99	7288.24	0.60	6.25	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	5400	7281.99	7288.30	0.60	6.31	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	5500	7281.99	7288.37	0.60	6.38	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	5600	7281.99	7288.44	0.60	6.45	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	5700	7281.99	7288.50	0.60	6.51	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	5800	7281.99	7288.57	0.60	6.58	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	5900	7281.99	7288.63	0.60	6.64	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	6000	7281.99	7288.69	0.60	6.70	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	6100	7281.99	7288.76	0.60	6.77	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	6200	7281.99	7288.81	0.60	6.82	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	6300	7281.99	7288.87	0.60	6.88	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	6400	7281.99	7288.93	0.60	6.94	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	6500	7281.99	7288.99	0.60	7.00	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	6600	7281.99	7289.06	0.59	7.07	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	6700	7281.99	7289.11	0.60	7.12	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	6800	7281.99	7289.17	0.59	7.18	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	6900	7281.99	7289.23	0.59	7.24	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	7000	7281.99	7289.28	0.59	7.29	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	7100	7281.99	7289.34	0.59	7.35	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	7200	7281.99	7289.39	0.59	7.40	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	7300	7281.99	7289.45	0.59	7.46	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	7400	7281.99	7289.51	0.59	7.52	Subcritical

Table 3: Laguna Del Campo Dam HEC-RAS Model Results, Tailwater Rating Curve Scenario

Plan: LDC_TWR **Geometry File:** LDC_TW
Steady Flow File: Tailwater Rating Flows **Selected Profile:** 100 cfs - 20000 cfs

River	Reach	HEC-RAS Cross Section (ft)	Channel Station (ft)	Peak Outflow (ft^3/s)	Channel Invert (ft)	Peak WS Elevation (ft)	Froude Number	Tailwater Depth (ft)	Flow Regime
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	7500	7281.99	7289.56	0.59	7.57	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	7600	7281.99	7289.61	0.59	7.62	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	7700	7281.99	7289.67	0.59	7.68	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	7800	7281.99	7289.72	0.59	7.73	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	7900	7281.99	7289.77	0.59	7.78	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	8000	7281.99	7289.82	0.59	7.83	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	8100	7281.99	7289.87	0.59	7.88	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	8200	7281.99	7289.93	0.59	7.94	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	8300	7281.99	7289.97	0.59	7.98	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	8400	7281.99	7290.03	0.59	8.04	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	8500	7281.99	7290.08	0.59	8.09	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	8600	7281.99	7290.15	0.59	8.16	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	8700	7281.99	7290.18	0.59	8.19	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	8800	7281.99	7290.23	0.59	8.24	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	8900	7281.99	7290.28	0.59	8.29	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	9000	7281.99	7290.32	0.59	8.33	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	9100	7281.99	7290.37	0.59	8.38	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	9200	7281.99	7290.43	0.59	8.44	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	9300	7281.99	7290.48	0.59	8.49	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	9400	7281.99	7290.53	0.59	8.54	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	9500	7281.99	7290.56	0.59	8.57	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	9600	7281.99	7290.61	0.59	8.62	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	9700	7281.99	7290.66	0.59	8.67	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	9800	7281.99	7290.70	0.59	8.71	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	9900	7281.99	7290.75	0.59	8.76	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	10000	7281.99	7290.80	0.59	8.81	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	10100	7281.99	7290.84	0.59	8.85	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	10200	7281.99	7290.88	0.59	8.89	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	10300	7281.99	7290.93	0.59	8.94	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	10400	7281.99	7290.98	0.59	8.99	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	10500	7281.99	7291.02	0.59	9.03	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	10600	7281.99	7291.06	0.59	9.07	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	10700	7281.99	7291.11	0.59	9.12	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	10800	7281.99	7291.15	0.59	9.16	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	10900	7281.99	7291.20	0.59	9.21	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	11000	7281.99	7291.24	0.59	9.25	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	11100	7281.99	7291.28	0.59	9.29	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	11200	7281.99	7291.32	0.59	9.33	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	11300	7281.99	7291.37	0.59	9.38	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	11400	7281.99	7291.42	0.59	9.43	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	11500	7281.99	7291.46	0.59	9.47	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	11600	7281.99	7291.50	0.59	9.51	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	11700	7281.99	7291.54	0.59	9.55	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	11800	7281.99	7291.57	0.60	9.58	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	11900	7281.99	7291.61	0.60	9.62	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	12000	7281.99	7291.65	0.60	9.66	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	12100	7281.99	7291.69	0.60	9.70	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	12200	7281.99	7291.73	0.60	9.74	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	12300	7281.99	7291.75	0.60	9.76	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	12400	7281.99	7291.80	0.60	9.81	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	12500	7281.99	7291.84	0.60	9.85	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	12600	7281.99	7291.88	0.60	9.89	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	12700	7281.99	7291.97	0.59	9.98	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	12800	7281.99	7291.95	0.60	9.96	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	12900	7281.99	7291.99	0.60	10.00	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	13000	7281.99	7292.03	0.60	10.04	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	13100	7281.99	7292.06	0.60	10.07	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	13200	7281.99	7292.10	0.60	10.11	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	13300	7281.99	7292.14	0.60	10.15	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	13400	7281.99	7292.18	0.60	10.19	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	13500	7281.99	7292.22	0.60	10.23	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	13600	7281.99	7292.25	0.60	10.26	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	13700	7281.99	7292.28	0.60	10.29	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	13800	7281.99	7292.32	0.60	10.33	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	13900	7281.99	7292.36	0.60	10.37	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	14000	7281.99	7292.40	0.60	10.41	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	14100	7281.99	7292.43	0.60	10.44	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	14200	7281.99	7292.47	0.60	10.48	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	14300	7281.99	7292.50	0.60	10.51	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	14400	7281.99	7292.54	0.60	10.55	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	14500	7281.99	7292.57	0.60	10.58	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	14600	7281.99	7292.61	0.60	10.62	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	14700	7281.99	7292.64	0.60	10.65	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	14800	7281.99	7292.67	0.60	10.68	Subcritical

Table 3: Laguna Del Campo Dam HEC-RAS Model Results, Tailwater Rating Curve Scenario

Plan: LDC_TWR
Steady Flow File: Tailwater Rating Flows
Geometry File: LDC_TW
Selected Profile: 100 cfs - 20000 cfs

River	Reach	HEC-RAS Cross Section (ft)	Channel Station (ft)	Peak Outflow (ft^3/s)	Channel Invert (ft)	Peak WS Elevation (ft)	Froude Number	Tailwater Depth (ft)	Flow Regime
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	14900	7281.99	7292.71	0.60	10.72	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	15000	7281.99	7292.77	0.60	10.78	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	15100	7281.99	7292.79	0.60	10.80	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	15200	7281.99	7292.82	0.60	10.83	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	15300	7281.99	7292.86	0.60	10.87	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	15400	7281.99	7292.90	0.60	10.91	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	15500	7281.99	7292.94	0.60	10.95	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	15600	7281.99	7292.97	0.60	10.98	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	15700	7281.99	7292.99	0.61	11.00	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	15800	7281.99	7293.03	0.61	11.04	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	15900	7281.99	7293.07	0.61	11.08	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	16000	7281.99	7293.11	0.61	11.12	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	16100	7281.99	7293.15	0.61	11.16	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	16200	7281.99	7293.18	0.61	11.19	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	16300	7281.99	7293.22	0.61	11.23	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	16400	7281.99	7293.26	0.61	11.27	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	16500	7281.99	7293.29	0.61	11.30	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	16600	7281.99	7293.31	0.61	11.32	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	16700	7281.99	7293.35	0.61	11.36	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	16800	7281.99	7293.39	0.61	11.40	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	16900	7281.99	7293.42	0.61	11.43	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	17000	7281.99	7293.45	0.61	11.46	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	17100	7281.99	7293.49	0.61	11.50	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	17200	7281.99	7293.52	0.61	11.53	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	17300	7281.99	7293.56	0.61	11.57	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	17400	7281.99	7293.58	0.61	11.59	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	17500	7281.99	7293.61	0.61	11.62	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	17600	7281.99	7293.65	0.61	11.66	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	17700	7281.99	7293.68	0.61	11.69	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	17800	7281.99	7293.71	0.61	11.72	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	17900	7281.99	7293.75	0.61	11.76	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	18000	7281.99	7293.77	0.61	11.78	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	18100	7281.99	7293.80	0.61	11.81	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	18200	7281.99	7293.85	0.61	11.86	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	18300	7281.99	7293.89	0.61	11.90	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	18400	7281.99	7293.93	0.61	11.94	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	18500	7281.99	7293.97	0.61	11.98	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	18600	7281.99	7294.06	0.60	12.07	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	18700	7281.99	7294.04	0.61	12.05	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	18800	7281.99	7294.08	0.61	12.09	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	18900	7281.99	7294.12	0.61	12.13	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	19000	7281.99	7294.18	0.61	12.19	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	19100	7281.99	7294.24	0.60	12.25	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	19200	7281.99	7294.36	0.60	12.37	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	19300	7281.99	7294.42	0.59	12.43	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	19400	7281.99	7294.47	0.59	12.48	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	19500	7281.99	7294.52	0.59	12.53	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	19600	7281.99	7294.55	0.59	12.56	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	19700	7281.99	7294.60	0.59	12.61	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	19800	7281.99	7294.65	0.59	12.66	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	19900	7281.99	7294.67	0.59	12.68	Subcritical
Laguna_Del_Campo	Natural_Channel	1570.0	4+30.0	20000	7281.99	7294.74	0.59	12.75	Subcritical

FIGURES

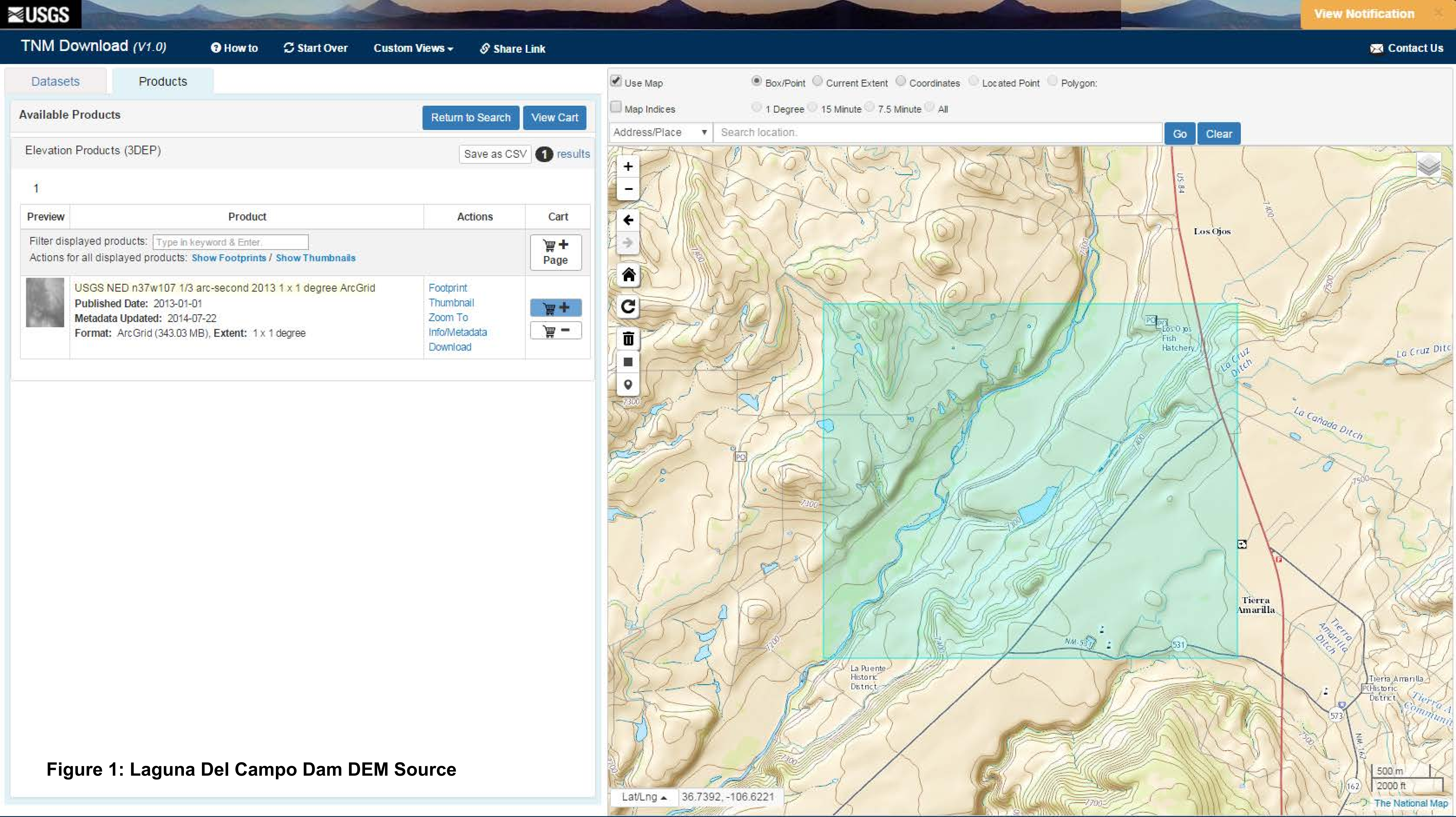
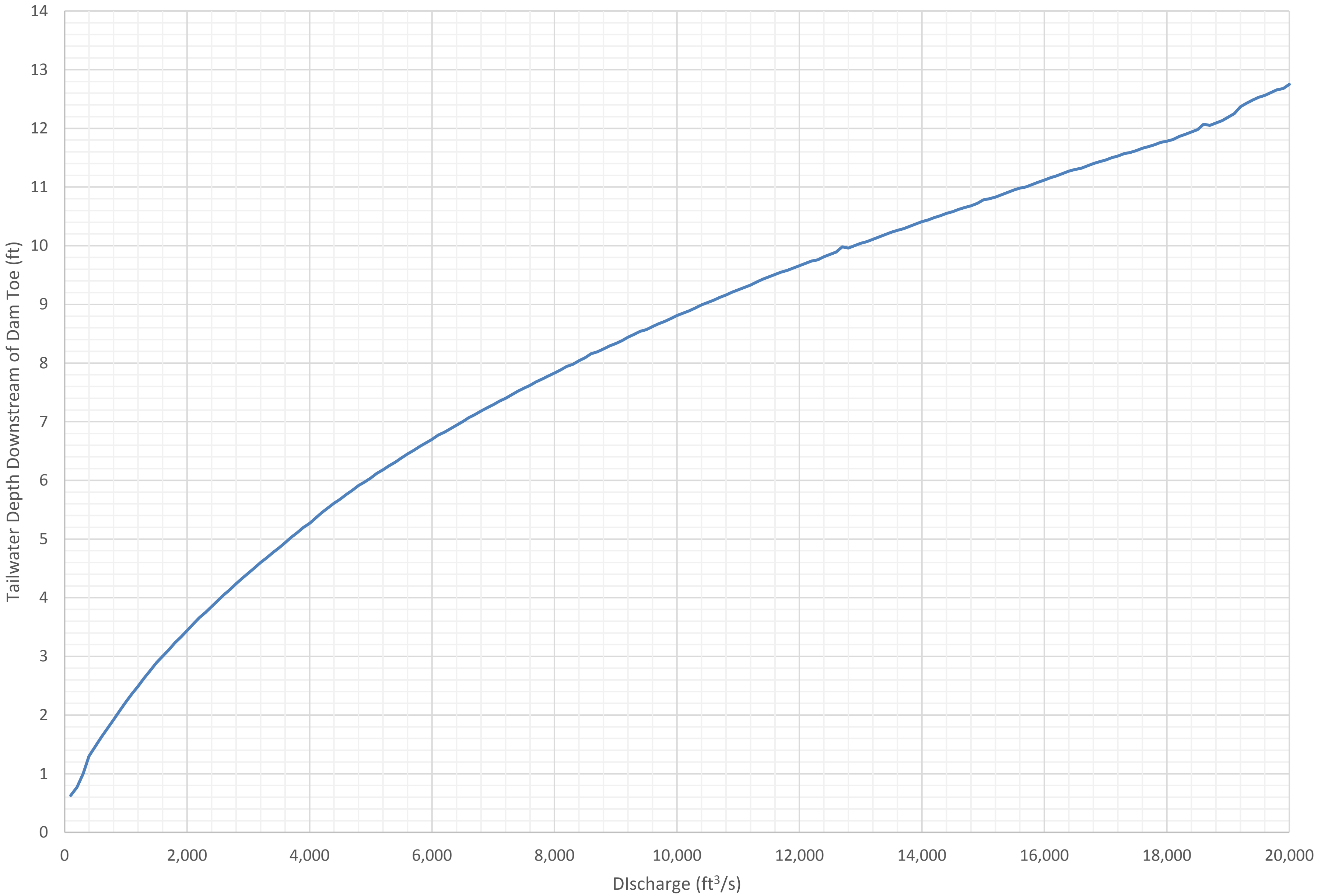


Figure 1: Laguna Del Campo Dam DEM Source

Figure 2: Laguna Del Campo Dam Tailwater Rating Curve



ATTACHMENT 1

HEC-RAS CROSS SECTION PLOTS COMPARING NO DAM AND DAM WITH 100 FOOT BREACH SCENARIOS

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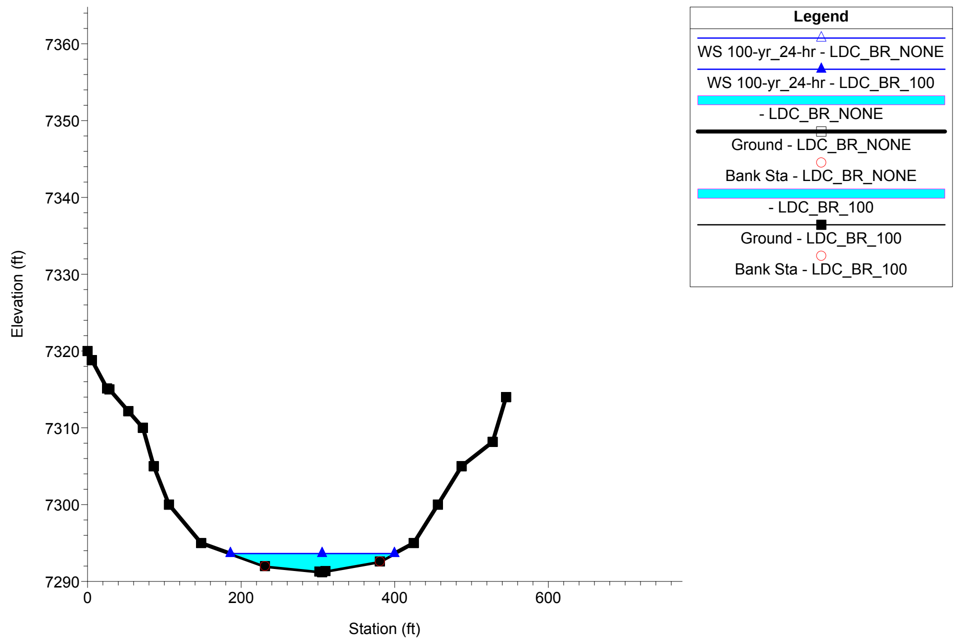
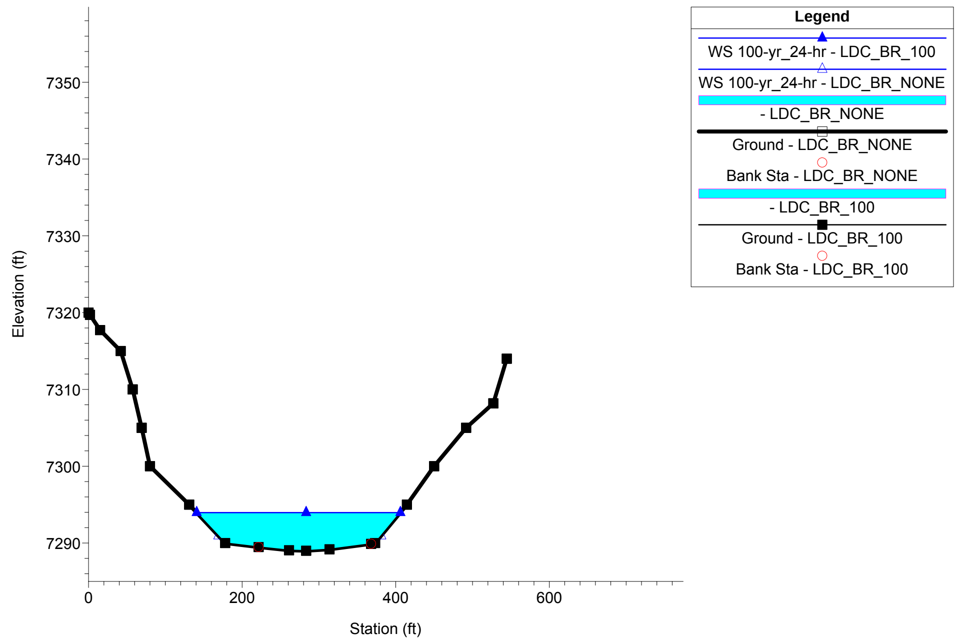
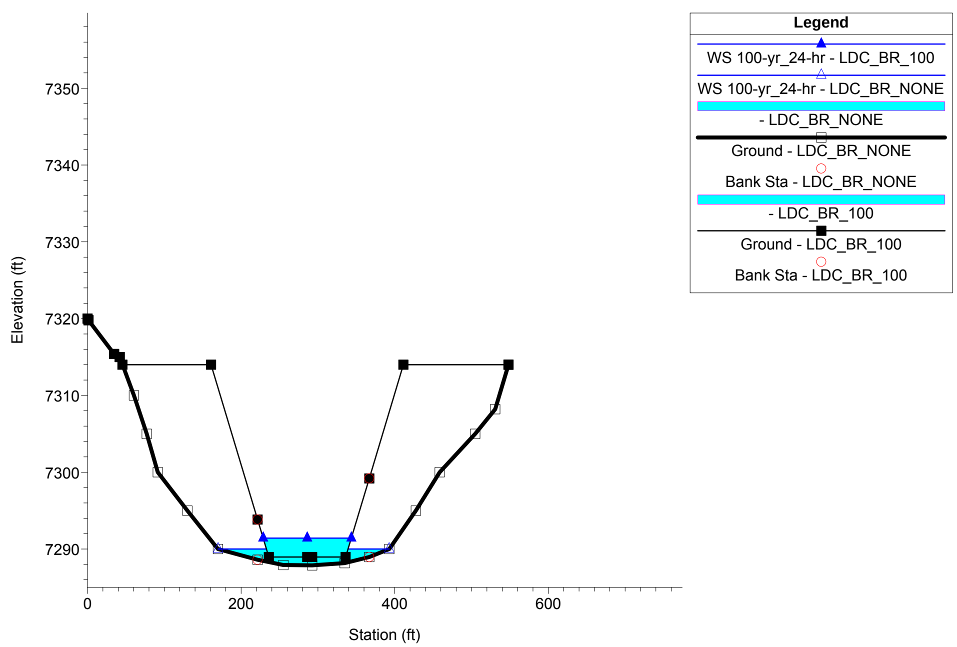
STA 0+00.0



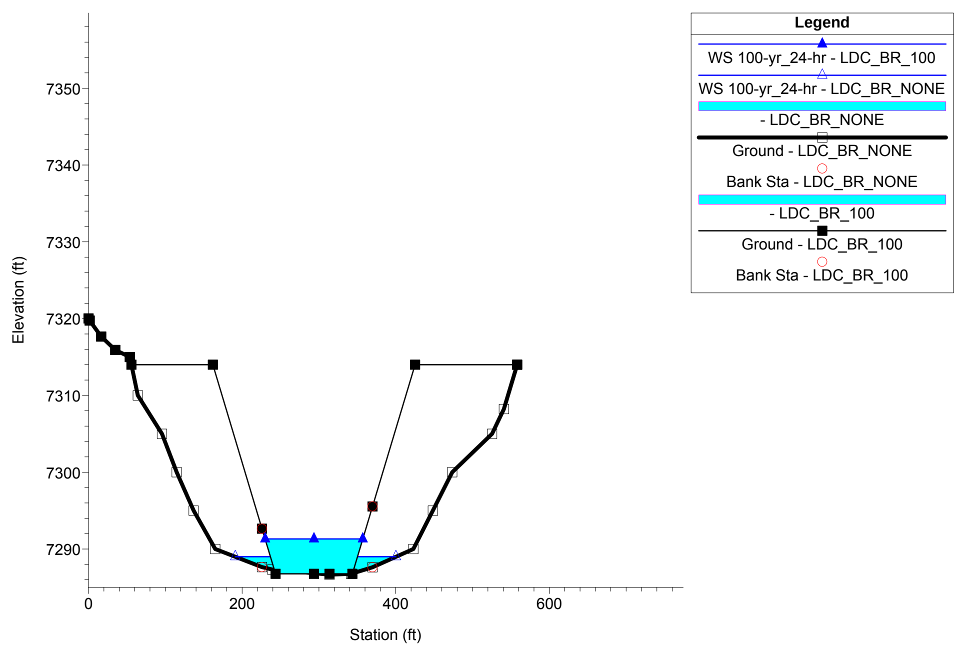
Laguna_Del_Campo Plan: 1) LDC_BR_100 2) LDC_BR_NONE
STA 1+00.0



Laguna_Del_Campo Plan: 1) LDC_BR_100 2) LDC_BR_NONE
STA 1+40.5 (US DAM TOE)



Laguna_Del_Campo Plan: 1) LDC_BR_100 2) LDC_BR_NONE
STA 2+00.0



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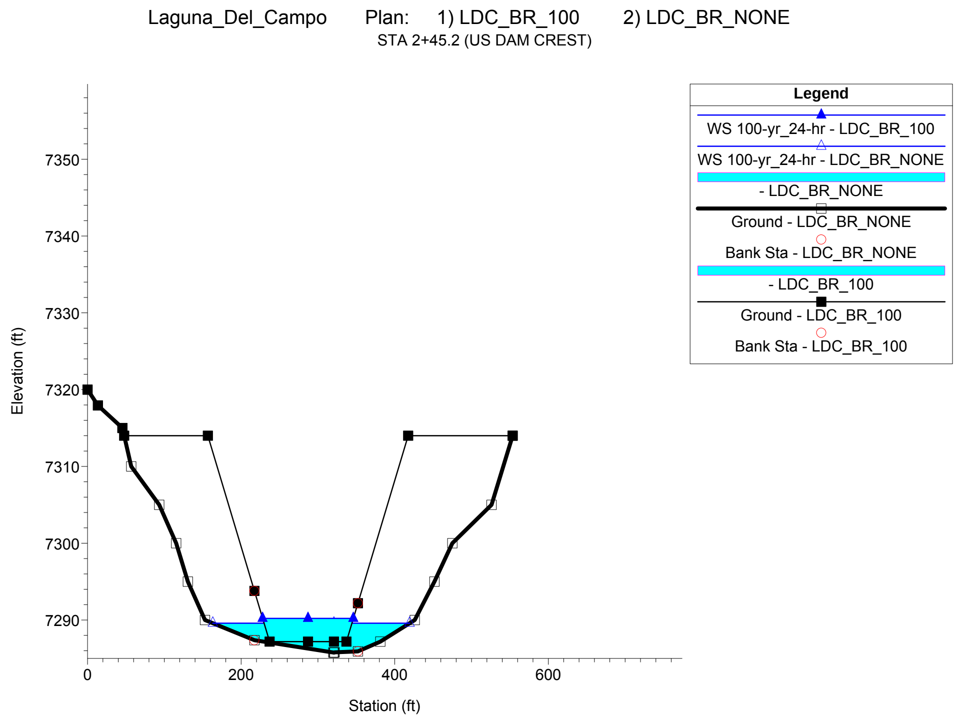
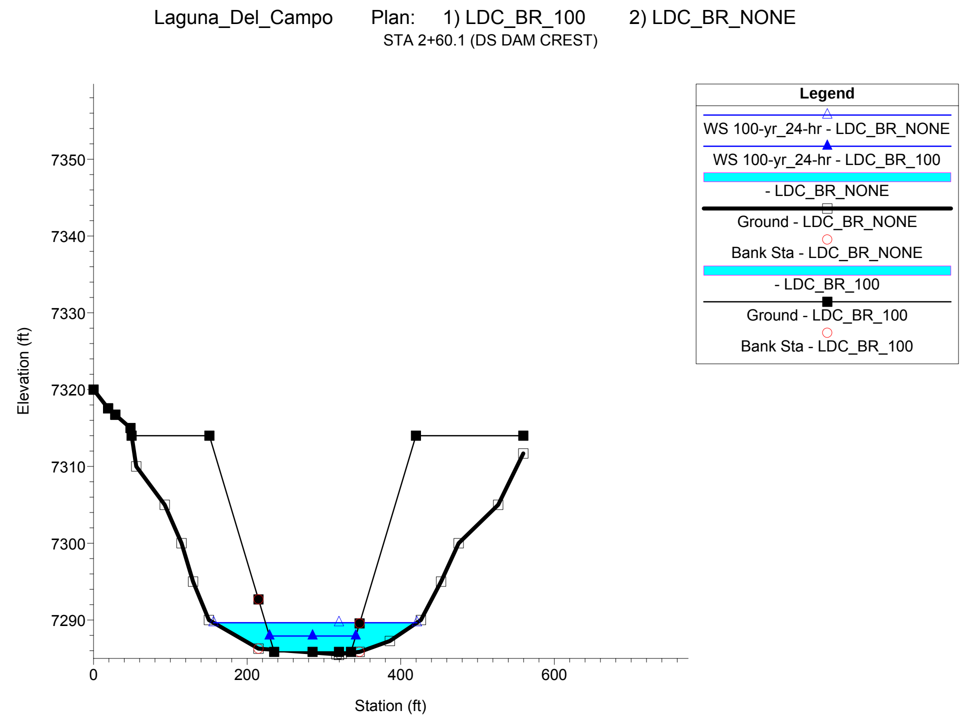
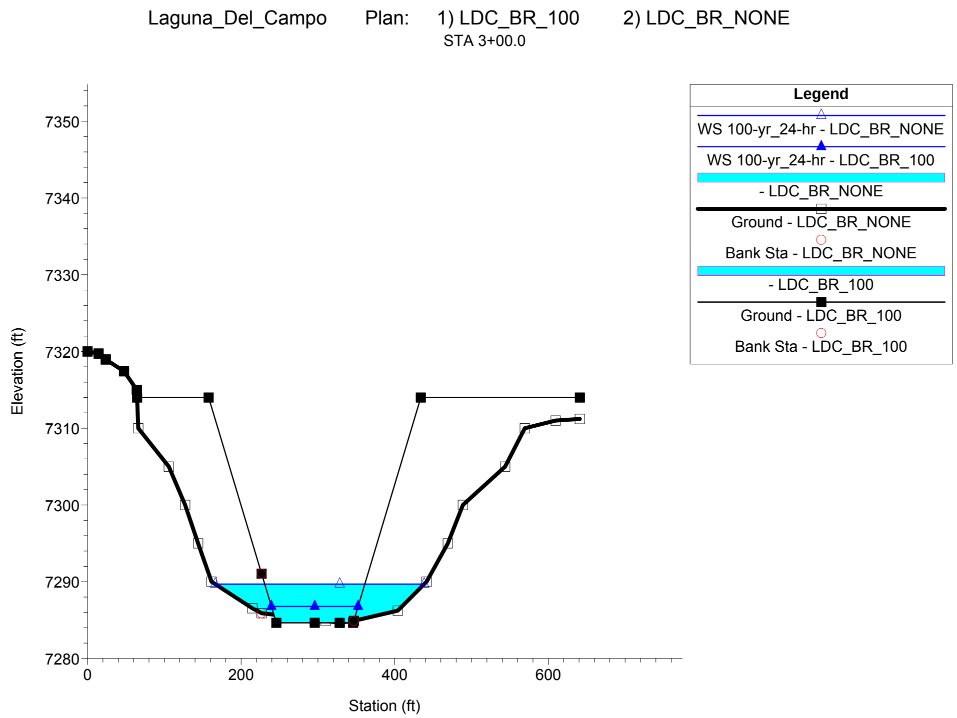
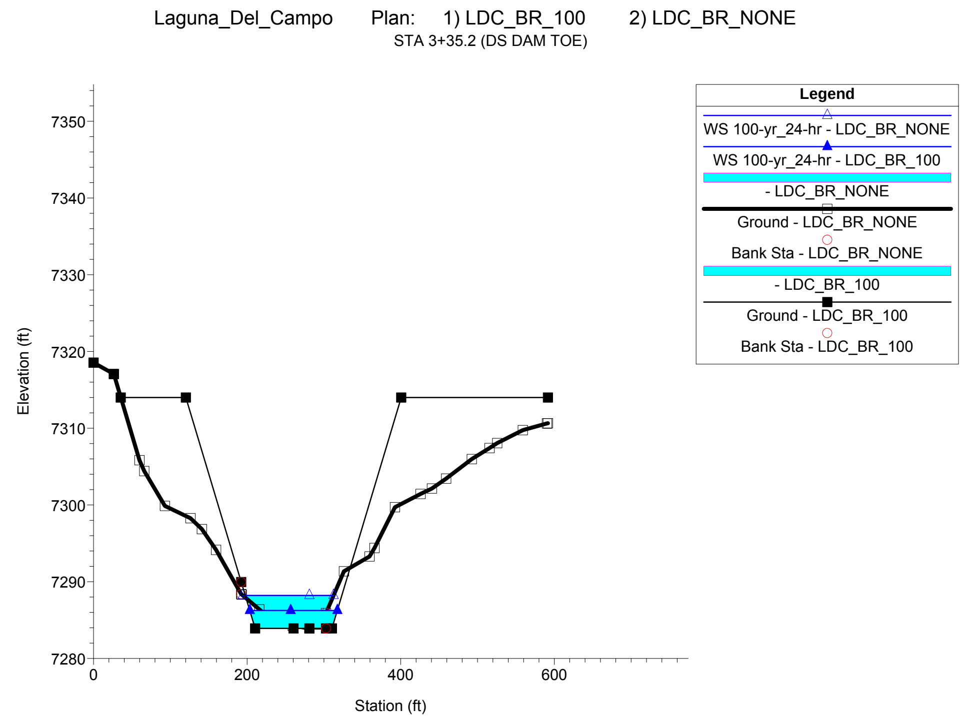


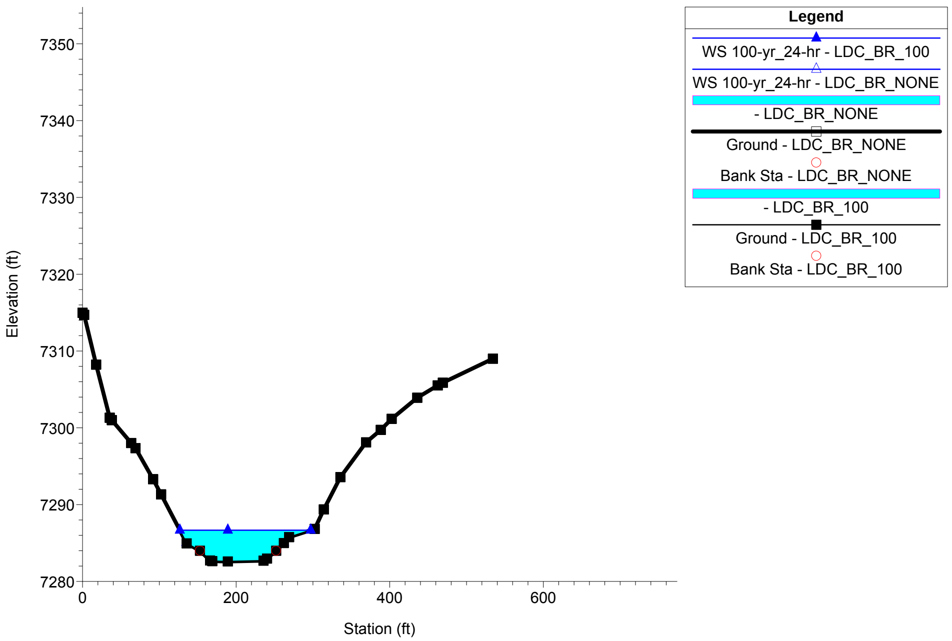




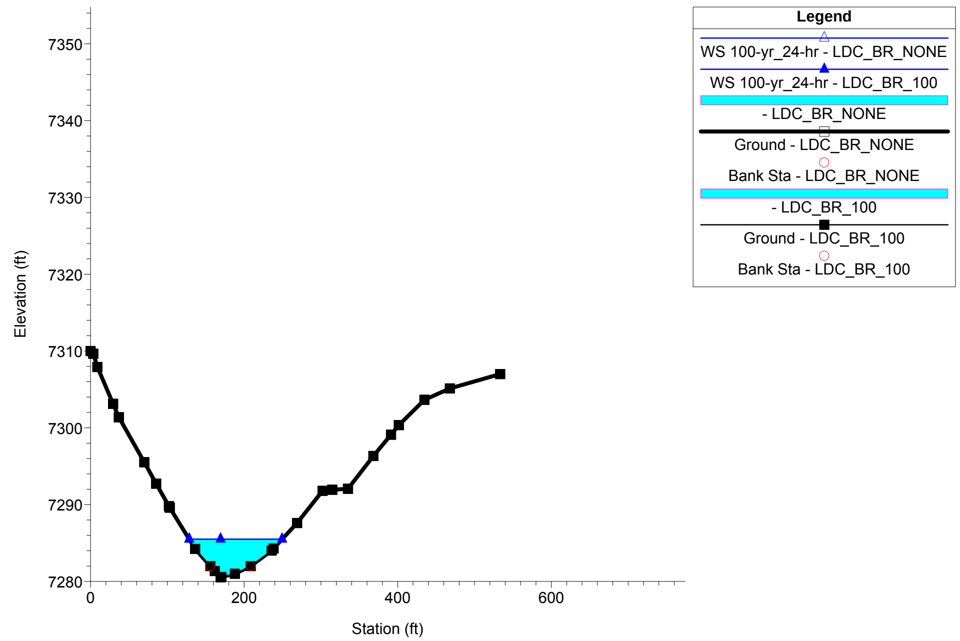


1 in Horiz. = 250 ft 1 in Vert. = 25 ft

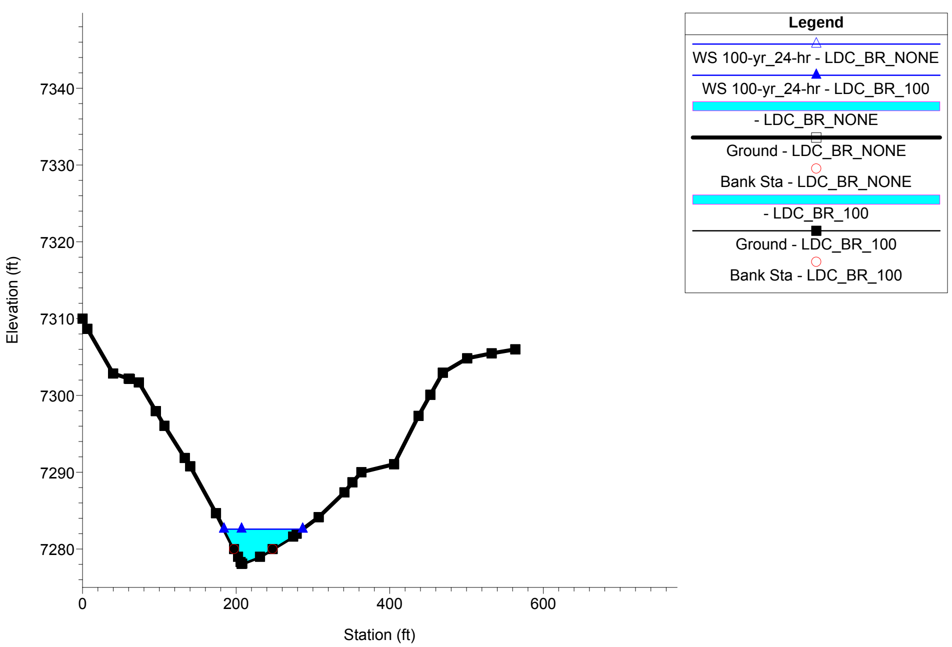
Laguna_Del_Campo Plan: 1) LDC_BR_100 2) LDC_BR_NONE
STA 4+00.0



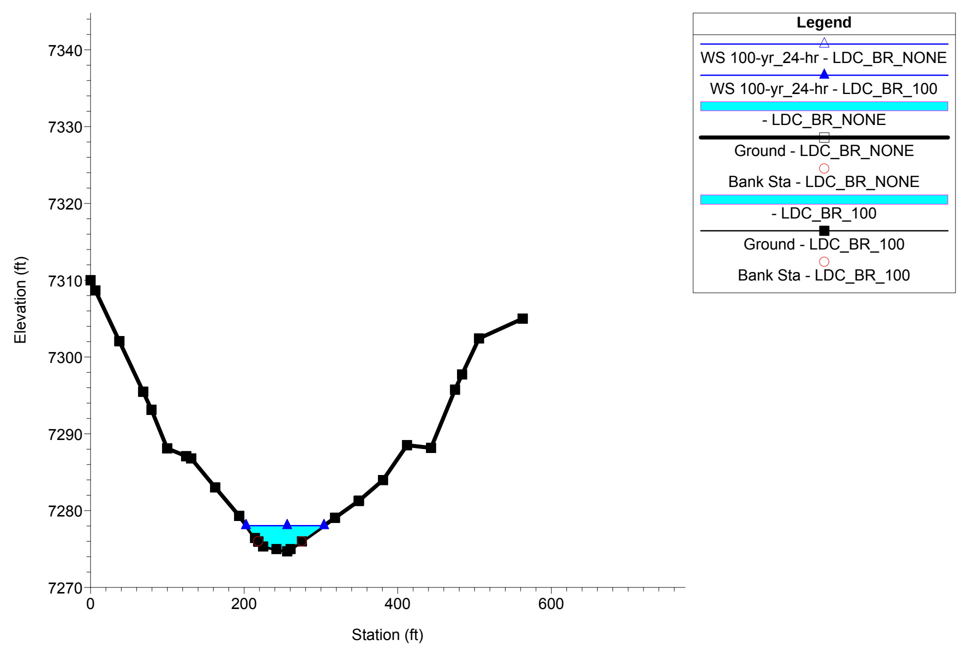
Laguna_Del_Campo Plan: 1) LDC_BR_100 2) LDC_BR_NONE
STA 5+00.0 (US OF ROADWAY)



Laguna_Del_Campo Plan: 1) LDC_BR_100 2) LDC_BR_NONE
STA 6+00.0 (DS OF ROADWAY)

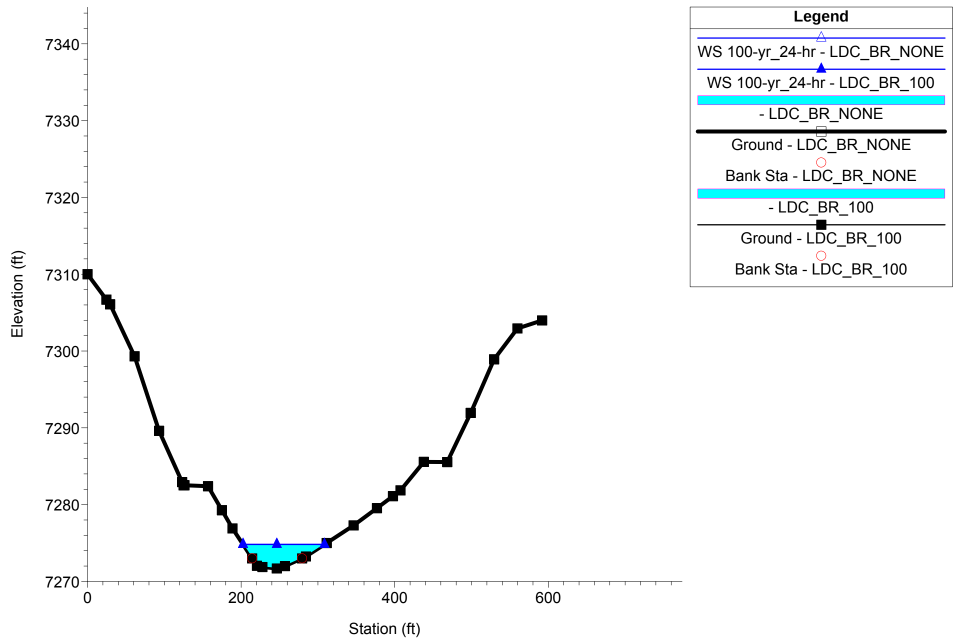


Laguna_Del_Campo Plan: 1) LDC_BR_100 2) LDC_BR_NONE
STA 7+00.0

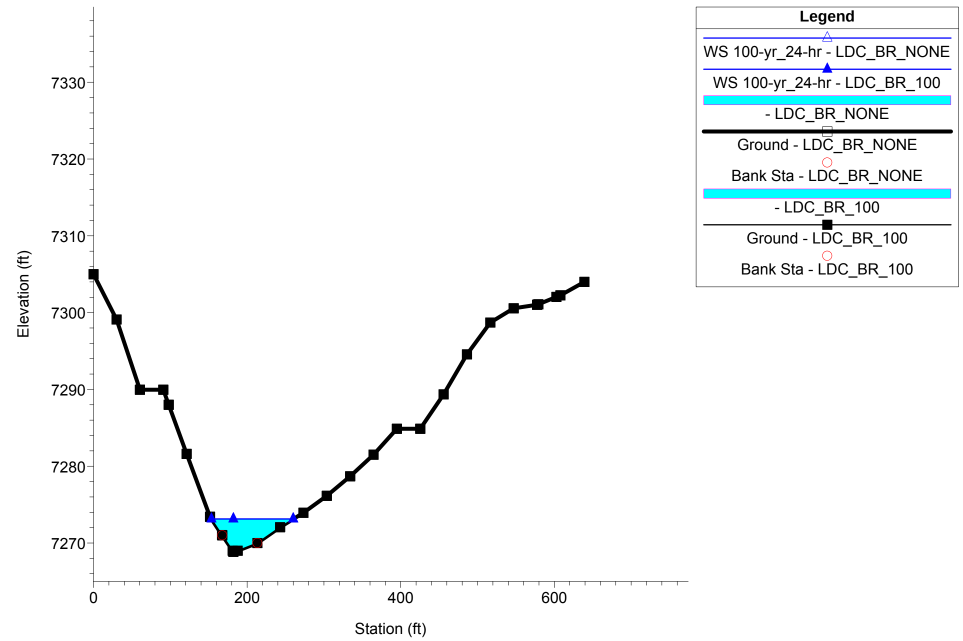


1 in Horiz. = 250 ft 1 in Vert. = 25 ft

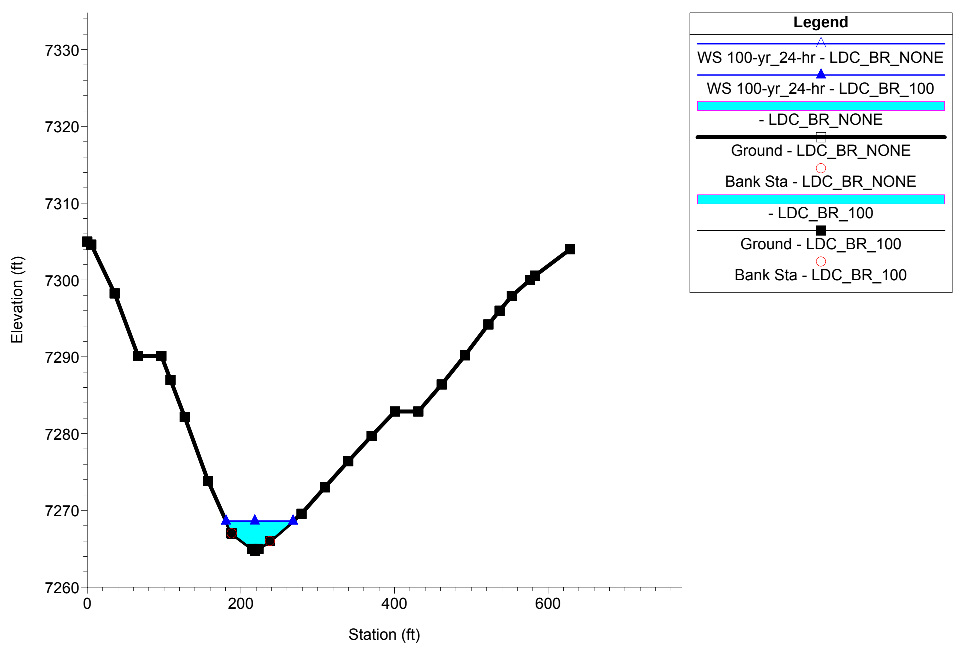
Laguna_Del_Campo Plan: 1) LDC_BR_100 2) LDC_BR_NONE
STA 8+00.0



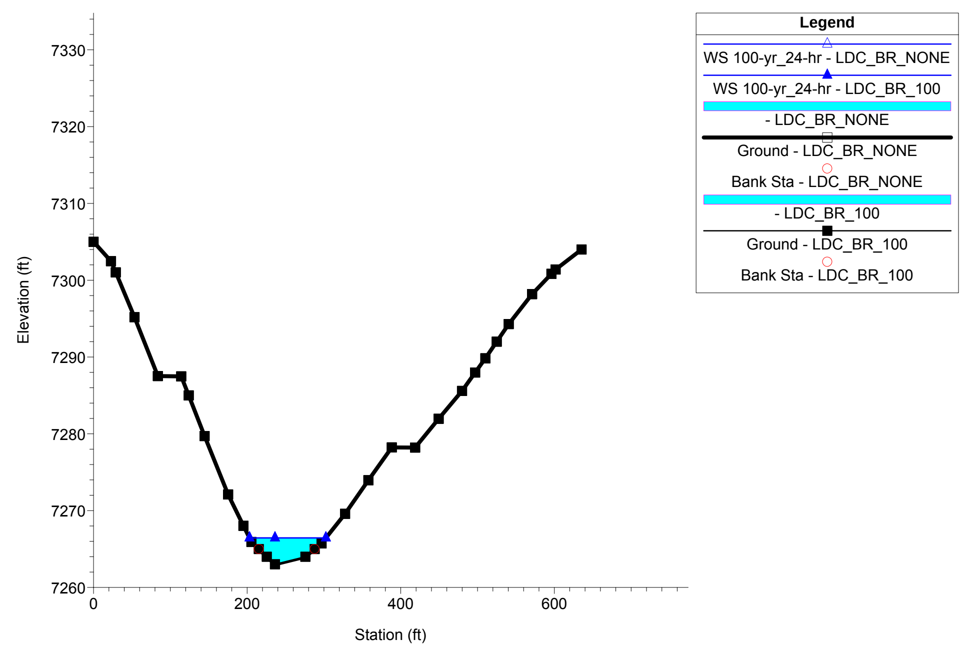
Laguna_Del_Campo Plan: 1) LDC_BR_100 2) LDC_BR_NONE
STA 9+00.0



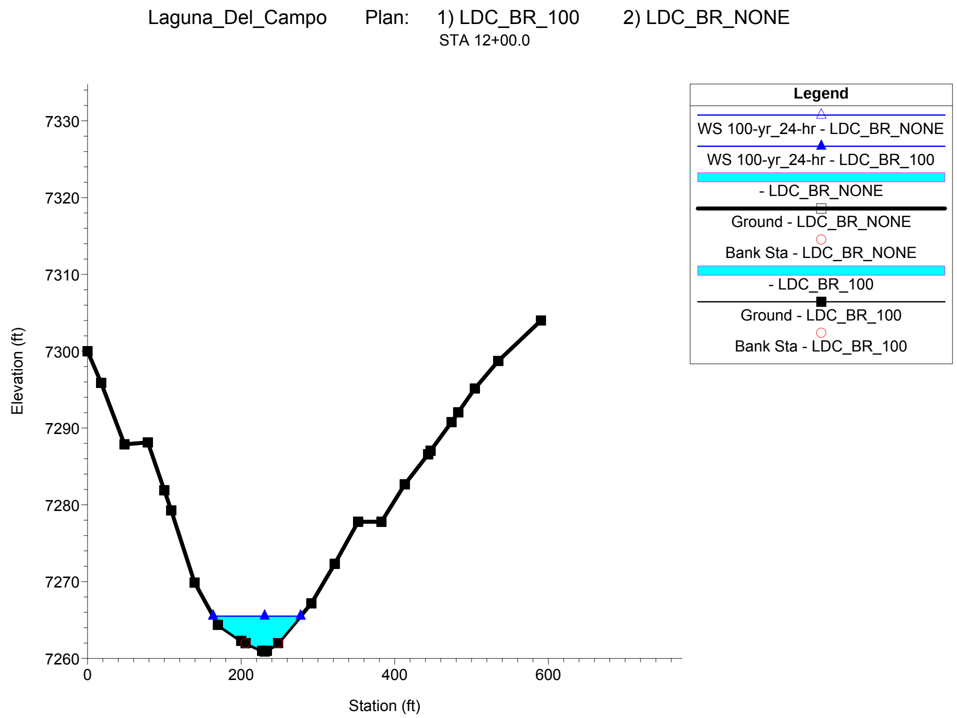
Laguna_Del_Campo Plan: 1) LDC_BR_100 2) LDC_BR_NONE
STA 10+00.0

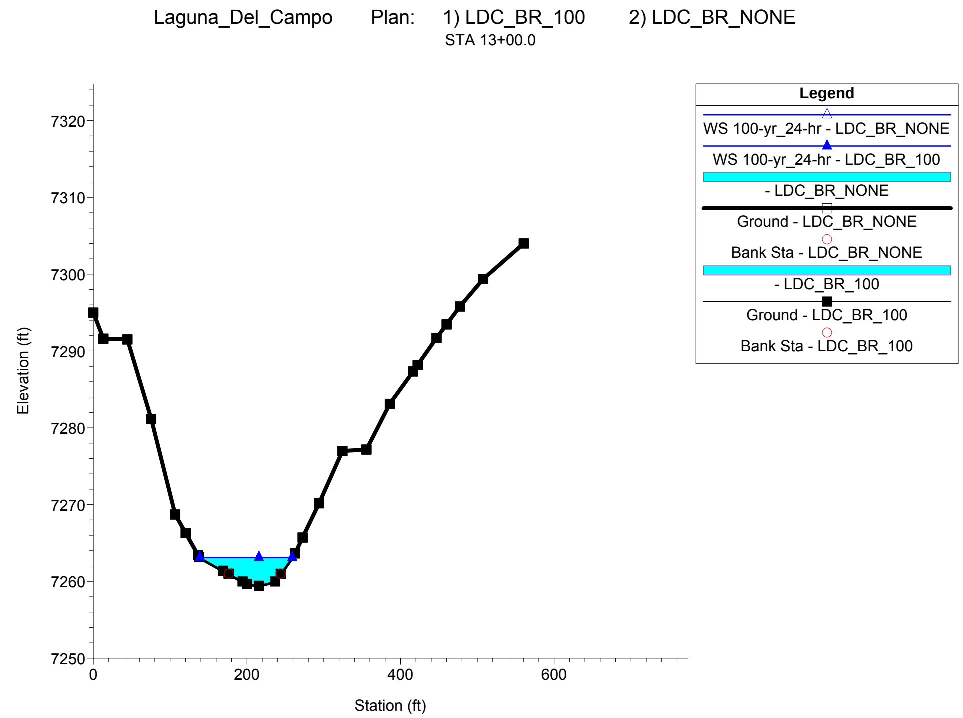


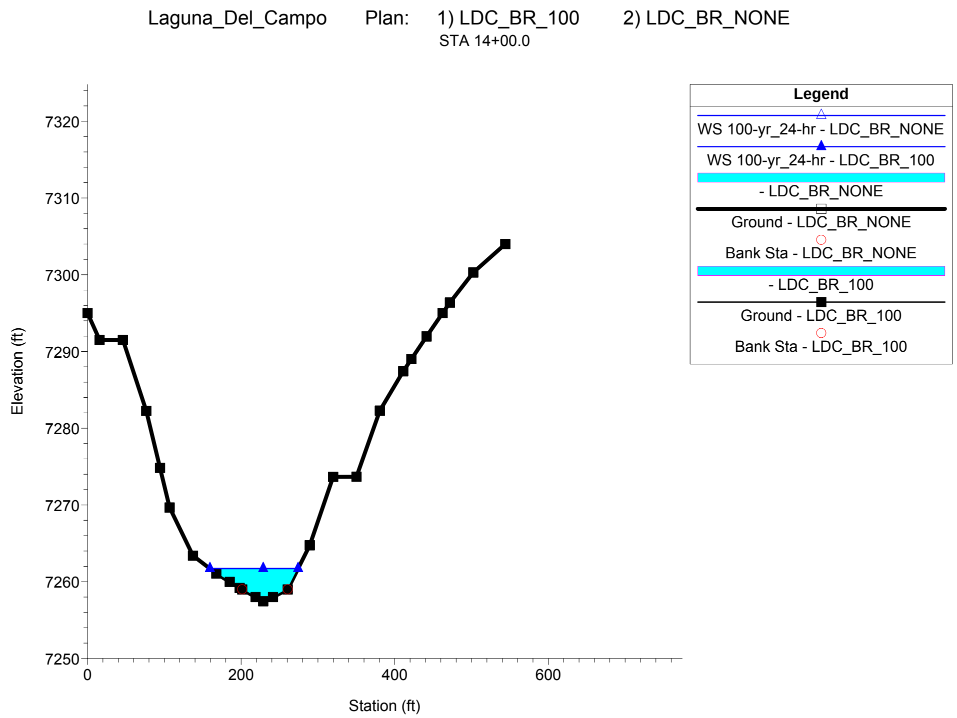
Laguna_Del_Campo Plan: 1) LDC_BR_100 2) LDC_BR_NONE
STA 11+00.0

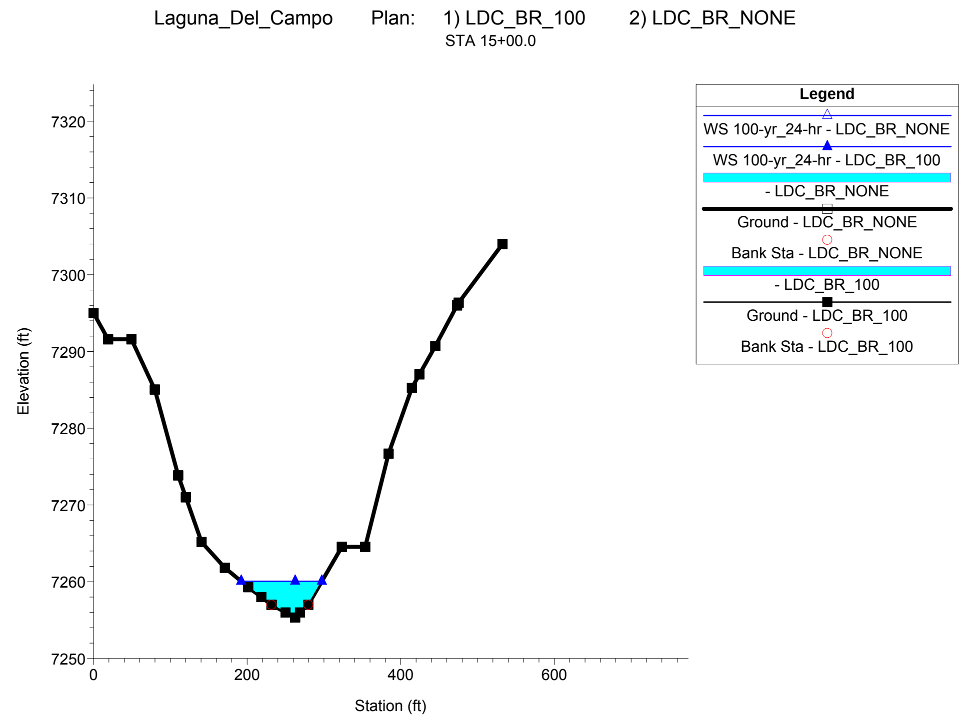


1 in Horiz. = 250 ft 1 in Vert. = 25 ft

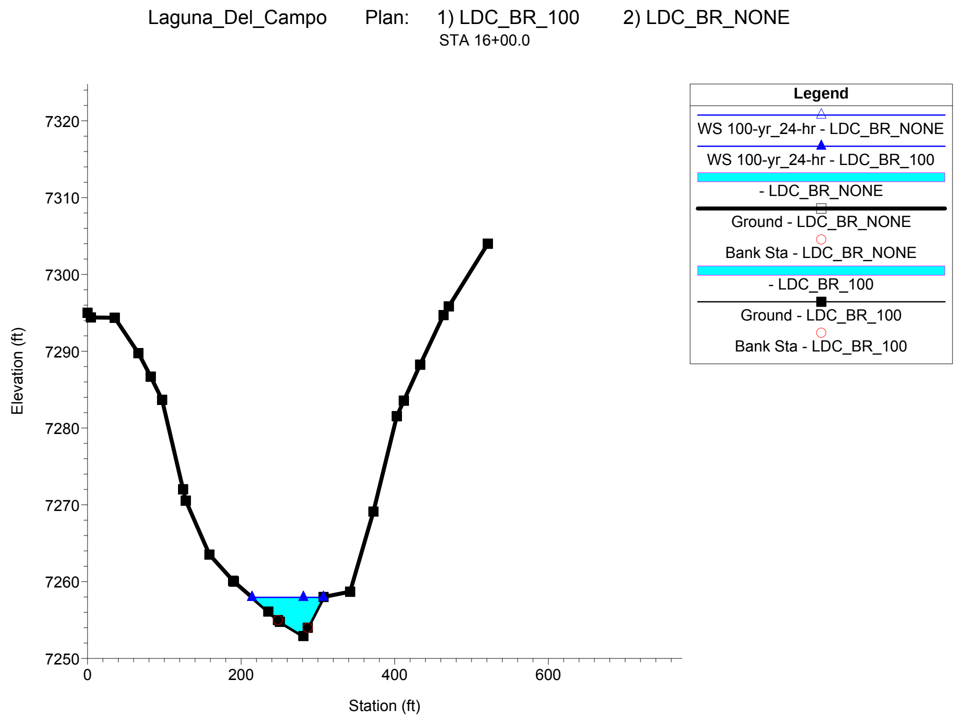


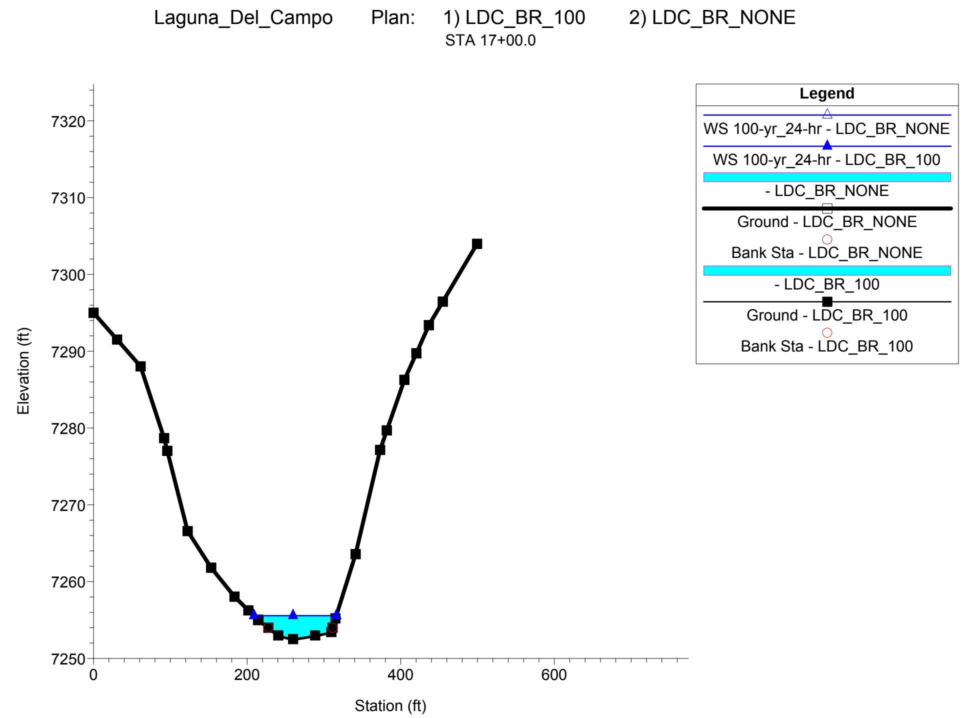


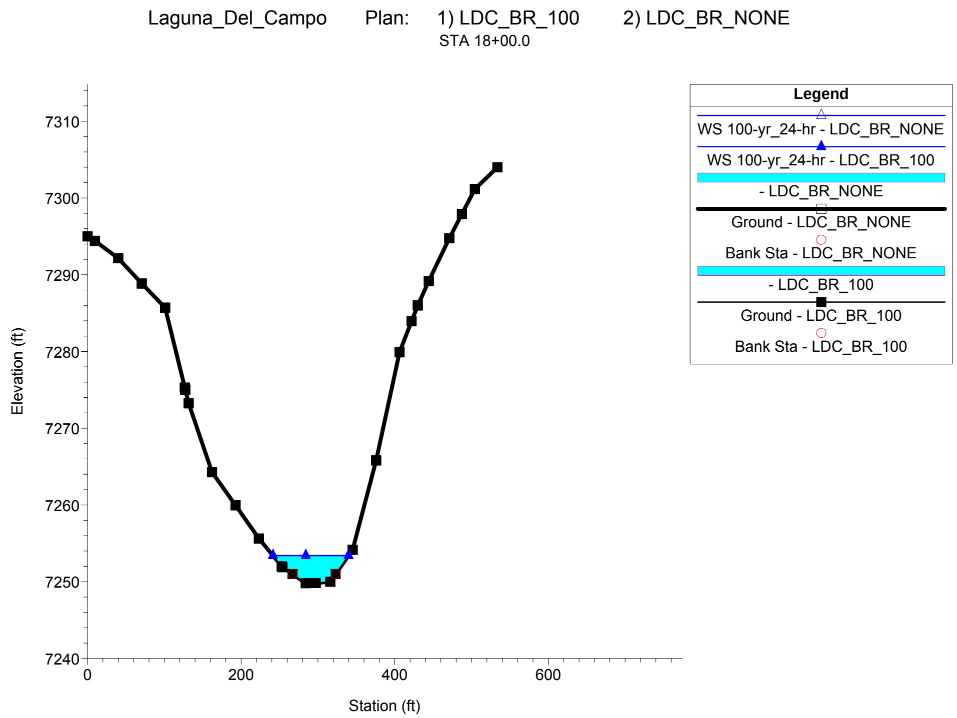


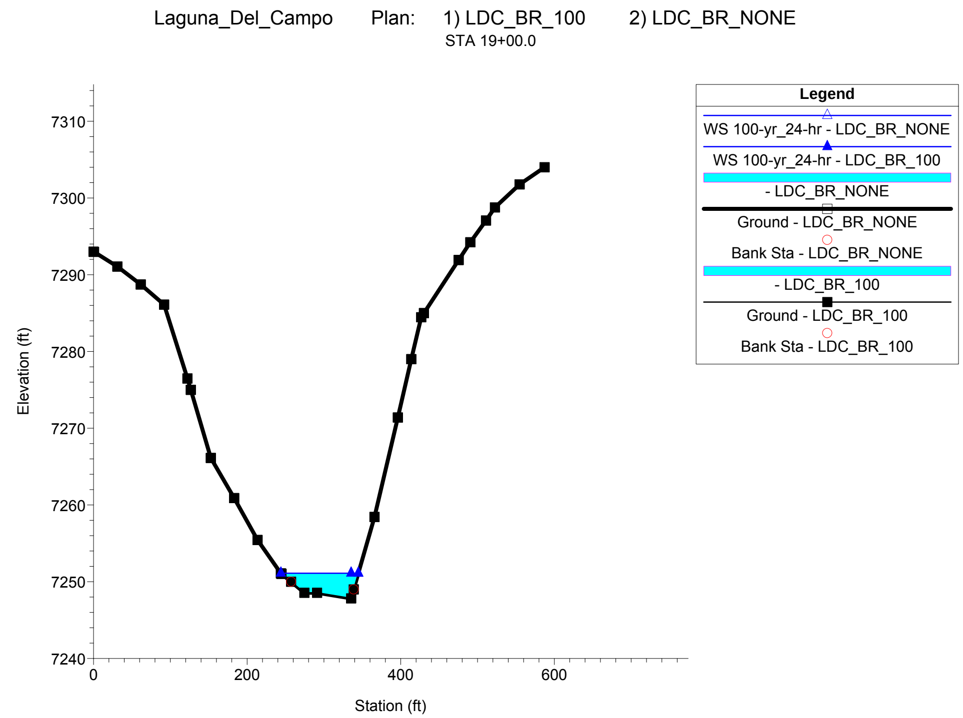


1 in Horiz. = 250 ft 1 in Vert. = 25 ft









1 in Horiz. = 250 ft 1 in Vert. = 25 ft

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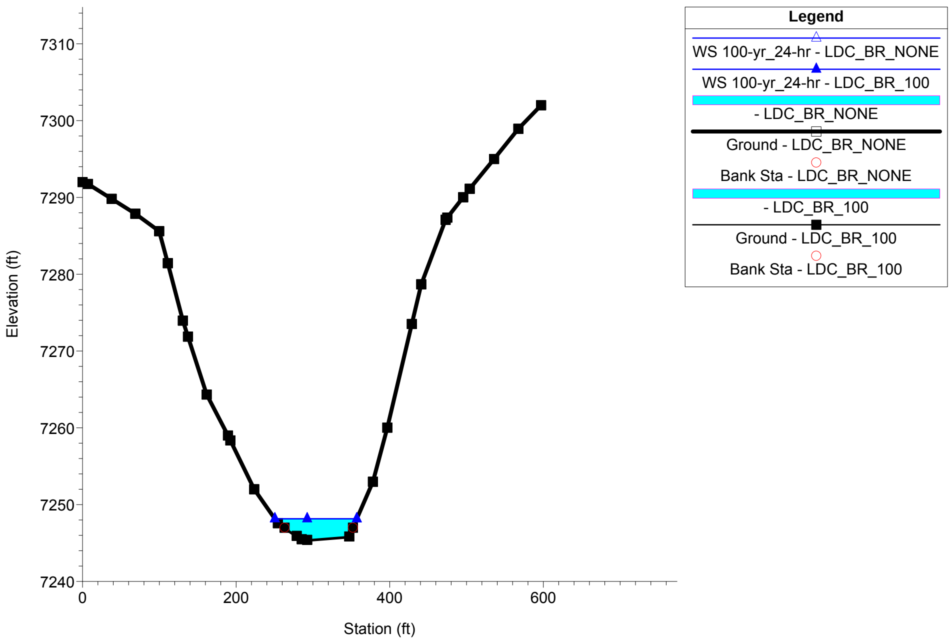
STA 20+00.0 (DS MODEL END)



1 in Horiz. = 250 ft 1 in Vert. = 25 ft

Appendix C3

Alternative 2 Calculations

OBJECTIVE:

Document the calculations involved in sizing a new spillway to be constructed as part of Laguna Del Campo Dam spillway Alternative 2. (This alternative calls for reducing the existing Laguna Del Campo Dam crest elevation from 7,314 feet to 7,302 feet, relative to the North American Vertical Datum of 1988 (NAVD88), and constructing a new spillway roughly where the existing emergency spillway is located.)

METHOD:

In order to size the spillway, the following iterative approach was employed:

1. Assume a crest elevation for the control section of the spillway along with a weir length (perpendicular to the direction of flow), weir breadth (in the direction of flow) and a weir height (between the weir crest and the top of the spillway floor).
2. Compute a rating curve for the assumed weir shape using the broad-crested weir equation and weir coefficients (varying with head over the weir crest) taken from "Handbook of Hydraulics, Fifth Edition" (Brater & King, 1963).
3. Input the assumed rating curve as the only outflow structure from the representation of Laguna Del Campo Dam in a hydrologic model of the Laguna Del Campo Dam watershed constructed using HEC-HMS version 4.1 (USACE, 2015).
4. Execute the HEC-HMS model with the selected design storm, in this case the 100-year average recurrence interval (ARI), 24-hour duration storm and note the peak water surface elevation attained during the simulation.
    a. If the water surface elevation attained during the simulation exceeds the dam crest elevation minus residual freeboard, this particular layout is not a potential solution; return to Step 1 and assume new input values.
    b. If the computed water surface elevation is less than or equal to the dam crest elevation minus residual freeboard, this particular layout is a potential solution; continue to Step 5.
5. In order to prevent tailwater on the downstream side of the spillway weir from "drowning" it (i.e. creating conditions where the water surface can't transition through critical depth as it goes over the weir), normal depth is computed on the spillway floor downstream of the weir through solution of Manning's equation.
    a. If normal depth on the spillway floor downstream of the weir exceeds 70% of the water surface elevation over the weir minus the spillway floor elevation, the possibility of drowning the weir exists, increase the slope of downstream spillway floor and recompute normal depth.
    b. If normal depth on the spillway floor downstream of the weir is less than or equal to 70% of the water surface elevation over the weir minus the spillway floor elevation, downstream tailwater should not drown the weir.

The sizing calculations were performed in order to simultaneously minimize the length of the weir and minimize the reduction in normal pool water storage necessary to create enough head on the weir to convey the design flow rate.

ASSUMPTIONS:

The following assumptions were employed:

- Elevations used in the spillway sizing calculations are based on a Local site datum. The conversion between the Local datum and the NAVD88 datum is:
  - NAVD88 elevation = Local elevation + 7,210 feet.

  The datum conversion was determined by comparing contours along the left abutment of the dam (looking downstream) from the 1/3 arc-second digital elevation model (DEM) of the Laguna Del Campo Dam stream reach obtained from the United States Geological Survey (USGS) as discussed in Appendix F.2 to reservoir contours taken from a scanned design drawing of Laguna Del Campo Dam, included as Figure A-2 in Appendix A of "Laguna Del Campo Dam OSE Filing No. D313 Breach Analysis Report – Rio Arriba County, New Mexico" (URS, 2012). From these two sources, it appears that along the left abutment immediately upstream of the dam that NAVD88 contour elevation 7,315 feet aligns with Local datum contour elevation 105 feet.
- The HEC-HMS version 4.1 model of the Laguna Del Campo watershed was originally developed by URS, as described in (URS, 2012). Key assumptions employed in this hydrologic model include:
  - Upstream basin area = 5.7 mi^2,
  - Rainfall loss method employed is the Initial Loss / Continuing Loss method, with the following parameters:
    - Initial loss = 0.0 in,
    - Continuing loss = 0.034 in/hr, and
    - Basin imperviousness = 0.0%.
  - Excess rainfall to runoff transformation method is the Unit Hydrograph method. Derivation of the Laguna Del Campo watershed unit hydrograph is detailed in Section 2.3 of (URS, 2012), and
  - Elevation vs. Storage information for Laguna Del Campo Dam was taken from Table 3-2 of (URS, 2012).
- A copy of the source HEC-HMS model files for (URS, 2012) was obtained from the New Mexico Department of Game and Fish (NMDGF). This model was then altered by replacing the original spillway rating curve with the various spillway trial curves and adding the 100-year ARI, 24-hour duration storm definition, the derivation of which is discussed in the Design Storms Appendix.
- Assumed constraints for sizing the spillway section include:
  - Dam crest elevation = 92.0 ft (Local),
  - Residual freeboard = 1.0 ft (based on wave run-up calculations for the Laguna Del Campo Dam site),
  - Maximum acceptable weir length = 100.0 ft, and
  - Maximum acceptable water surface elevation = 92.0 ft – 1.0 ft = 91.0 ft (Local).
- The spillway channel is assumed to be made of concrete and rectangular in shape, with a width equal to the assumed weir length and a channel roughness (Manning's n) equal to 0.013.

CALCULATIONS:

The procedure discussed in the Methods section was employed to determine the necessary configuration of the spillway for Laguna Del Campo Dam spillway Alternative 2. Results of this procedure are given in the following section.

CONCLUSIONS/RESULTS:

The following spillway weir crest configuration was found to give satisfactory performance:

- Weir crest elevation = 86.0 ft (Local),
- Weir length (perpendicular to flow) = 85.0 ft,
- Weir breadth (in direction of flow) = 1.0 ft,
- Weir height = 1.0 ft, and
- Spillway floor elevation (top of concrete) at weir = 85.0 ft (Local).

The resulting spillway rating curve is tabulated in Table 1 and is illustrated on Figure 1. When used in the HEC-HMS model, the aforementioned spillway rating curve gave the following results when run with the 100-year ARI, 24-hour duration storm:

- Peak inflow = 3,148 ft^3/s,
- Peak outflow = 3,139 ft^3/s,
- Peak storage volume = 38.7 acre-ft, and
- Peak water surface elevation = 91.0 ft (Local).

Detailed results of the HEC-HMS modeling are provided in Attachment 1.

A tailwater check (analysis Step 5) was then made on the sized spillway weir. The results of this assessment, documented in Attachment 2, show that as long as the downstream slope of the spillway channel is greater than 0.001 ft/ft, the spillway weir will function as intended. In order to be provide a conservative margin of safety, a downstream spillway slope of 0.005 ft/ft (or steeper) is suggested for construction.

REFERENCES:

1. Brater, E.F. & King, H.W., “Handbook of Hydraulics, Fifth Edition”, 1963. Boston MA.
2. URS, *“Laguna Del Campo Dam OSE Filing No. D313 Breach Analysis Report – Rio Arriba County, New Mexico”*, Design report prepared for the New Mexico Department of Game and Fish, July, 2012. Denver, CO.
3. United States Army Corps of Engineers (USACE), *“HEC-HMS Hydrologic Modeling System, Version 4.1”*, Computer software, July, 2015. Davis, CA.

TABLES

Table 1: Spillway Alternative 2 Elevation / Discharge Relationship for Laguna Del Campo Reservoir Auxilliary Spillway (After Dam has been lowered to a Non-Jurisdictional Height)

Elevation / Discharge data was computed using an assumed narrow broad-crested weir.
For the (narrow) broad-crested weir assumption, discharge was computed using equations taken from "Handbook of Hydraulics, Fifth Edition" (Brater & King, 1963).
Ideal entrance (i.e. parallel streamlines & minimal losses) and exit conditions (i.e. no tailwater) are assumed to exist.

Height, P = 1.0 **ft** **Length, L =** 85.0 **ft** **Breadth, B =** 1.0 **ft** **Crest EL =** 86.0 **ft**

Laguna Del Campo		Narrow Broad-Crested Weir		
Elevation z (ft)	Piez. Head h (ft)	Coefficient C_o ($ft^{0.5}/s$)	Discharge Q_{BC} (ft^3/s)	
86.00	-	#N/A	-	⇦ Invert for weir wall
86.20	0.20	2.690	20.5	
86.40	0.40	2.720	58.5	
86.60	0.60	2.750	108.6	
86.80	0.80	2.850	173.3	
87.00	1.00	2.980	253.3	
87.20	1.20	3.080	344.1	
87.40	1.40	3.200	450.6	
87.60	1.60	3.280	564.3	
87.80	1.80	3.310	679.4	
88.00	2.00	3.300	793.4	
88.20	2.20	3.304	916.4	
88.40	2.40	3.308	1,045.4	
88.60	2.60	3.312	1,180.2	
88.80	2.80	3.316	1,320.6	
89.00	3.00	3.320	1,466.4	
89.20	3.20	3.320	1,615.4	
89.40	3.40	3.320	1,769.2	
89.60	3.60	3.320	1,927.6	
89.80	3.80	3.320	2,090.4	
90.00	4.00	3.320	2,257.6	
90.20	4.20	3.320	2,429.0	
90.40	4.40	3.320	2,604.6	
90.60	4.60	3.320	2,784.2	
90.80	4.80	3.320	2,967.7	
91.00	5.00	3.320	3,155.1	
91.20	5.20	3.320	3,346.3	
91.40	5.40	3.320	3,541.2	
91.60	5.60	3.320	3,739.7	
91.80	5.80	3.320	3,941.8	
92.00	6.00	3.320	4,147.5	⇦ Lowered dam crest elevation
92.20	6.20	3.320	4,356.6	
92.40	6.40	3.320	4,569.1	
92.60	6.60	3.320	4,784.9	
92.80	6.80	3.320	5,004.0	
93.00	7.00	3.320	5,226.4	
93.20	7.20	3.320	5,452.0	
93.40	7.40	3.320	5,680.7	
93.60	7.60	3.320	5,912.6	
93.80	7.80	3.320	6,147.5	
94.00	8.00	3.320	6,385.5	
94.20	8.20	3.320	6,626.4	
94.40	8.40	3.320	6,870.3	
94.60	8.60	3.320	7,117.1	
94.80	8.80	3.320	7,366.8	
95.00	9.00	3.320	7,619.4	
95.20	9.20	3.320	7,874.8	
95.40	9.40	3.320	8,133.0	
95.60	9.60	3.320	8,393.9	
95.80	9.80	3.320	8,657.6	
96.00	10.00	3.320	8,923.9	
96.20	10.20	3.320	9,193.0	
96.40	10.40	3.320	9,464.7	
96.60	10.60	3.320	9,739.0	
96.80	10.80	3.320	10,016.0	

	Subject New Mexico Department of Game & Fish	Made by TML	Job No. 1772.16.00
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Laguna Del Campo Dam	Checked DTH	Date 5/20/2016
	Spillway Evaluation - Alternative 2 Calculations	Approved TSS	

Table 1: Spillway Alternative 2 Elevation / Discharge Relationship for Laguna Del Campo Reservoir Auxilliary Spillway (After Dam has been lowered to a Non-Jurisdictional Height)

Elevation / Discharge data was computed using an assumed narrow broad-crested weir.
For the (narrow) broad-crested weir assumption, discharge was computed using equations taken from "Handbook of Hydraulics, Fifth Edition" (Brater & King, 1963).
Ideal entrance (i.e. parallel streamlines & minimal losses) and exit conditions (i.e. no tailwater) are assumed to exist.

Height, P = 1.0 **ft** **Length, L =** 85.0 **ft** **Breadth, B =** 1.0 **ft** **Crest EL =** 86.0 **ft**

Laguna Del Campo		Narrow Broad-Crested Weir		
Elevation z (ft)	Piez. Head h (ft)	Coefficient C_o ($ft^{0.5}/s$)	Discharge Q_{BC} (ft^3/s)	
97.00	11.00	3.320	10,295.5	
97.20	11.20	3.320	10,577.5	
97.40	11.40	3.320	10,862.1	
97.60	11.60	3.320	11,149.2	
97.80	11.80	3.320	11,438.8	
98.00	12.00	3.320	11,730.8	
98.20	12.20	3.320	12,025.3	
98.40	12.40	3.320	12,322.2	
98.60	12.60	3.320	12,621.6	
98.80	12.80	3.320	12,923.3	
99.00	13.00	3.320	13,227.3	
99.20	13.20	3.320	13,533.7	
99.40	13.40	3.320	13,842.5	
99.60	13.60	3.320	14,153.5	
99.80	13.80	3.320	14,466.9	
100.00	14.00	3.320	14,782.5	
100.20	14.20	3.320	15,100.4	
100.40	14.40	3.320	15,420.6	
100.60	14.60	3.320	15,743.0	
100.80	14.80	3.320	16,067.5	
101.00	15.00	3.320	16,394.3	
101.20	15.20	3.320	16,723.3	
101.40	15.40	3.320	17,054.5	
101.60	15.60	3.320	17,387.8	
101.80	15.80	3.320	17,723.2	
102.00	16.00	3.320	18,060.8	
102.20	16.20	3.320	18,400.5	
102.40	16.40	3.320	18,742.3	
102.60	16.60	3.320	19,086.2	
102.80	16.80	3.320	19,432.2	
103.00	17.00	3.320	19,780.2	
103.20	17.20	3.320	20,130.3	
103.40	17.40	3.320	20,482.4	
103.60	17.60	3.320	20,836.6	
103.80	17.80	3.320	21,192.7	
104.00	18.00	3.320	21,550.9	⇦ Original dam & North Dike crest elevation

FIGURES

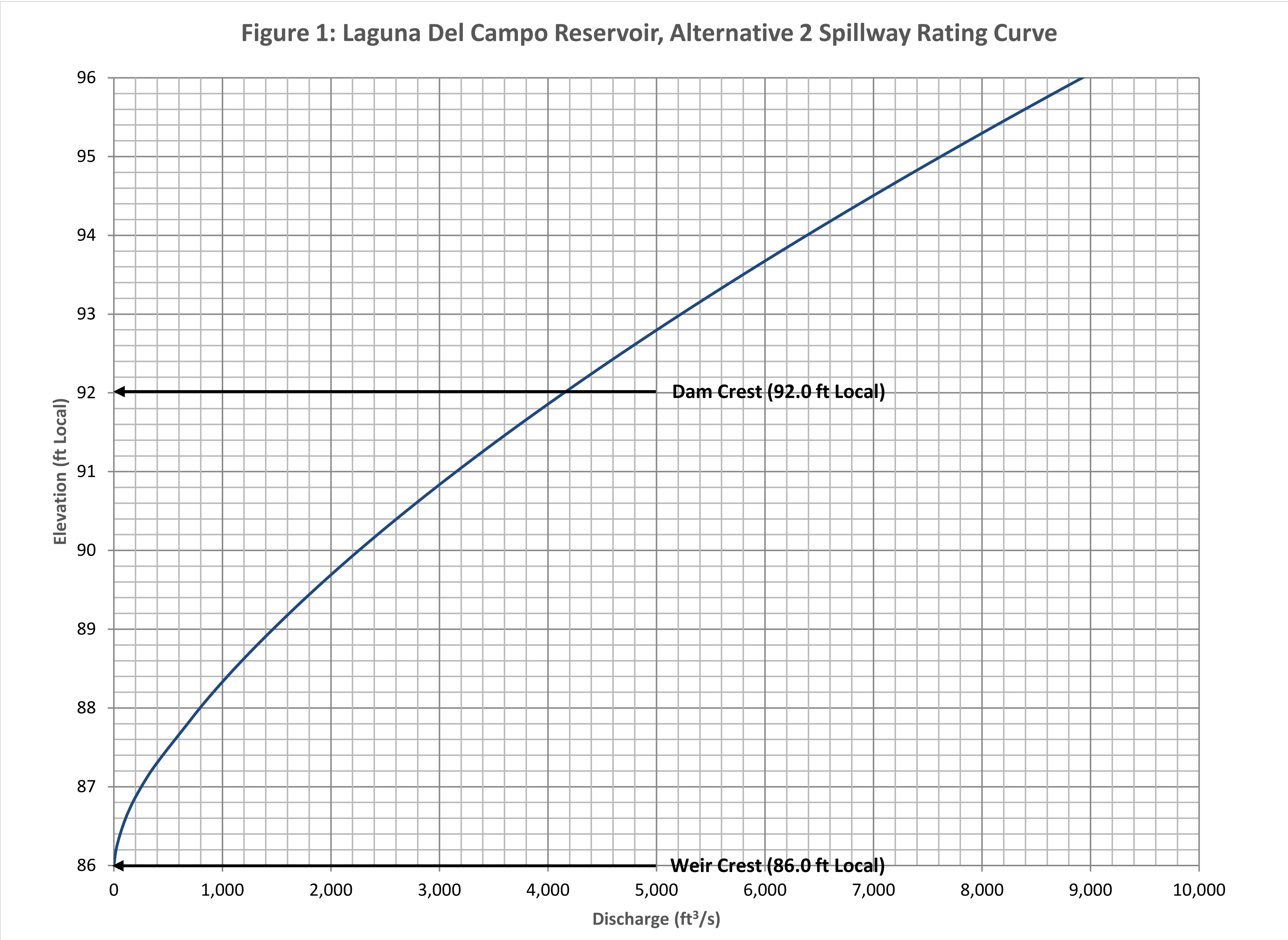
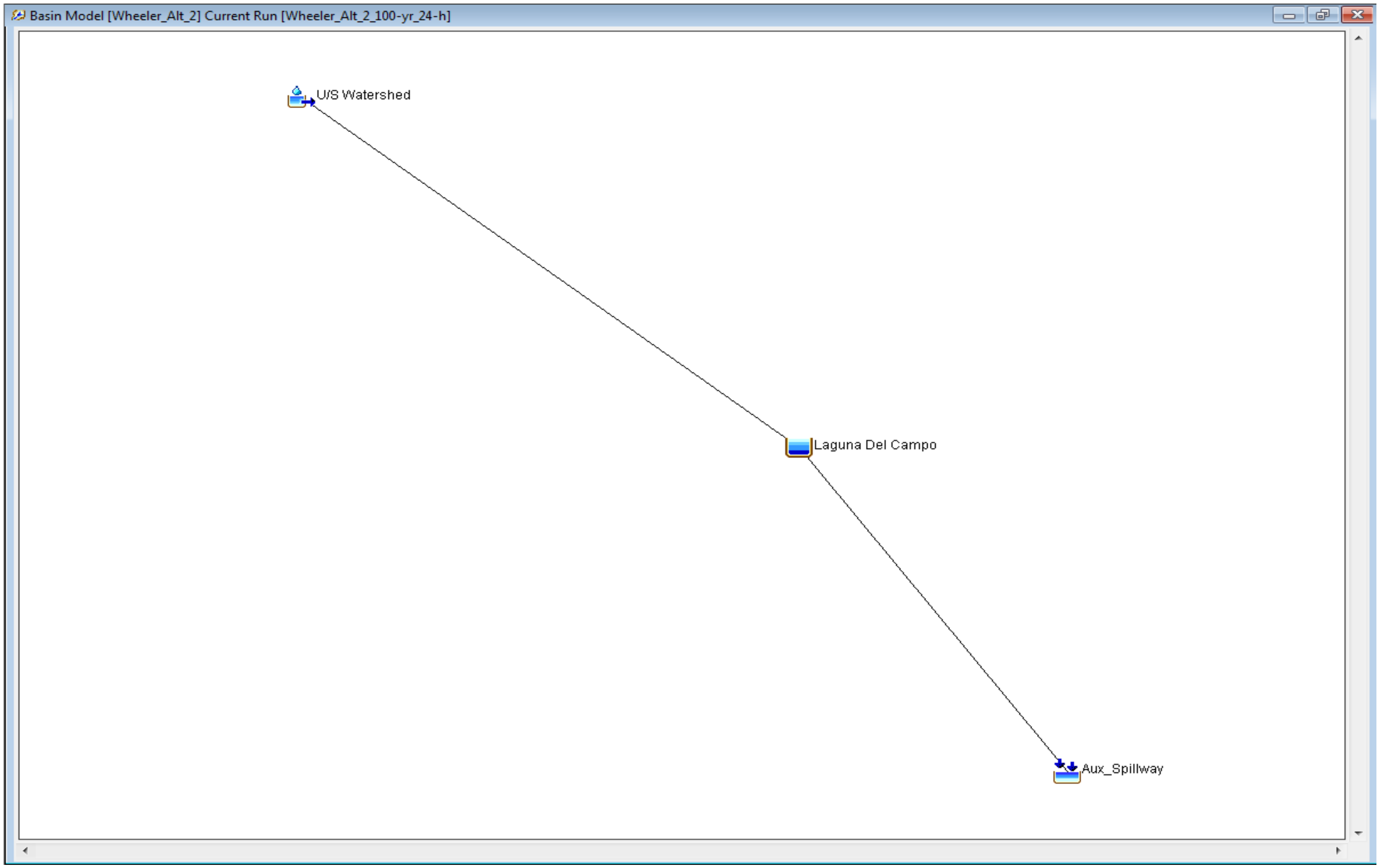


Figure 1: Laguna Del Campo Reservoir, Alternative 2 Spillway Rating Curve
Elevation (ft Local)
96
95
94
93
92
91
90
89
88
87
86
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Discharge (ft³/s)
Dam Crest (92.0 ft Local)
Weir Crest (86.0 ft Local)

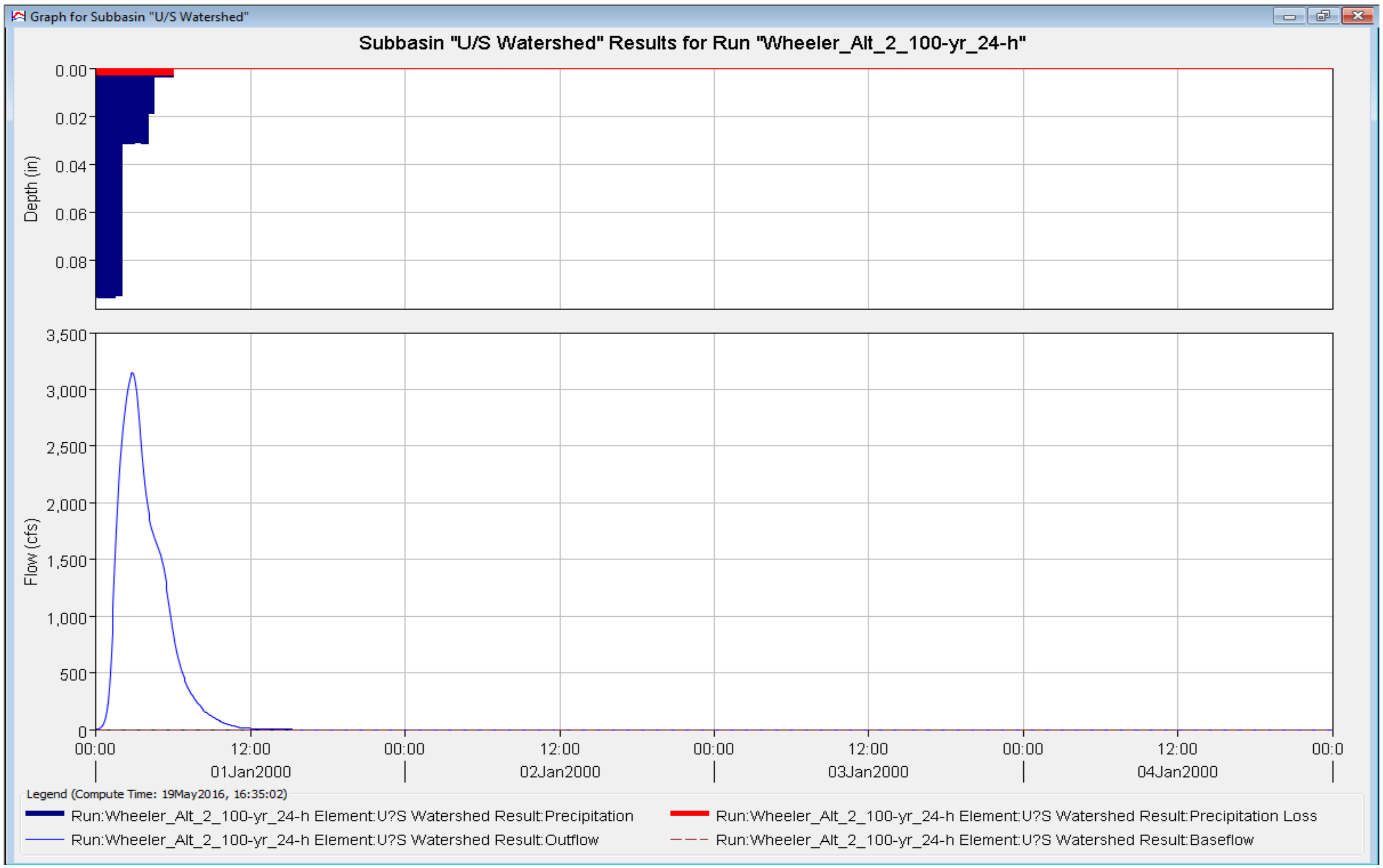
ATTACHMENT 1

SPILLWAY ALTERNATIVE 2 HEC-HMS RESULTS

Attachment 1: Spillway Alternative 2 HEC-HMS Results (Basin Schematic)



Attachment 1: Spillway Alternative 2 HEC-HMS Results (Upstream Watershed Results Graph)



Attachment 1: Spillway Alternative 2 HEC-HMS Results (Upstream Watershed Results Table)

Summary Results for Subbasin "U/S Watershed"

Project: LagunaDamSpwyAlts   Simulation Run: Wheeler_Alt_2_100-yr_24-h

Subbasin: U/S Watershed

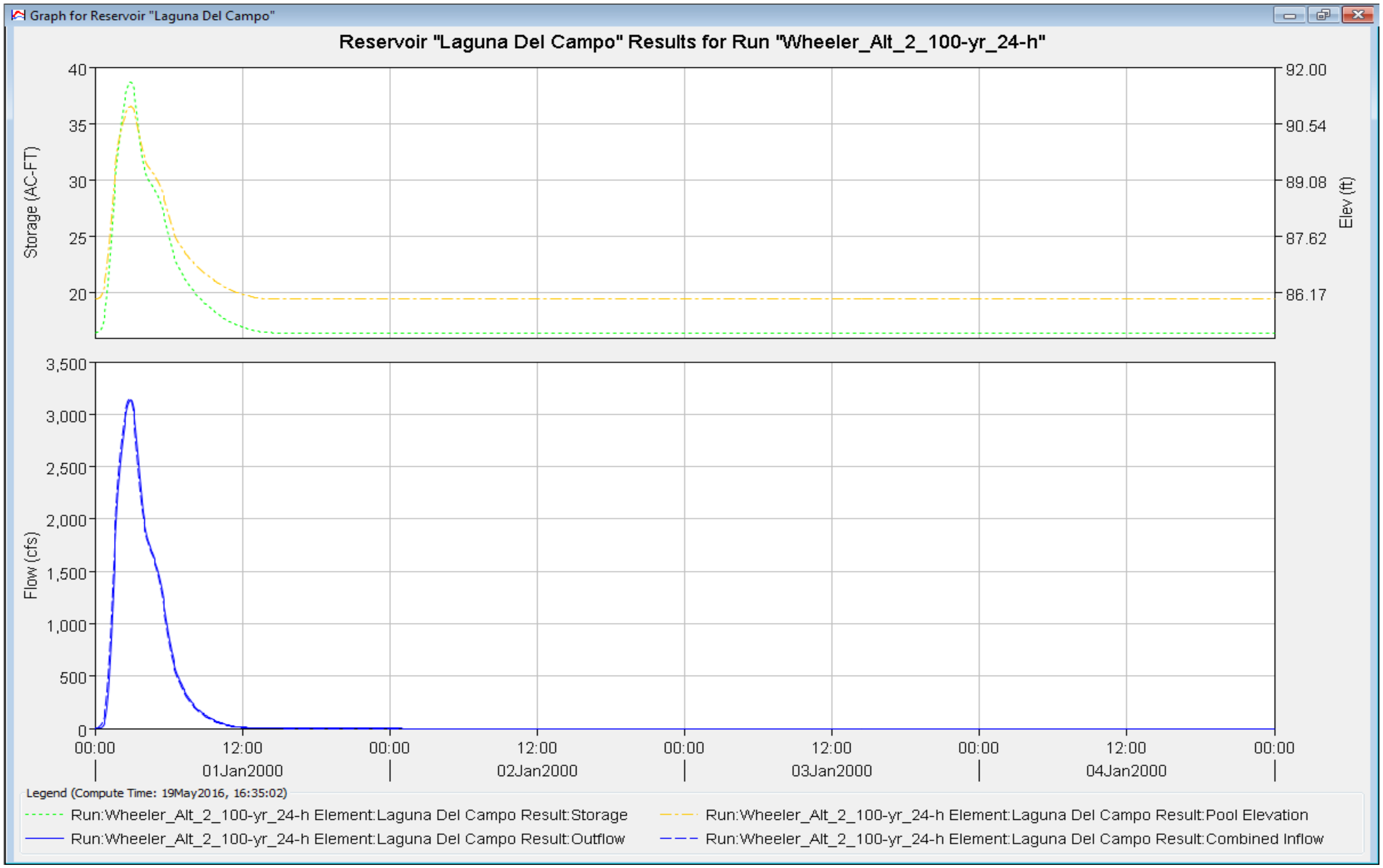
Start of Run:	01Jan2000, 00:00	Basin Model:	Wheeler_Alt_2
End of Run:	05Jan2000, 00:00	Meteorologic Model:	100-yr ARI, 24-hr FS
Compute Time:	19May2016, 16:35:02	Control Specifications:	24-hr_FS

Volume Units: (•) IN ( ) AC-FT

Computed Results

Peak Discharge:	3147.822 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 02:50
Precipitation Volume:	3.220 (IN)	Direct Runoff Volume:	3.038 (IN)
Loss Volume:	0.210 (IN)	Baseflow Volume:	0.000 (IN)
Excess Volume:	3.010 (IN)	Discharge Volume:	3.038 (IN)

Attachment 1: Spillway Alternative 2 HEC-HMS Results (Reservoir Results Graph)



Attachment 1: Spillway Alternative 2 HEC-HMS Results (Reservoir Results Table)

Summary Results for Reservoir "Laguna Del Campo"

Project: LagunaDamSpwyAlts   Simulation Run: Wheeler_Alt_2_100-yr_24-h

Reservoir: Laguna Del Campo

Start of Run:	01Jan2000, 00:00	Basin Model:	Wheeler_Alt_2
End of Run:	05Jan2000, 00:00	Meteorologic Model:	100-yr ARI, 24-hr FS
Compute Time:	19May2016, 16:35:02	Control Specifications:	24-hr_FS

Volume Units: (•) IN ( ) AC-FT

Computed Results

Peak Inflow:	3147.822 (CFS)	Date/Time of Peak Inflow:	01Jan2000, 02:50
Peak Discharge:	3138.901 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 02:55
Inflow Volume:	3.038 (IN)	Peak Storage:	38.682 (AC-FT)
Discharge Volume:	3.035 (IN)	Peak Elevation:	90.983 (FT)

ATTACHMENT 2

SPILLWAY ALTERNATIVE 2 TAILWATER CHECK FOR SIZED SPILLWAY SECTION

Attachment 2: Spillway Alternative 2 Tailwater Check for Sized Spillway Section

Run a quick check on the tailwater for the selected alternative. Assume that the exit away from the broad-crested weir is a rectangular concrete channel of the same width as the weir, but sloped in the downstream direction.

Laguna Del Campo Spillway Alternative 2 Tailwater Check

Design Discharge Q (ft^3/s)	Manning's Roughness n	Exit Apron Slope S (ft/ft)	Bottom Width b (ft)	Gravitational Acceleration g (ft/s^2)	Normal TW Depth d_n (ft)	Flow Area A_n (ft^2)	Flow Velocity V_n (ft/s)	Froude Number Fr	Head on Weir H (ft)	Comparison TW Depth $0.7 \cdot (H + P)$ (ft)	Tailwater Check $d_n \leq 0.7 \cdot (H + P)$ (ft)
3,138.9	0.013	0.0005	85.0	32.17	5.20	441.92	7.10	0.55	4.98	4.19	Not Ok
3,138.9	0.013	0.0010	85.0	32.17	4.19	355.89	8.82	0.76	4.98	4.19	Ok
3,138.9	0.013	0.0050	85.0	32.17	2.55	216.47	14.50	1.60	4.98	4.19	Ok
3,138.9	0.013	0.0100	85.0	32.17	2.06	175.07	17.93	2.20	4.98	4.19	Ok

Normal depth at the approach section is found by simultaneously solving the following:

a) Manning's equation: $Q = (1/n) \cdot A_n \cdot R_n^{2/3} \cdot S^{1/2}$

b) Area equation: $A_n = (b + d_n \cdot (z_L + z_R) / 2) \cdot d_n$

c) Wetted perimeter equation: $P_n = b + d_n \cdot ((1 + z_L^2)^{1/2} + (1 + z_R^2)^{1/2})$

d) Hydraulic radius equation: $R_n = A_n / P_n$

e) Velocity equation: $V_n = Q / A_n$

f) Froude number equation: $Fr = V_n / (g \cdot d_n)^{1/2}$

(Note that the area and wetted perimeter equations are for a trapezoidal section, but are equivalent to a rectangular section with the sideslopes z_L & z_R set to zero.)

As long as the exit apron slope is steeper than 0.001 ft/ft, the weir should function as desired. To be conservative, I suggest using a slope of 0.005 ft/ft or steeper.

Appendix C4

Alternative 3a and 3b Calculations

OBJECTIVE:

Document the calculations involved in sizing a new roller compacted concrete (RCC) spillway, along with necessary appurtenances to be constructed as part of Laguna Del Campo Dam spillway Alternative 3.

This alternative calls for removing the existing emergency and service spillways and replacing them with an RCC overtopping emergency weir section constructed in line with the main dam embankment, with a service weir notch placed inside of the emergency weir. The service weir crest elevation is to be 2 feet lower than the emergency weir crest elevation and its length (perpendicular to the direction of flow) is to be 50 feet. The shape of the emergency spillway crest section is to be that of a (upstream) vertical-faced ogee weir. The service spillway crest section is to be shaped as a broad-crested weir.

After flowing down the downstream RCC dam face, excess kinetic energy is to be dissipated by a United States Bureau of Reclamation (USBR) Type I stilling basin, sized for the given inflow design flood (IDF).

Two different IDFs are to be considered with this alternative:

- Alternative 3a: IDF = 60% of probable maximum precipitation (PMP) and
- Alternative 3b: IDF = 100% of PMP.

METHOD:

In order to size the spillway and it appurtenances, the following iterative approach was employed with both IDFs considered, for Alternatives 3a and 3b:

1. Assume a crest elevation for the control section of the emergency spillway along with a weir length (perpendicular to the direction of flow) and a weir height (between the weir crest and the top of the upstream spillway approach section).
2. Compute a rating curve for the assumed weir shape (vertical faced ogee) using the weir equation and weir coefficients (varying with head over the weir crest) taken from “Design of Small Dams, Third Edition” (USBR, 1987). The rating curve will also incorporate a service section consisting of a 50 foot long broad-crested weir sited an elevation 2 feet lower than the assumed main crest elevation. Discharge for the service section will also be computed using the weir equation and weir coefficients (varying with head over the weir crest) taken from “Handbook of Hydraulics, Fifth Edition” (Brater & King, 1963). The two rating curves are to be combined into a single comprehensive rating for the RCC overtopping section.
3. Input the assumed combined rating curve as the only outflow structure from the representation of Laguna Del Campo Dam in a hydrologic model of the Laguna Del Campo Dam watershed constructed using HEC-HMS version 4.1 (USACE, 2015).
4. Execute the HEC-HMS model with the selected design storm, either 60% PMP for Alternative 3a or 100% PMP for Alternative 3b. Note both the peak water surface elevation and peak IDF outflow attained during the simulation.
   a. If the water surface elevation attained during the simulation <u>exceeds</u> the dam crest elevation minus residual freeboard, this particular layout is not a potential solution; return to Step 1 and assume new input values.

   b. If the computed water surface elevation is <u>less than or equal to</u> the dam crest elevation minus residual freeboard, this particular layout is a potential solution; continue to Step 5.
5. Size a stilling basin for construction at the downstream toe of the RCC dam using methods taken from "Hydraulic Design of Stilling Basins and Energy Dissipators, Eighth Edition" (USBR, 1984). Note the sequent depth (D_2) of the hydraulic jump which forms on the sized stilling basin.
6. Compare the sequent depth (D_2) from Step 5 with the corresponding tailwater depth (TW) from the rating curve developed in the Alternative 1 Calculations Appendix.
   a. If the sequent depth <u>exceeds</u> the corresponding tailwater depth, then "sweep out" of the hydraulic jump is predicted. To correct this deficiency, the stilling basin needs to be excavated below the existing downstream ground surface by a height equal to D_2 – TW.
   b. If the sequent depth is <u>less than or equal to</u> the corresponding tailwater depth, then no further action needs to be performed.
7. Finally, the height of training walls on either side of the RCC spillway on the downstream face of the dam are computed with the peak IDF outflow from Step 4 with methods taken from (USBR, 1987).

ASSUMPTIONS:

The following assumptions were employed:

- Elevations used in the spillway sizing calculations are based on a Local site datum. The conversion between the Local datum and the North American Vertical Datum of 1988 (NAVD88) is:
  – NAVD88 elevation = Local elevation + 7,210 feet.

  The datum conversion was determined by comparing contours along the left abutment of the dam (looking downstream) from the 1/3 arc-second digital elevation model (DEM) of the Laguna Del Campo Dam stream reach obtained from the United States Geological Survey (USGS) as discussed in the Alternative 1 Calculations Appendix to reservoir contours taken from a scanned design drawing of Laguna Del Campo Dam, included as Figure A-2 in Appendix A of "Laguna Del Campo Dam OSE Filing No. D313 Breach Analysis Report – Rio Arriba County, New Mexico" (URS, 2012). From these two sources, it appears that along the left abutment immediately upstream of the dam that NAVD88 contour elevation 7,315 feet aligns with Local datum contour elevation 105 feet.
- The HEC-HMS version 4.1 model of the Laguna Del Campo watershed was originally developed by URS, as described in (URS, 2012). Key assumptions employed in this hydrologic model include:
  – Upstream basin area = 5.7 mi^2,
  – Rainfall loss method employed is the Initial Loss / Continuing Loss method, with the following parameters:
    - o Initial loss = 0.0 in,
    - o Continuing loss = 0.034 in/hr, and
    - o Basin imperviousness = 0.0%.
  – Excess rainfall to runoff transformation accomplished with the Unit Hydrograph method. Derivation of the Laguna Del Campo watershed unit hydrograph is detailed in Section 2.3 of (URS, 2012), and

  - Elevation vs. Storage information for Laguna Del Campo Dam was taken from Table 3-2 of (URS, 2012).
- A copy of the source HEC-HMS model files for (URS, 2012) was obtained from the New Mexico Department of Game and Fish (NMDGF). This model was then altered by replacing the original spillway rating curve with the various spillway trials.
- Assumed constraints for sizing the Alternative 3a (60% PMP) RCC emergency spillway section include:
  - Dam crest elevation = 104.0 ft (Local),
  - Residual freeboard = 1.0 ft (based on wave run-up calculations for the Laguna Del Campo Dam site),
  - Maximum acceptable weir length = 500.0 ft,
  - Maximum acceptable water surface elevation = 104.0 ft – 1.0 ft = 103.0 ft (Local),
  - Emergency spillway weir crest elevation = 99.75 ft (Local),
  - Service spillway weir crest elevation = 97.75 ft (Local),
  - Emergency spillway weir height = 2.0 ft,
  - Service spillway weir height = 0.0 ft, and
  - Starting water surface elevation = 97.75 ft (Local).
- Assumed constraints for sizing the Alternative 3b (100% PMP) RCC emergency spillway section include:
  - Dam crest elevation = 104.0 ft (Local),
  - Residual freeboard = 1.0 ft (based on wave run-up calculations for the Laguna Del Campo Dam site),
  - Maximum acceptable weir length = 500.0 ft,
  - Maximum acceptable water surface elevation = 104.0 ft – 1.0 ft = 103.0 ft (Local),
  - Emergency spillway weir crest elevation = 96.75 ft (Local),
  - Service spillway weir crest elevation = 94.75 ft (Local),
  - Emergency spillway weir height = 2.0 ft,
  - Service spillway weir height = 0.0 ft, and
  - Starting water surface elevation = 94.75 ft (Local).

CALCULATIONS:

The procedure discussed in the Methods section was employed to determine the necessary configuration of the spillway for Laguna Del Campo Dam spillway Alternatives 3a and 3b. Results of this procedure are given in the following section.

CONCLUSIONS/RESULTS:

For Alternative 3a, the following spillway configuration was found to give satisfactory performance:

- Emergency weir length (perpendicular to flow) = 488.3 ft,
- Service weir length = 50.0 ft (contained within the emergency weir),
- Weir breadth (in direction of flow for both emergency and service portions) = 1.0 ft,
- Stilling basin length = 49.6 ft,
- Minimum stilling basin wall height = 13.6 ft,
- Additional excavation for the stilling basin is not required as (D_2: 8.1 ft < TW: 9.6 ft), and

- Height of training walls on either side of the RCC spillway on the downstream face of the dam = 3.5 ft.

The resulting spillway rating curves for Alternative 3a are tabulated in Table 1 and illustrated on Figure 1. When used in the HEC-HMS model, the aforementioned spillway rating curve gave the following results when run with the 60% PMP, 6-hour duration storm:

- Peak inflow = 11,877 ft^3/s,
- Peak outflow = 11,836 ft^3/s,
- Peak storage volume = 162.4 acre-ft, and
- Peak water surface elevation = 103.0 ft (Local).

Detailed results of the HEC-HMS modeling for Alternative 3a are provided in Attachment 1.

For Alternative 3b, the following spillway configuration was found to give satisfactory performance:

- Emergency weir length (perpendicular to flow) = 324.5 ft,
- Service weir length = 50.0 ft (contained within the emergency weir),
- Weir breadth (in direction of flow for both emergency and service portions) = 1.0 ft,
- Stilling basin length = 94.2 ft,
- Minimum stilling basin wall height = 23.8 ft,
- Additional excavation is required the stilling basin as (D_2: 15.5 ft > TW: 12.7 ft); the required excavation depth is 2.9 ft, and
- Height of training walls on either side of the RCC spillway on the downstream face of the dam = 4.5 ft.

The resulting spillway rating curves for Alternative 3b are tabulated in Table 2 and illustrated on Figure 2. When used in the HEC-HMS model, the aforementioned spillway rating curve gave the following results when run with the 100% PMP, 6-hour duration storm:

- Peak inflow = 19,875 ft^3/s,
- Peak outflow = 19,784 ft^3/s,
- Peak storage volume = 162.4 acre-ft, and
- Peak water surface elevation = 103.0 ft (Local).

Detailed results of the HEC-HMS modeling for Alternative 3b are provided in Attachment 2.

Stilling basin design calculations, including the tailwater check and approach chute height determination (Steps 5, 6 & 7) for Alternatives 3a and 3b are detailed in Attachment 3.

REFERENCES:

1. Brater, E.F. & King, H.W., “Handbook of Hydraulics, Fifth Edition”, 1963. Boston MA.
2. URS, *“Laguna Del Campo Dam OSE Filing No. D313 Breach Analysis Report – Rio Arriba County, New Mexico”*, Design report prepared for the New Mexico Department of Game and Fish, July, 2012. Denver, CO.
3. United States Army Corps of Engineers (USACE), *“HEC-HMS Hydrologic Modeling System, Version 4.1”*, Computer software, July, 2015. Davis, CA.
4. United States Bureau of Reclamation (USBR), *“Hydraulic Design of Stilling Basins and Energy Dissipators, Eighth Edition”*, May, 1984. Washington, DC.
5. United States Bureau of Reclamation (USBR), *“Design of Small Dams, Third Edition”*, 1987. Washington, DC.

TABLES

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Subject New Mexico Department of Game & Fish	Made by TML	Job No. 1772.16.00
	Laguna Del Campo Dam	Checked DTH	Date 5/20/2016
	Spillway Evaluation - Alternative 3a & 3b Calculations	Approved TSS	

Table 1: Spillway Alternative 3a Elevation / Discharge Relationships for Laguna Del Campo Reservoir RCC Spillways

Elevation / Discharge data was computed using different assumptions: a narrow broad-crested weir and a vertical-faced ogee crest.
For the (narrow) broad-crested weir assumption, discharge was computed using equations taken from "Handbook of Hydraulics, Fifth Edition" (Brater & King, 1963).
For the vertical-faced ogee weir assumption, discharge was computed using equations & data taken from "Design of Small Dams" (USBR, 1987).
With both rating curves, ideal entrance (i.e. parallel streamlines & minimal losses) and exit conditions (i.e. no tailwater) are assumed to exist.

BC Weir Height, P = 0.0 **ft** | **VF Ogee Weir Height, P =** 2.0 **ft**
BC Weir Length, L = 50.0 **ft** | **VF Ogee Weir Length, L =** 438.3 **ft**
BC Weir Breadth, B = 1.0 **ft** | **Total Weir Length, L =** 488.3 **ft**

Water Surface Elevation z (ft)	Narrow Broad-Crested Weir (Service) Piez. Head h (ft)	Coefficient C_o ($ft^{0.5}/s$)	Discharge Q_{BC} (ft^3/s)	Vertical-Faced Ogee Weir (Emergency) Piez. Head h (ft)	Ratio P / h (ft/ft)	Coefficient C_o ($ft^{0.5}/s$)	Discharge Q_{OG} (ft^3/s)	Total Discharge $Q_{BC} + Q_{OG}$ (ft^3/s)	
97.75	-	#N/A	-	#N/A	#N/A	#N/A	-	-	⇦ Invert for service weir
97.80	0.05	2.690	1.5	#N/A	#N/A	#N/A	-	1.5	
98.00	0.25	2.698	16.9	#N/A	#N/A	#N/A	-	16.9	
98.20	0.45	2.728	41.2	#N/A	#N/A	#N/A	-	41.2	
98.40	0.65	2.775	72.7	#N/A	#N/A	#N/A	-	72.7	
98.60	0.85	2.883	112.9	#N/A	#N/A	#N/A	-	112.9	
98.80	1.05	3.005	161.7	#N/A	#N/A	#N/A	-	161.7	
99.00	1.25	3.110	217.3	#N/A	#N/A	#N/A	-	217.3	
99.20	1.45	3.220	281.1	#N/A	#N/A	#N/A	-	281.1	
99.40	1.65	3.288	348.4	#N/A	#N/A	#N/A	-	348.4	
99.60	1.85	3.308	416.1	#N/A	#N/A	#N/A	-	416.1	
99.75	2.00	3.300	466.7	-	#N/A	#N/A	-	466.7	⇦ Invert for emergency weir
99.80	2.05	3.301	484.4	0.05	40.00	3.950	19.4	503.8	
100.00	2.25	3.305	557.7	0.25	8.00	3.950	216.4	774.1	
100.20	2.45	3.309	634.5	0.45	4.44	3.950	522.6	1,157.1	
100.40	2.65	3.313	714.6	0.65	3.08	3.950	907.3	1,621.9	
100.60	2.85	3.317	798.0	0.85	2.35	3.941	1,353.8	2,151.7	
100.80	3.05	3.320	884.2	1.05	1.90	3.932	1,854.3	2,738.5	
101.00	3.25	3.320	972.6	1.25	1.60	3.923	2,403.0	3,375.6	
101.20	3.45	3.320	1,063.7	1.45	1.38	3.914	2,995.3	4,059.0	
101.40	3.65	3.320	1,157.6	1.65	1.21	3.906	3,628.2	4,785.7	

Table 1: Spillway Alternative 3a Elevation / Discharge Relationships for Laguna Del Campo Reservoir RCC Spillways

Elevation / Discharge data was computed using different assumptions: a narrow broad-crested weir and a vertical-faced ogee crest.
For the (narrow) broad-crested weir assumption, discharge was computed using equations taken from "Handbook of Hydraulics, Fifth Edition" (Brater & King, 1963).
For the vertical-faced ogee weir assumption, discharge was computed using equations & data taken from "Design of Small Dams" (USBR, 1987).
With both rating curves, ideal entrance (i.e. parallel streamlines & minimal losses) and exit conditions (i.e. no tailwater) are assumed to exist.

BC Weir Height, P =	0.0	**ft**	**VF Ogee Weir Height, P =**	2.0	**ft**
BC Weir Length, L =	50.0	**ft**	**VF Ogee Weir Length, L =**	438.3	**ft**
BC Weir Breadth, B =	1.0	**ft**	**Total Weir Length, L =**	488.3	**ft**

Water Surface	Narrow Broad-Crested Weir (Service)			Vertical-Faced Ogee Weir (Emergency)				Total	
Elevation z (ft)	Piez. Head h (ft)	Coefficient C_o ($ft^{0.5}/s$)	Discharge Q_{BC} (ft^3/s)	Piez. Head h (ft)	Ratio P / h (ft/ft)	Coefficient C_o ($ft^{0.5}/s$)	Discharge Q_{OG} (ft^3/s)	Discharge $Q_{BC} + Q_{OG}$ (ft^3/s)	
101.60	3.85	3.320	1,254.0	1.85	1.08	3.893	4,293.6	5,547.6	
101.80	4.05	3.320	1,353.0	2.05	0.98	3.883	4,994.8	6,347.8	
102.00	4.25	3.320	1,454.4	2.25	0.89	3.874	5,730.5	7,184.9	
102.20	4.45	3.320	1,558.3	2.45	0.82	3.867	6,499.1	8,057.4	
102.40	4.65	3.320	1,664.5	2.65	0.75	3.860	7,299.3	8,963.8	
102.60	4.85	3.320	1,773.0	2.85	0.70	3.850	8,119.7	9,892.7	
102.80	5.05	3.320	1,883.8	3.05	0.66	3.841	8,967.7	10,851.6	
103.00	5.25	3.320	1,996.9	3.25	0.62	3.833	9,843.4	11,840.2	
103.20	5.45	3.320	2,112.0	3.45	0.58	3.824	10,740.1	12,852.1	
103.40	5.65	3.320	2,229.4	3.65	0.55	3.814	11,658.3	13,887.7	
103.60	5.85	3.320	2,348.8	3.85	0.52	3.806	12,601.2	14,950.0	
103.80	6.05	3.320	2,470.3	4.05	0.49	3.798	13,566.1	16,036.4	
104.00	6.25	3.320	2,593.8	4.25	0.47	3.788	14,547.6	17,141.4	⇦ Dam & North Dike crest elevation

W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Subject New Mexico Department of Game & Fish	Made by TML	Job No. 1772.16.00
	Laguna Del Campo Dam	Checked DTH	Date 5/20/2016
	Spillway Evaluation - Alternative 3a & 3b Calculations	Approved TSS	

Table 2: Spillway Alternative 3b Elevation / Discharge Relationships for Laguna Del Campo Reservoir RCC Spillways

Elevation / Discharge data was computed using different assumptions: a narrow broad-crested weir and a vertical-faced ogee crest.
For the (narrow) broad-crested weir assumption, discharge was computed using equations taken from "Handbook of Hydraulics, Fifth Edition" (Brater & King, 1963).
For the vertical-faced ogee weir assumption, discharge was computed using equations & data taken from "Design of Small Dams" (USBR, 1987).
With both rating curves, ideal entrance (i.e. parallel streamlines & minimal losses) and exit conditions (i.e. no tailwater) are assumed to exist.

BC Weir Height, P =	0.0	**ft**	**VF Ogee Weir Height, P =**	2.0	**ft**
BC Weir Length, L =	50.0	**ft**	**VF Ogee Weir Length, L =**	274.5	**ft**
BC Weir Breadth, B =	1.0	**ft**	**Total Weir Length, L =**	324.5	**ft**

Water Surface	Narrow Broad-Crested Weir (Service)			Vertical-Faced Ogee Weir (Emergency)				Total	
Elevation z (ft)	Piez. Head h (ft)	Coefficient C_o ($ft^{0.5}/s$)	Discharge Q_{BC} (ft^3/s)	Piez. Head h (ft)	Ratio P / h (ft/ft)	Coefficient C_o ($ft^{0.5}/s$)	Discharge Q_{OG} (ft^3/s)	Discharge $Q_{BC} + Q_{OG}$ (ft^3/s)	
94.75	-	#N/A	-	#N/A	#N/A	#N/A	-	-	⇦ Invert for service weir
94.80	0.05	2.690	1.5	#N/A	#N/A	#N/A	-	1.5	
95.00	0.25	2.698	16.9	#N/A	#N/A	#N/A	-	16.9	
95.20	0.45	2.728	41.2	#N/A	#N/A	#N/A	-	41.2	
95.40	0.65	2.775	72.7	#N/A	#N/A	#N/A	-	72.7	
95.60	0.85	2.883	112.9	#N/A	#N/A	#N/A	-	112.9	
95.80	1.05	3.005	161.7	#N/A	#N/A	#N/A	-	161.7	
96.00	1.25	3.110	217.3	#N/A	#N/A	#N/A	-	217.3	
96.20	1.45	3.220	281.1	#N/A	#N/A	#N/A	-	281.1	
96.40	1.65	3.288	348.4	#N/A	#N/A	#N/A	-	348.4	
96.60	1.85	3.308	416.1	#N/A	#N/A	#N/A	-	416.1	
96.75	2.00	3.300	466.7	-	#N/A	#N/A	-	466.7	⇦ Invert for emergency weir
96.80	2.05	3.301	484.4	0.05	40.00	3.950	12.1	496.6	
97.00	2.25	3.305	557.7	0.25	8.00	3.950	135.5	693.3	
97.20	2.45	3.309	634.5	0.45	4.44	3.950	327.3	961.8	
97.40	2.65	3.313	714.6	0.65	3.08	3.950	568.2	1,282.8	
97.60	2.85	3.317	798.0	0.85	2.35	3.941	847.8	1,645.8	
97.80	3.05	3.320	884.2	1.05	1.90	3.932	1,161.3	2,045.5	
98.00	3.25	3.320	972.6	1.25	1.60	3.923	1,505.0	2,477.6	
98.20	3.45	3.320	1,063.7	1.45	1.38	3.914	1,875.9	2,939.7	
98.40	3.65	3.320	1,157.6	1.65	1.21	3.906	2,272.3	3,429.8	

Table 2: Spillway Alternative 3b Elevation / Discharge Relationships for Laguna Del Campo Reservoir RCC Spillways

Elevation / Discharge data was computed using different assumptions: a narrow broad-crested weir and a vertical-faced ogee crest.
For the (narrow) broad-crested weir assumption, discharge was computed using equations taken from "Handbook of Hydraulics, Fifth Edition" (Brater & King, 1963).
For the vertical-faced ogee weir assumption, discharge was computed using equations & data taken from "Design of Small Dams" (USBR, 1987).
With both rating curves, ideal entrance (i.e. parallel streamlines & minimal losses) and exit conditions (i.e. no tailwater) are assumed to exist.

BC Weir Height, P = 0.0 **ft** | **VF Ogee Weir Height, P =** 2.0 **ft**
BC Weir Length, L = 50.0 **ft** | **VF Ogee Weir Length, L =** 274.5 **ft**
BC Weir Breadth, B = 1.0 **ft** | **Total Weir Length, L =** 324.5 **ft**

Water Surface Elevation z (ft)	Narrow Broad-Crested Weir (Service) Piez. Head h (ft)	Coefficient C_o ($ft^{0.5}/s$)	Discharge Q_{BC} (ft^3/s)	Vertical-Faced Ogee Weir (Emergency) Piez. Head h (ft)	Ratio P / h (ft/ft)	Coefficient C_o ($ft^{0.5}/s$)	Discharge Q_{OG} (ft^3/s)	Total Discharge $Q_{BC} + Q_{OG}$ (ft^3/s)
98.60	3.85	3.320	1,254.0	1.85	1.08	3.893	2,689.0	3,943.0
98.80	4.05	3.320	1,353.0	2.05	0.98	3.883	3,128.2	4,481.2
99.00	4.25	3.320	1,454.4	2.25	0.89	3.874	3,588.9	5,043.3
99.20	4.45	3.320	1,558.3	2.45	0.82	3.867	4,070.3	5,628.6
99.40	4.65	3.320	1,664.5	2.65	0.75	3.860	4,571.4	6,235.9
99.60	4.85	3.320	1,773.0	2.85	0.70	3.850	5,085.2	6,858.3
99.80	5.05	3.320	1,883.8	3.05	0.66	3.841	5,616.3	7,500.2
100.00	5.25	3.320	1,996.9	3.25	0.62	3.833	6,164.7	8,161.6
100.20	5.45	3.320	2,112.0	3.45	0.58	3.824	6,726.3	8,838.4
100.40	5.65	3.320	2,229.4	3.65	0.55	3.814	7,301.4	9,530.8
100.60	5.85	3.320	2,348.8	3.85	0.52	3.806	7,892.0	10,240.7
100.80	6.05	3.320	2,470.3	4.05	0.49	3.798	8,496.2	10,966.5
101.00	6.25	3.320	2,593.8	4.25	0.47	3.788	9,110.9	11,704.7
101.20	6.45	3.320	2,719.2	4.45	0.45	3.780	9,739.8	12,459.0
101.40	6.65	3.320	2,846.7	4.65	0.43	3.772	10,382.4	13,229.1
101.60	6.85	3.320	2,976.1	4.85	0.41	3.765	11,038.6	14,014.7
101.80	7.05	3.320	3,107.4	5.05	0.40	3.757	11,704.3	14,811.7
102.00	7.25	3.320	3,240.5	5.25	0.38	3.747	12,371.6	15,612.1
102.20	7.45	3.320	3,375.5	5.45	0.37	3.737	13,051.1	16,426.6
102.40	7.65	3.320	3,512.4	5.65	0.35	3.728	13,742.5	17,254.9

Table 2: Spillway Alternative 3b Elevation / Discharge Relationships for Laguna Del Campo Reservoir RCC Spillways

Elevation / Discharge data was computed using different assumptions: a narrow broad-crested weir and a vertical-faced ogee crest.
For the (narrow) broad-crested weir assumption, discharge was computed using equations taken from "Handbook of Hydraulics, Fifth Edition" (Brater & King, 1963).
For the vertical-faced ogee weir assumption, discharge was computed using equations & data taken from "Design of Small Dams" (USBR, 1987).
With both rating curves, ideal entrance (i.e. parallel streamlines & minimal losses) and exit conditions (i.e. no tailwater) are assumed to exist.

BC Weir Height, P =	0.0	**ft**	**VF Ogee Weir Height, P =**	2.0	**ft**
BC Weir Length, L =	50.0	**ft**	**VF Ogee Weir Length, L =**	274.5	**ft**
BC Weir Breadth, B =	1.0	**ft**	**Total Weir Length, L =**	324.5	**ft**

Water Surface Elevation z (ft)	Narrow Broad-Crested Weir (Service) Piez. Head h (ft)	Coefficient C_o ($ft^{0.5}/s$)	Discharge Q_{BC} (ft^3/s)	Vertical-Faced Ogee Weir (Emergency) Piez. Head h (ft)	Ratio P / h (ft/ft)	Coefficient C_o ($ft^{0.5}/s$)	Discharge Q_{OG} (ft^3/s)	Total Discharge $Q_{BC} + Q_{OG}$ (ft^3/s)	
102.60	7.85	3.320	3,651.0	5.85	0.34	3.718	14,439.4	18,090.4	
102.80	8.05	3.320	3,791.4	6.05	0.33	3.708	15,144.6	18,936.1	
103.00	8.25	3.320	3,933.6	6.25	0.32	3.698	15,861.0	19,794.5	
103.20	8.45	3.320	4,077.5	6.45	0.31	3.689	16,588.2	20,665.7	
103.40	8.65	3.320	4,223.1	6.65	0.30	3.681	17,326.2	21,549.3	
103.60	8.85	3.320	4,370.4	6.85	0.29	3.672	18,070.8	22,441.2	
103.80	9.05	3.320	4,519.4	7.05	0.28	3.664	18,825.4	23,344.8	
104.00	9.25	3.320	4,670.0	7.25	0.28	3.656	19,590.2	24,260.3	⇦ Dam & North Dike crest elevation

FIGURES

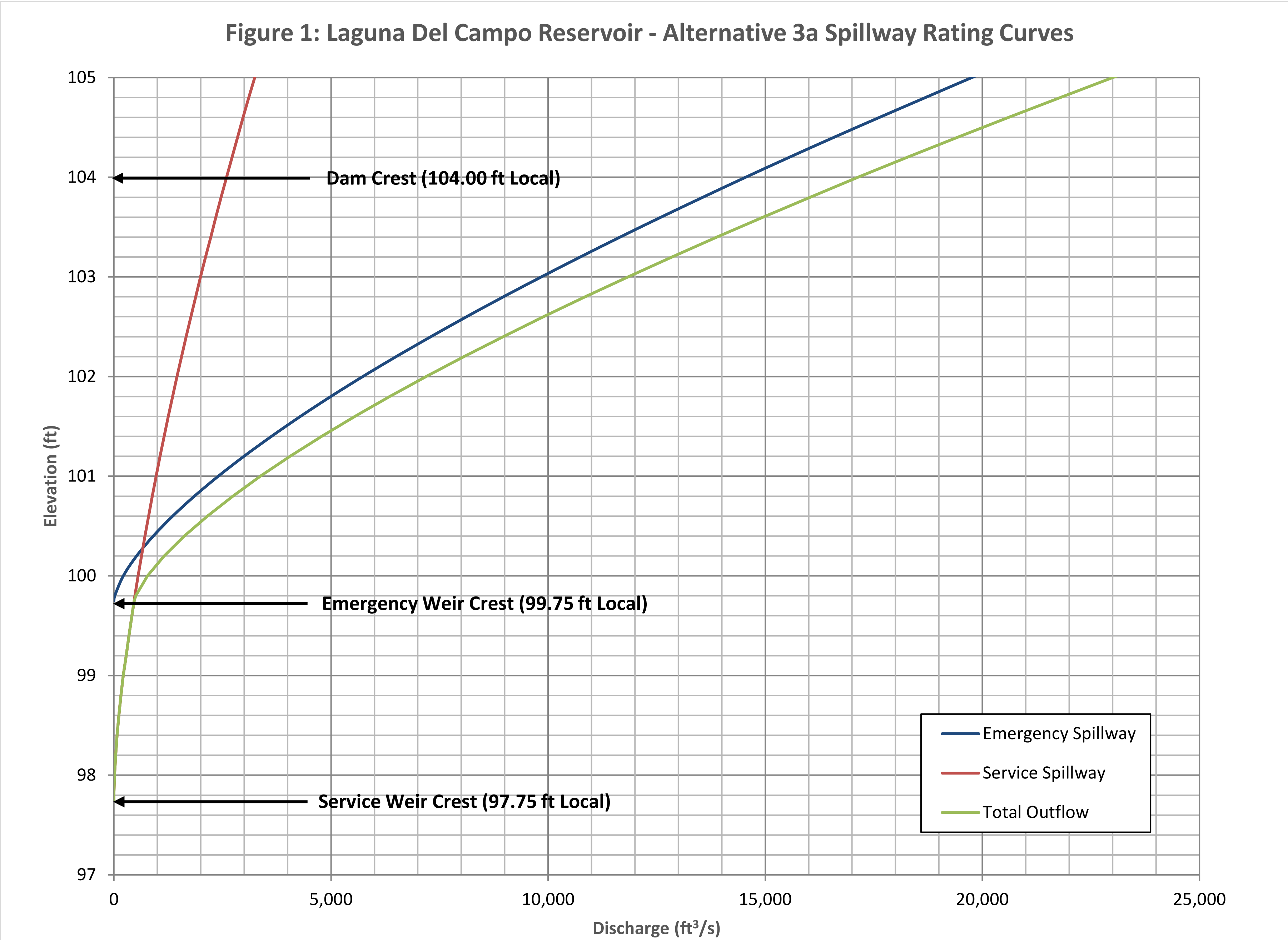
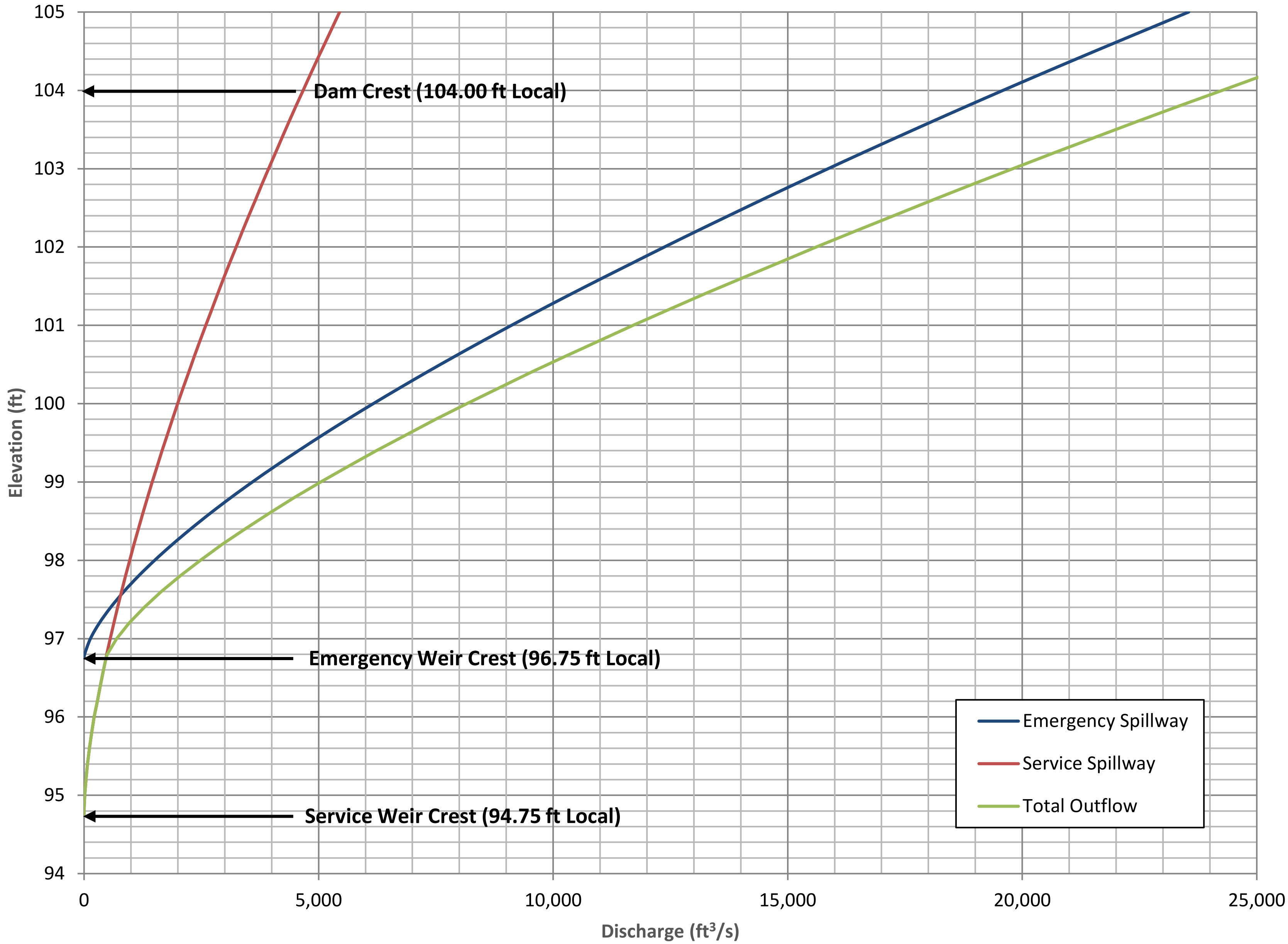


Figure 1: Laguna Del Campo Reservoir - Alternative 3a Spillway Rating Curves
Elevation (ft)
Discharge (ft³/s)
105
104
103
102
101
100
99
98
97
0
5,000
10,000
15,000
20,000
25,000
Dam Crest (104.00 ft Local)
Emergency Weir Crest (99.75 ft Local)
Service Weir Crest (97.75 ft Local)
Emergency Spillway
Service Spillway
Total Outflow

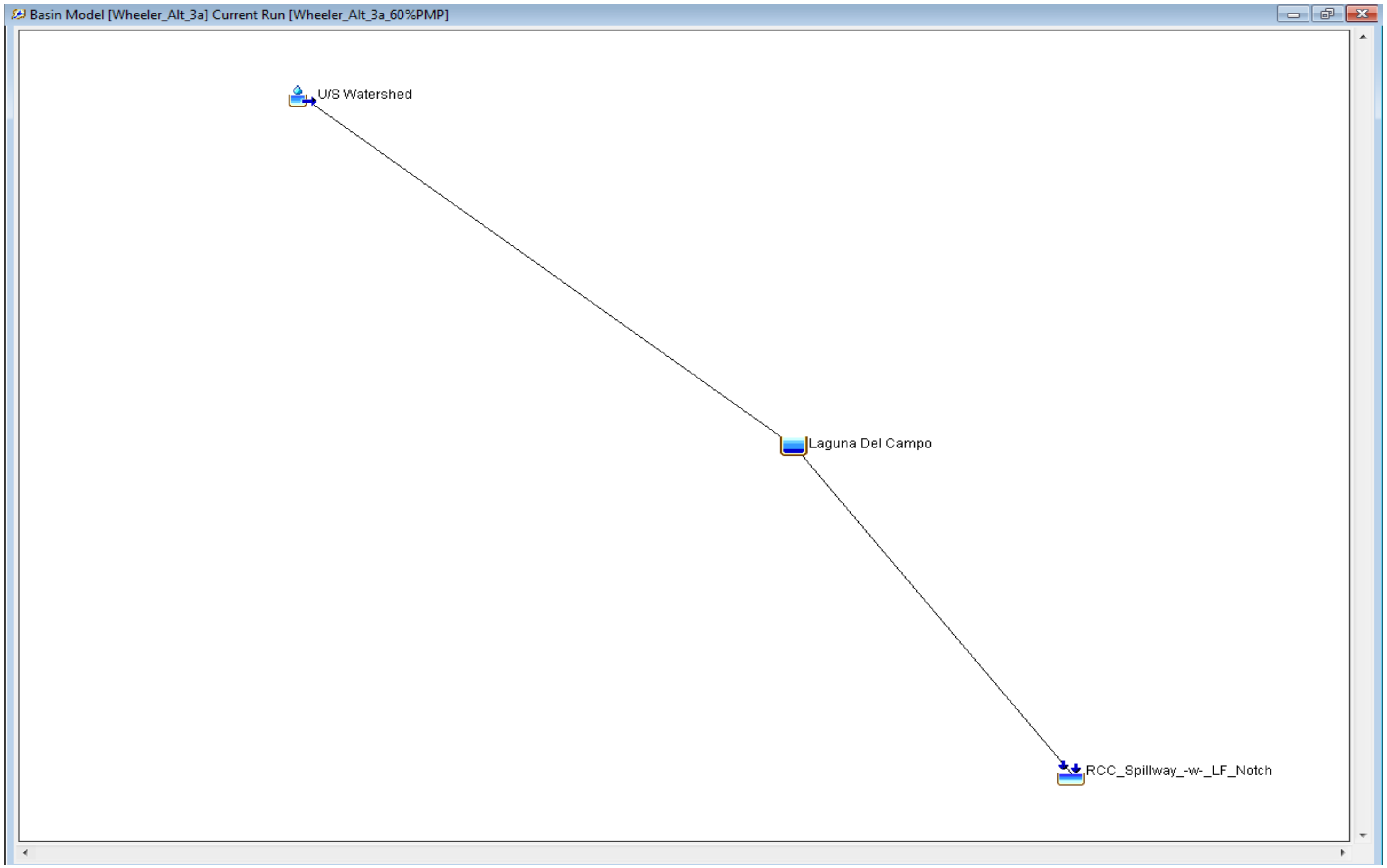
Figure 2: Laguna Del Campo Reservoir - Alternative 3b Spillway Rating Curves



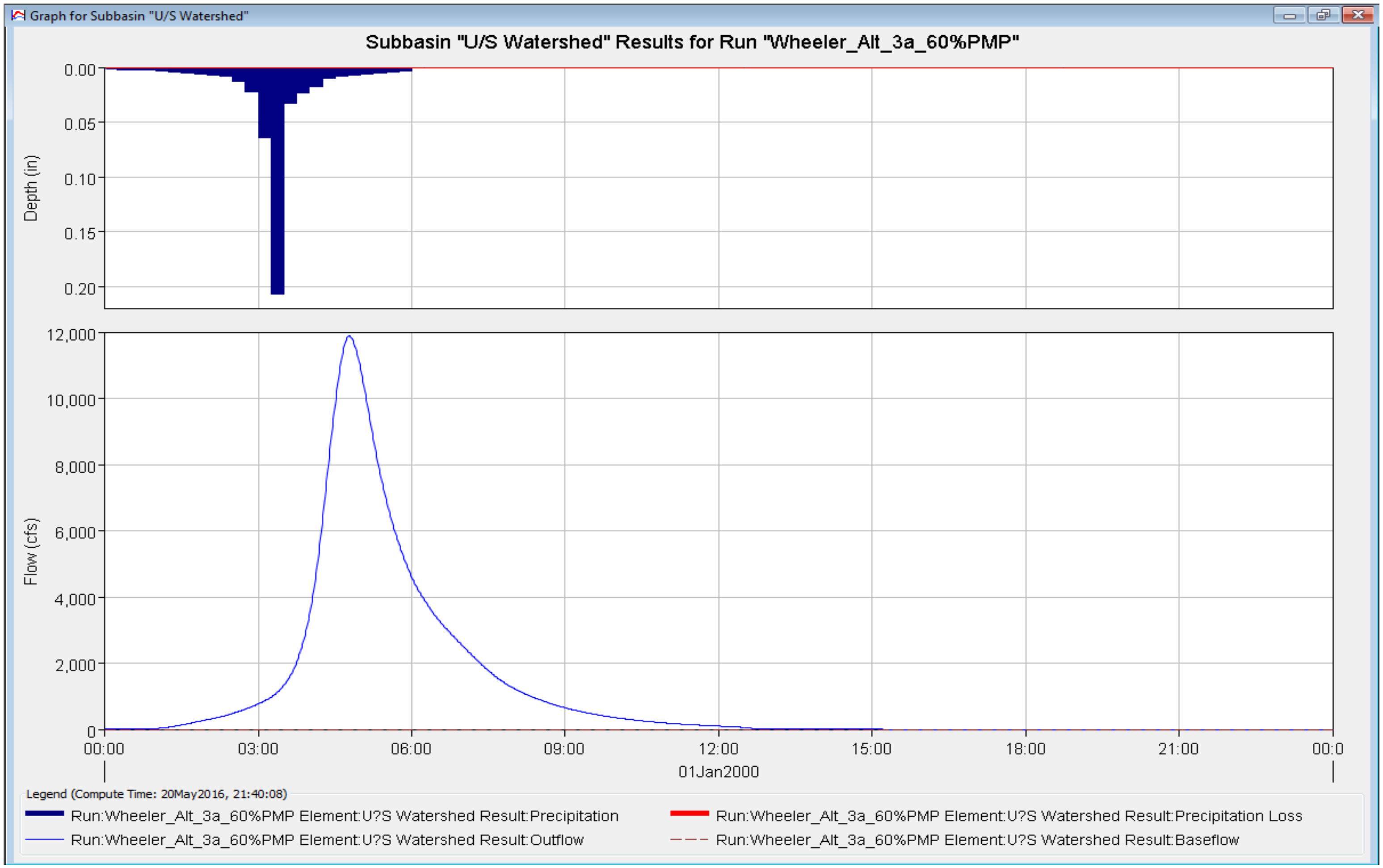
ATTACHMENT 1

SPILLWAY ALTERNATIVE 3a HEC-HMS RESULTS

Attachment 1: Spillway Alternative 3a HEC-HMS Results (Basin Schematic)



Attachment 1: Spillway Alternative 3a HEC-HMS Results (Upstream Watershed Results Graph for 60% PMP Storm)



Attachment 1: Spillway Alternative 3a HEC-HMS Results (Upstream Watershed Results Table for 60% PMP Storm)

Summary Results for Subbasin "U/S Watershed"

Project: LagunaDamSpwyAlts Simulation Run: Wheeler_Alt_3a_60%PMP

Subbasin: U/S Watershed

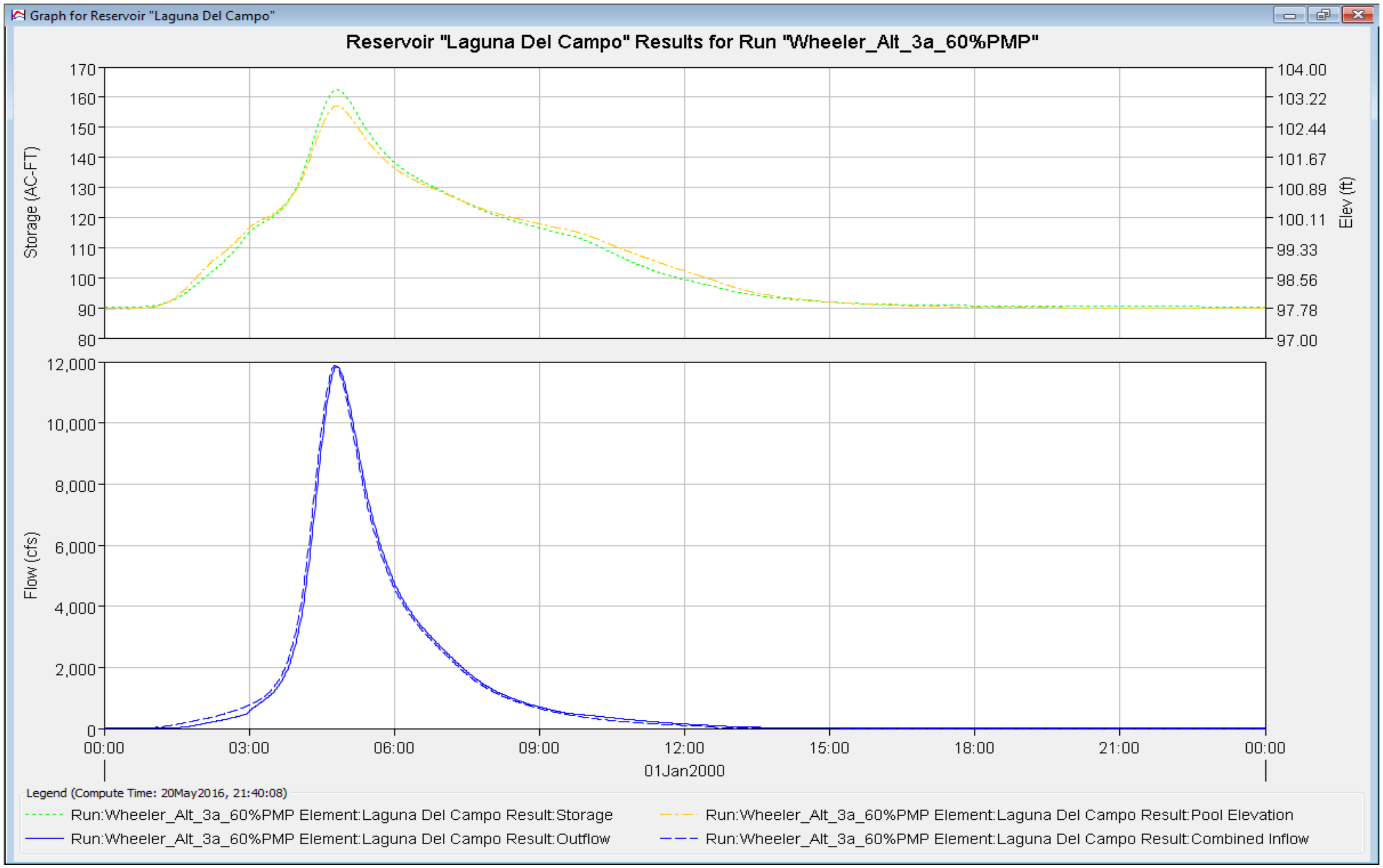
Start of Run:	01Jan2000, 00:00	Basin Model:	Wheeler_Alt_3a
End of Run:	02Jan2000, 00:00	Meteorologic Model:	6-hr_PMP_EM
Compute Time:	20May2016, 21:40:08	Control Specifications:	6-hr_PMP

Volume Units: (•) IN ( ) AC-FT

Computed Results

Peak Discharge:	11877.230 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 04:46
Precipitation Volume:	7.038 (IN)	Direct Runoff Volume:	6.898 (IN)
Loss Volume:	0.204 (IN)	Baseflow Volume:	0.000 (IN)
Excess Volume:	6.834 (IN)	Discharge Volume:	6.898 (IN)

Attachment 1: Spillway Alternative 3a HEC-HMS Results (Reservoir Results Graph for 60% PMP Storm)



Attachment 1: Spillway Alternative 3a HEC-HMS Results (Reservoir Results Table for 60% PMP Storm)

Summary Results for Reservoir "Laguna Del Campo"

Project: LagunaDamSpwyAlts   Simulation Run: Wheeler_Alt_3a_60%PMP

Reservoir: Laguna Del Campo

Start of Run:	01Jan2000, 00:00	Basin Model:	Wheeler_Alt_3a
End of Run:	02Jan2000, 00:00	Meteorologic Model:	6-hr_PMP_EM
Compute Time:	20May2016, 21:40:08	Control Specifications:	6-hr_PMP

Volume Units: (•) IN ( ) AC-FT

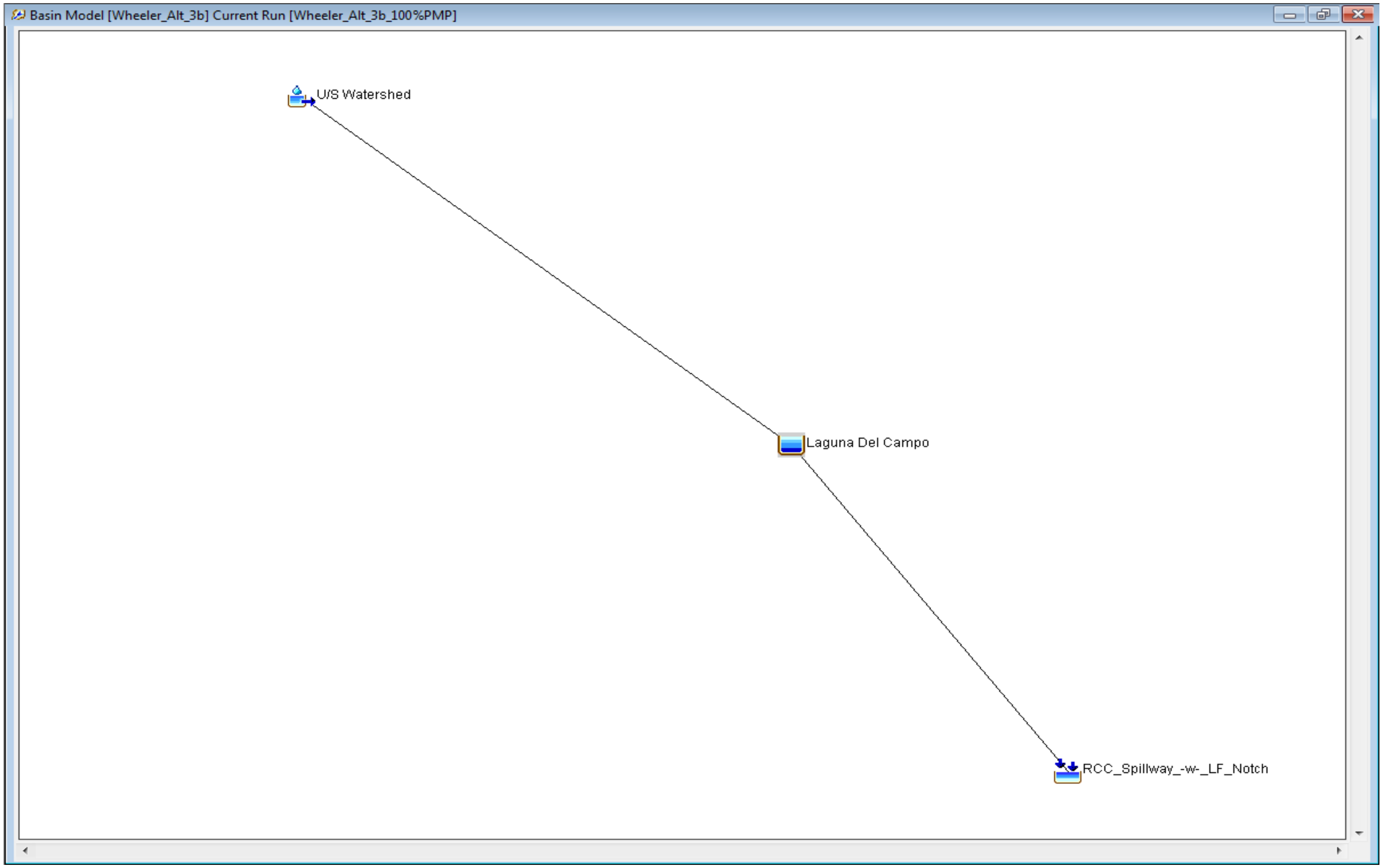
Computed Results

Peak Inflow:	11877.230 (CFS)	Date/Time of Peak Inflow:	01Jan2000, 04:46
Peak Discharge:	11836.058 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 04:49
Inflow Volume:	6.898 (IN)	Peak Storage:	162.437 (AC-FT)
Discharge Volume:	6.897 (IN)	Peak Elevation:	102.999 (FT)

ATTACHMENT 2

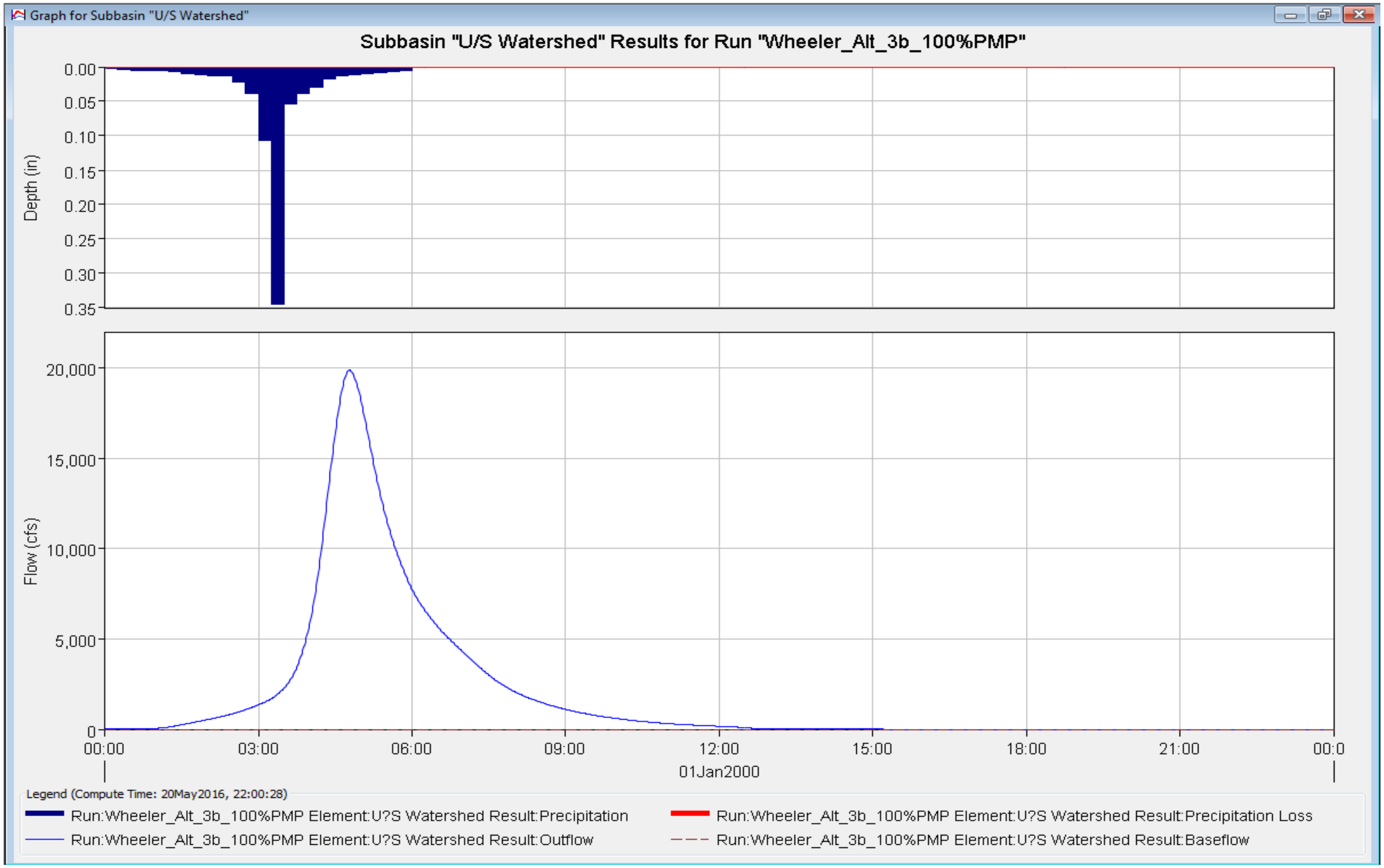
SPILLWAY ALTERNATIVE 3b HEC-HMS RESULTS

Attachment 2: Spillway Alternative 3b HEC-HMS Results (Basin Schematic)



	Subject	New Mexico Department of Game & Fish	Made by	TML	Job No.	1772.16.00
W. W. WHEELER & ASSOCIATES, INC. Water Resources Engineers	Laguna Del Campo Dam		Checked	DTH	Date	5/20/2016
	Spillway Evaluation - Alternative 3a & 3b Calculations		Approved	TSS		

Attachment 2: Spillway Alternative 3b HEC-HMS Results (Upstream Watershed Results Graph for 100% PMP Storm)



Attachment 2: Spillway Alternative 3b HEC-HMS Results (Upstream Watershed Results Table for 100% PMP Storm)

Summary Results for Subbasin "U/S Watershed"

Project: LagunaDamSpwyAlts Simulation Run: Wheeler_Alt_3b_100%PMP

Subbasin: U/S Watershed

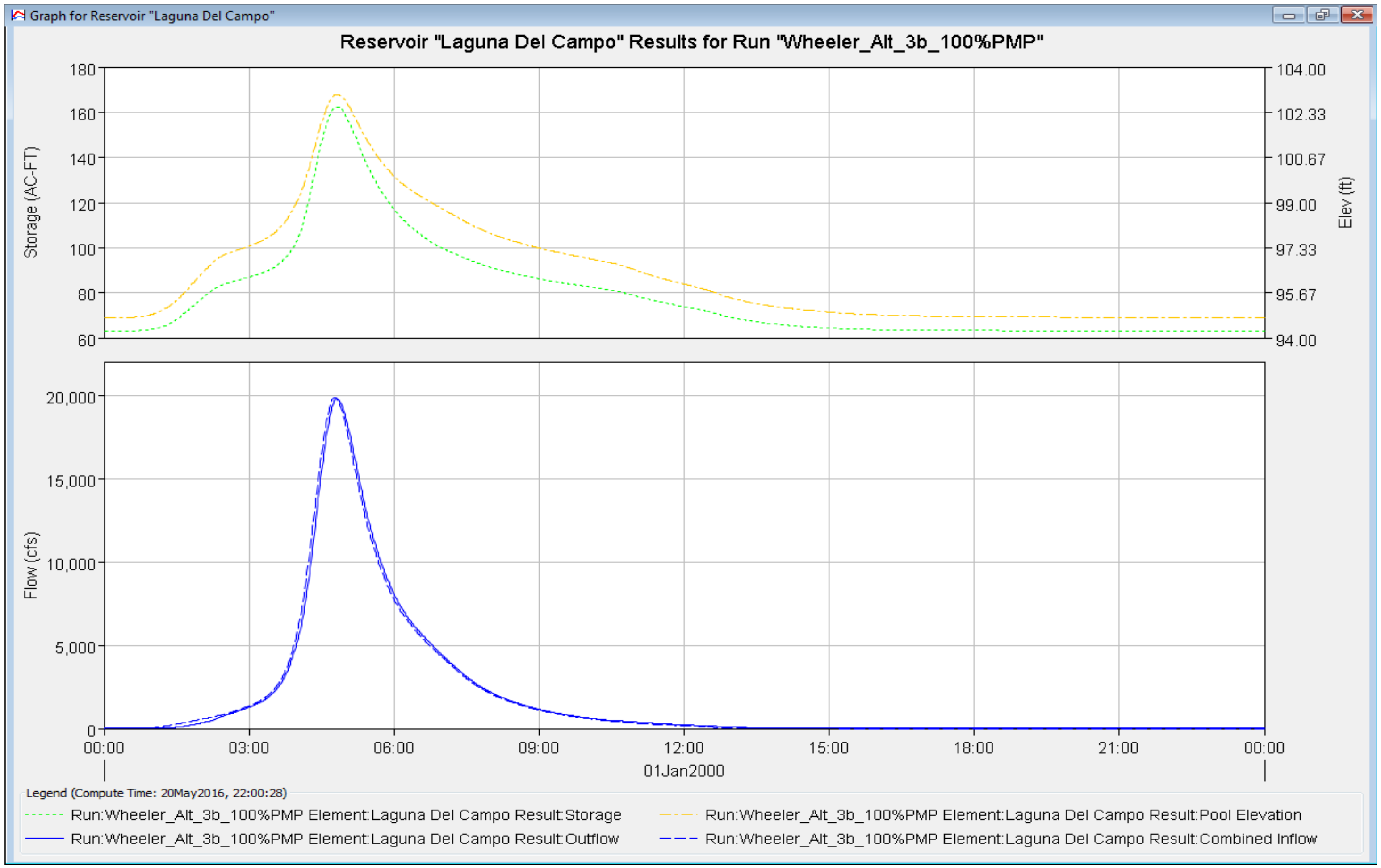
Start of Run:	01Jan2000, 00:00	Basin Model:	Wheeler_Alt_3b
End of Run:	02Jan2000, 00:00	Meteorologic Model:	6-hr_PMP_EM
Compute Time:	20May2016, 22:00:28	Control Specifications:	6-hr_PMP

Volume Units: (•) IN ( ) AC-FT

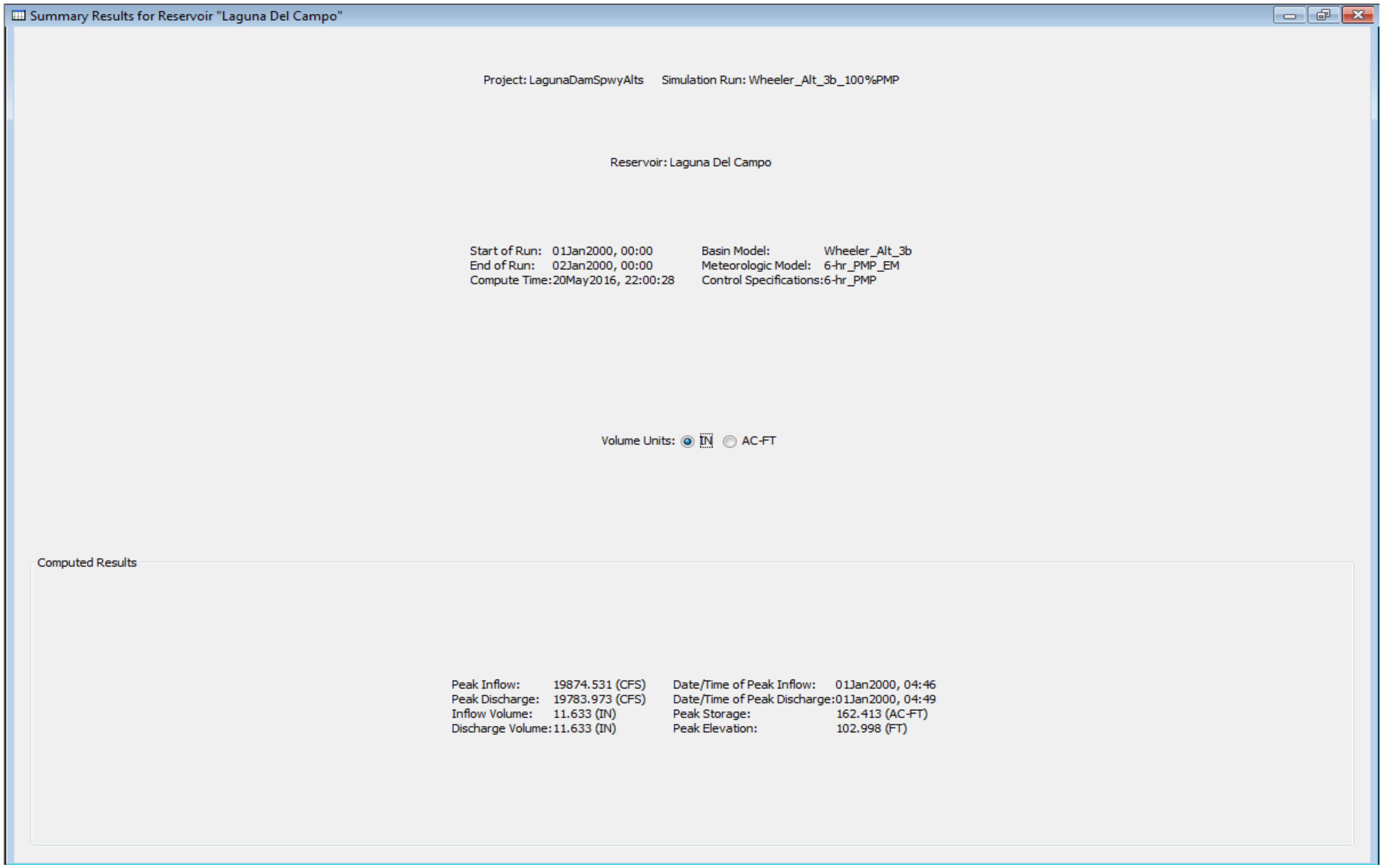
Computed Results

Peak Discharge:	19874.531 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 04:46
Precipitation Volume:	11.730 (IN)	Direct Runoff Volume:	11.633 (IN)
Loss Volume:	0.204 (IN)	Baseflow Volume:	0.000 (IN)
Excess Volume:	11.526 (IN)	Discharge Volume:	11.633 (IN)

Attachment 2: Spillway Alternative 3b HEC-HMS Results (Reservoir Results Graph for 100% PMP Storm)



Attachment 2: Spillway Alternative 3b HEC-HMS Results (Reservoir Results Table for 100% PMP Storm)



Summary Results for Reservoir "Laguna Del Campo"

Project: LagunaDamSpwyAlts   Simulation Run: Wheeler_Alt_3b_100%PMP

Reservoir: Laguna Del Campo

Start of Run:	01Jan2000, 00:00	Basin Model:	Wheeler_Alt_3b
End of Run:	02Jan2000, 00:00	Meteorologic Model:	6-hr_PMP_EM
Compute Time:	20May2016, 22:00:28	Control Specifications:	6-hr_PMP

Volume Units: IN AC-FT

Computed Results

Peak Inflow:	19874.531 (CFS)	Date/Time of Peak Inflow:	01Jan2000, 04:46
Peak Discharge:	19783.973 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 04:49
Inflow Volume:	11.633 (IN)	Peak Storage:	162.413 (AC-FT)
Discharge Volume:	11.633 (IN)	Peak Elevation:	102.998 (FT)

ATTACHMENT 3

SPILLWAY ALTERNATIVE 3a and 3b
STILLING BASIN DESIGN

Attachment 3 Spillway Alternatve 3a and 3b Stilling Basin Design (USBR Type I - Natural Hydraulic Jump)

Size a USBR Type I stilling basin by estimating the length required for a steady hydraulic jump to form at the peak design flow rate.
First, the hydraulic characteristics of the approach flow must be estimated by solving for normal depth on the approach chute at the peak design flow.

USBR Type I Stilling Basin Design: Approach Section Input Parameters

Alternative ID	Design Discharge Q (ft³/s)	Manning's Roughness n	Approach Slope S_1 (ft/ft)	Outlet Slope S_2 (ft/ft)	Bottom Width b (ft)	Channel Side Slopes Left z_L (H:1V)	Channel Side Slopes Right z_R (H:1V)	Gravitational Acceleration g (ft/s²)
3a	11,836.1	0.013	0.400	0.000	488.3	0.0	0.0	32.17
3b	19,784.0	0.013	0.400	0.000	324.5	0.0	0.0	32.17

Normal depth at the approach section (1) is found by simultaneously solving the following:

a) Manning's equation: $Q = (1/n) \cdot A_1 \cdot R_1^{2/3} \cdot S_1^{1/2}$

b) Area equation: $A_1 = (b + D_1 \cdot (z_L + z_R) / 2) \cdot D_1$

c) Wetted perimeter equation: $P_1 = b + D_1 \cdot ((1 + z_L^2)^{1/2} + (1 + z_R^2)^{1/2})$

d) Hydraulic radius equation: $R_1 = A_1 / P_1$

and the additional required hydraulic parameters are also determined:

e) Flow top width equation: $T_1 = b + (z_L \cdot D_1) + (z_R \cdot D_1)$

f) Velocity equation: $V_1 = Q / A_1$

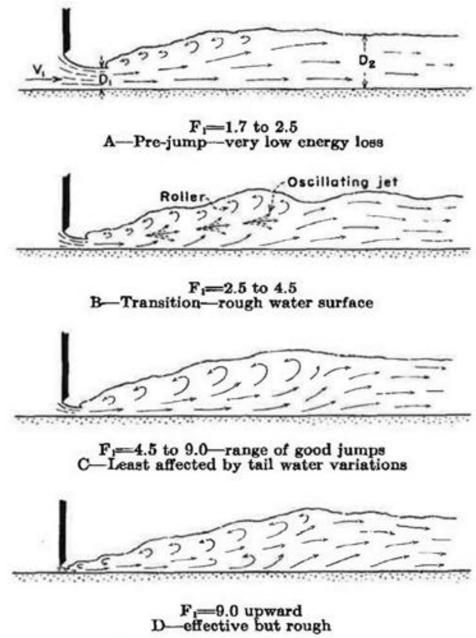
g) Froude number equation: $Fr_1 = V_1 / (g \cdot D_1)^{1/2}$

USBR Type I Stilling Basin Design: Approach Section Output Parameters

Alternative ID	Normal Depth D_1 (ft)	Flow Area A_1 (ft²)	Wetted Perimeter P_1 (ft)	Hydraulic Radius R_1 (ft)	Top Width T_1 (ft)	Flow Velocity V_1 (ft/s)	Froude Number Fr_1
3a	0.52	253.69	489.34	0.52	488.30	46.66	11.41
3b	0.90	293.61	326.31	0.90	324.50	67.38	12.49

Note that for the best performance (USBR, 1984), a steady hydraulic jump requires that $4.5 \le Fr_1 \le 9.0$.

Consequently, this spreadsheet has been programmed to only compute basin length (L) if the approach Froude number lies in the range of jumps denoted as Class "C" or "D" in the illustration to the right.



Jump Forms (Type I)

Attachment 3 Spillway Alternatve 3a and 3b Stilling Basin Design (USBR Type I - Natural Hydraulic Jump)

The flow depth at the downstream end of the hydraulic jump (sequent depth; D_2) is taken from (USBR, 1984). The other hydraulic parameters (A_2, P_2, R_2, T_2, V_2, and Fr_2) at the outlet section (2) are computed using the same relationships as previously presented, with the exception that the sequent depth (D_2) is used.

h) Sequent depth equation: $D_2 = (D_1 / 2) \cdot ((1 + 8 \cdot Fr_1^2)^{1/2} - 1)$

USBR Type I Stilling Basin Design: Outlet (Post-Jump) Section Hydraulic Parameters

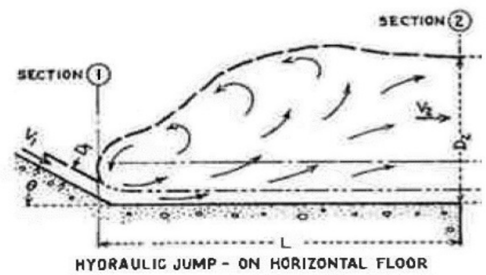
Alternative ID	Sequent Depth D_2 (ft)	Flow Area A_2 (ft^2)	Wetted Perimeter P_2 (ft)	Hydraulic Radius R_2 (ft)	Top Width T_2 (ft)	Flow Velocity V_2 (ft/s)	Froude Number Fr_2
3a	8.13	3969.23	504.56	7.87	488.30	2.98	0.18
3b	15.53	5040.82	355.57	14.18	324.50	3.92	0.18

The length of the hydraulic jump is determined using experimental data taken from (USBR, 1984):

USBR Type I Stilling Basin Design: Results

Alternative ID	Sequent Depth D_2 (ft)	Froude Number Fr_1	Design Freeboard FB (ft)	Sizing Parameter L / D_2	Min. Basin Length L (ft)	Basin Wall Height $D = D_2 + FB$ (ft)
3a	8.13	11.41	5.48	6.10	49.56	13.61
3b	15.53	12.49	8.29	6.06	94.18	23.83

Note: design freeboard, $FB = 0.1 \cdot (V_1 + D_2)$ - see (USBR,1987) page 398. The basin floor elevation should be set so that D_2 & TW match!



Basin Sketch - Type I

USBR Type I Stilling Basin Design: Tailwater Check and Approach Chute Height

Alternative ID	Tailwater Depth TW (ft)	Stilling Basin Ex. Depth EX (ft)	Normal Depth D_1 (ft)	Flow Velocity V_1 (ft/s)	Chute Height C (ft)
3a	9.59	0.00	0.52	46.66	3.46
3b	12.65	2.88	0.90	67.38	4.53

The training wall height on the spillway chute (approach section) is computed using:
i) Chute height equation: $C = D_1 + (2.0 + 0.025 \cdot V_1 \cdot D_1^{1/3})$ - see (USBR, 1987) page 385.

References:

U.S. Bureau of Reclamation (USBR). 1984. *Hydraulic Design of Stilling Basins and Energy Dissipators, 8th ed*. Washington D.C.: United States Government Printing Office.

U.S. Bureau of Reclamation (USBR). 1987. *Design of small dams, 3rd ed*. Washington D.C.: United States Government Printing Office.

Appendix C5

Residual Freeboard Calculations

W. W. Wheeler & Associates, Inc.

Client:	NMDGF	Date:	4/14/2016	By	TSS
Job No.	1772.16	Checked:	6/27/2016	By	DTH
		Approved:	6/28/2016	By	TSS

Subject: Calculation to determine the Normal Freeboard Requirement

Required:

1. USBR ACER Technical Memo No. 2: Freeboard Criteria and Guidelines for Computing Freeboard Allowances for Storage Dams published December 1981 (USBR TM2, ‘81)
2. Reservoir fetch lengths

Analysis Summary:

1. The effective reservoir fetch length (Fe) was calculated using Equation 1 from the USBR TM2 (‘81):

$$Equation\ 1: Fe = \frac{\sum X_i * \left(Cos^2(\alpha_i)\right)}{\sum Cos(\alpha_i)}$$

   The calculation is shown on Page 13, and Page 4 illustrates the radials (X_i) and angles (α_i) used in the calculation.

2. The maximum wind velocities at Laguna Del Campo were determined using Figures 1-8 from USBR TM2 (‘81) which depict Maximum 1-Minute (Fastest Mile of Record) and 1-Hour wind velocities. USBR TM2 Figures 1-8 are included in these calculations on Pages 5-12 and are summarized below:

Fastest Mile of Record, MPH (From Figure 1-4, USBR TM2, '81)			
Winter	76	Summer	75
Spring	71	Fall	55

Maximum One Hour Wind Velocity, MPH (From Figure 5-8, USBR TM2, '81)			
Winter	52	Summer	36
Spring	48	Fall	36

Maximum Two Hour Wind Velocity, MPH (1hr * 0.96 = 2hr, USBR TM2, '81)			
Winter	50	Summer	35
Spring	46	Fall	35

The 2-Hour wind speed was determined as a function of the 1-Hour wind speed as described in the USBR TM2:

$$2\ Hour\ Velocity = 1\ Hour\ Velocity * 0.96$$

An "over-water" wind velocity correction factor of 1.02 was determined by extrapolating the calculated effective fetch length for Laguna Del Campo Reservoir with Table 2 (USBR TM2, '81). The Fastest Mile of Record and Maximum One Hour velocities are used in normal freeboard calculations starting on Page 13 and minimum freeboard calculations starting on Page 20.

3. Wind velocity durations were determined as a function of the effective fetch length and over-water wind speed using Figure 9 (USBR TM2, '81) and are illustrated on Page 15.

4. The maximum design wind velocity and duration were determined as the intersection point between the velocity-duration curves for the MacFarlane Dam (1-Minute, 1-Hour and 2-Hour Duration) and the wind velocity durations for the effective fetch length, see Page 16.

5. The significant wave height (Hs) was determined as a function of the effective fetch length and maximum design wind velocity using Figure 9 (USBR TM2, '81) and is illustrated on Page 17.

6. The wave period (T) was determined as a function of the effective fetch length and design velocity using Figure 10 (USBR TM2, '81) and is illustrated on Page 18.

7. The deep water wave length (L) was calculated using Equation 2 from the USBR TM2 ('81).

$$Equation\ 2: L = 5.12 * T^2$$

8. The Runup from a significant wave (Rs) was calculated using Equation 3 from the USBR TM2 ('81).

$$Equation\ 3: R_s = \frac{H_S}{0.4 + \left(\frac{H_S}{L}\right)^{0.5} * cot(\theta)}$$

9. The Wind Setup (S) was calculated using Equation 4 from the USBR TM2 ('81).

$$Equation\ 4: S = \frac{U^2 * F}{1400 * D}$$

10. The Normal Freeboard Requirement is calculated as the sum of the Runup and Wind Setup and uses the maximum design parameters calculated above. The Minimum Freeboard Requirement was determined by repeating Analysis Summary Steps 2-9. The effective fetch remained the same, but the maximum 1-Minute and 1-Hour wind velocities used for the Normal Freeboard calculation were reduced by a factor of 80% which is consistent with the adjustment factor used in the USBR TM2 pg 37. The design maximum WSEL while routing the will be the dam crest elevation of 104' minus the calculated minimum freeboard.

Assumptions:

1. Wind data at or near the dam site are not available. The Fastest Mile (1-Minute Duration) and Maximum 1-Hour wind speeds were used to determine the maximum wind speed at Laguna Del Campo Reservoir. The maximum wind speed was used to determine the Normal Freeboard Requirement. The maximum wind speed was then reduced by a factor of 80% to determine the Minimum Freeboard Requirement.

Summary of Results:

1. Normal Freeboard

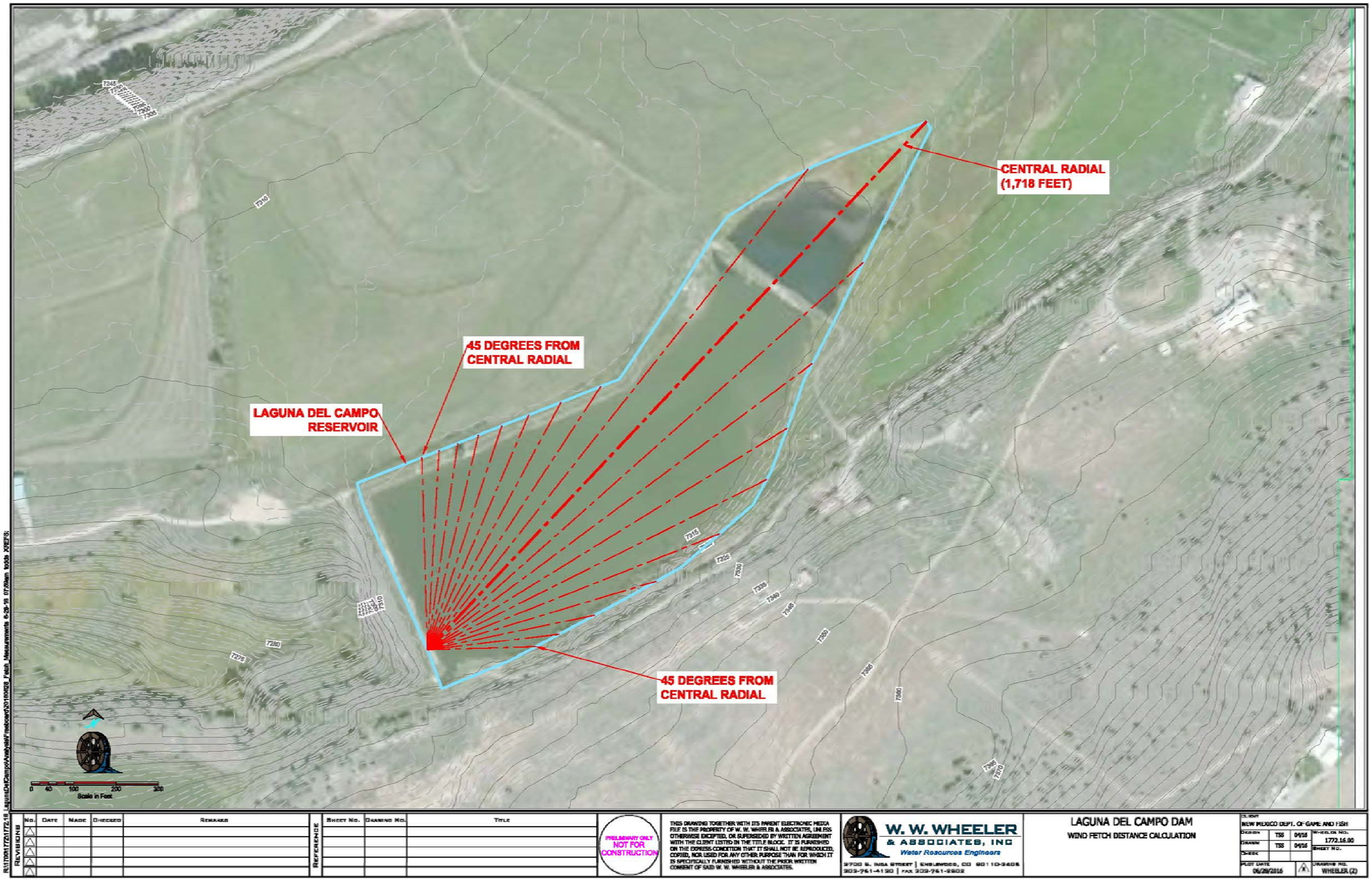
Freeboard Case	Reservoir Pool El.		Design Wind Speed	Design Wind Duration	Wave Runup	Wind Setup	Freeboard Requirement	Minimum Crest El.
	(FEET)		(MPH)	(MIN)	(FEET)	(FEET)	(FEET)	(FEET)
Normal	98.75	*	76	4	1.19	0.08	1.27	100.0
Minimum	103.0	**	61	4	0.97	0.05	1.02	104.0

* Elevation of spillway crest, normal operating level

** Elevation of water surface after routing the 60% PMP IDF (design WSEL)

Checked: DTH

Effective Fetch Length:



Fastest Mile of Record: Figure 1-4 of USBR ACER TM No.2: Freeboard Criteria and Guidelines for Computing Freeboard Allowances for Storage Dams

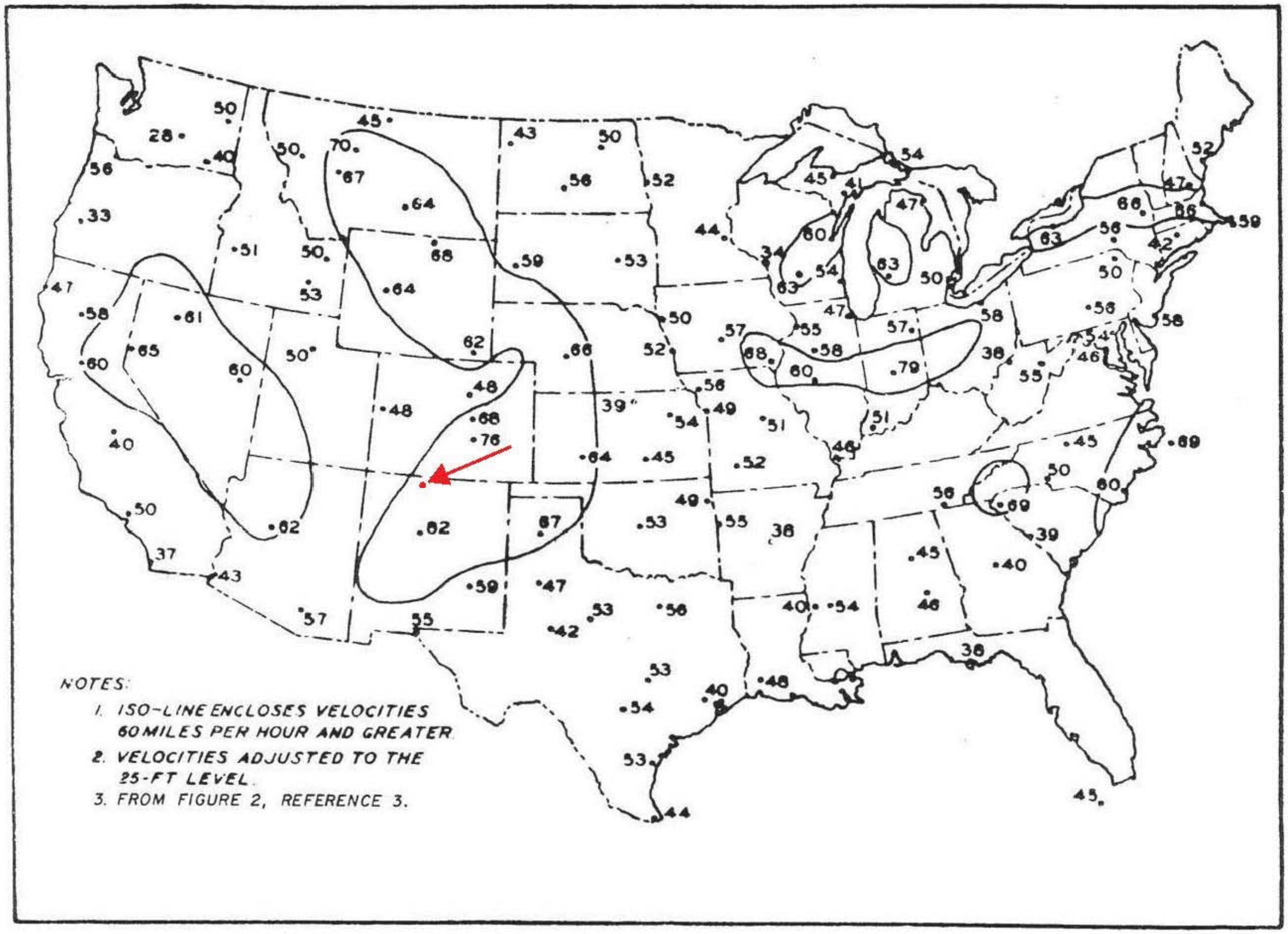


FIGURE I.-FASTEST MILE OF RECORD-WINTER

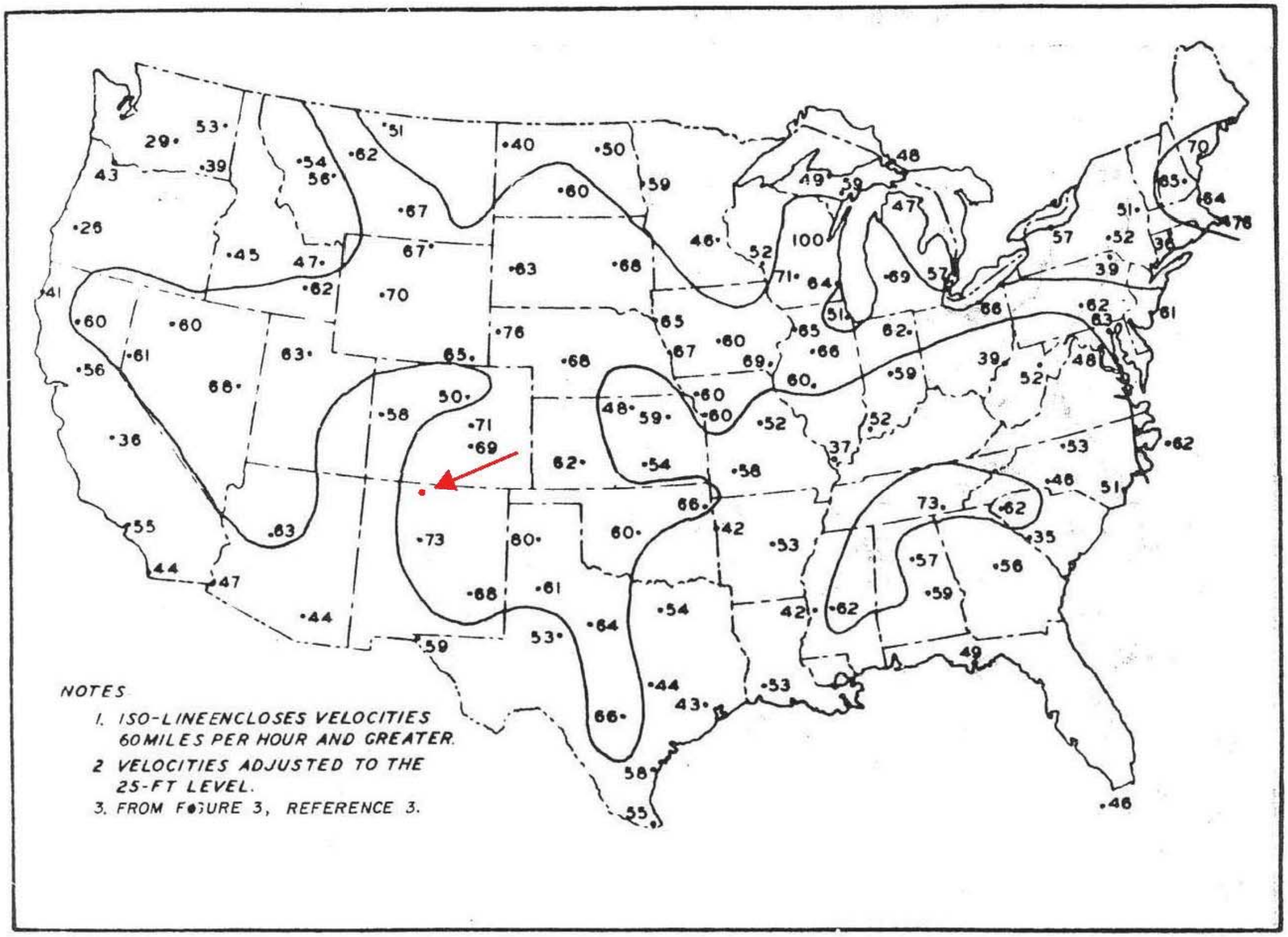


FIGURE 2.-FASTEST MILE OF RECORD-SPRING

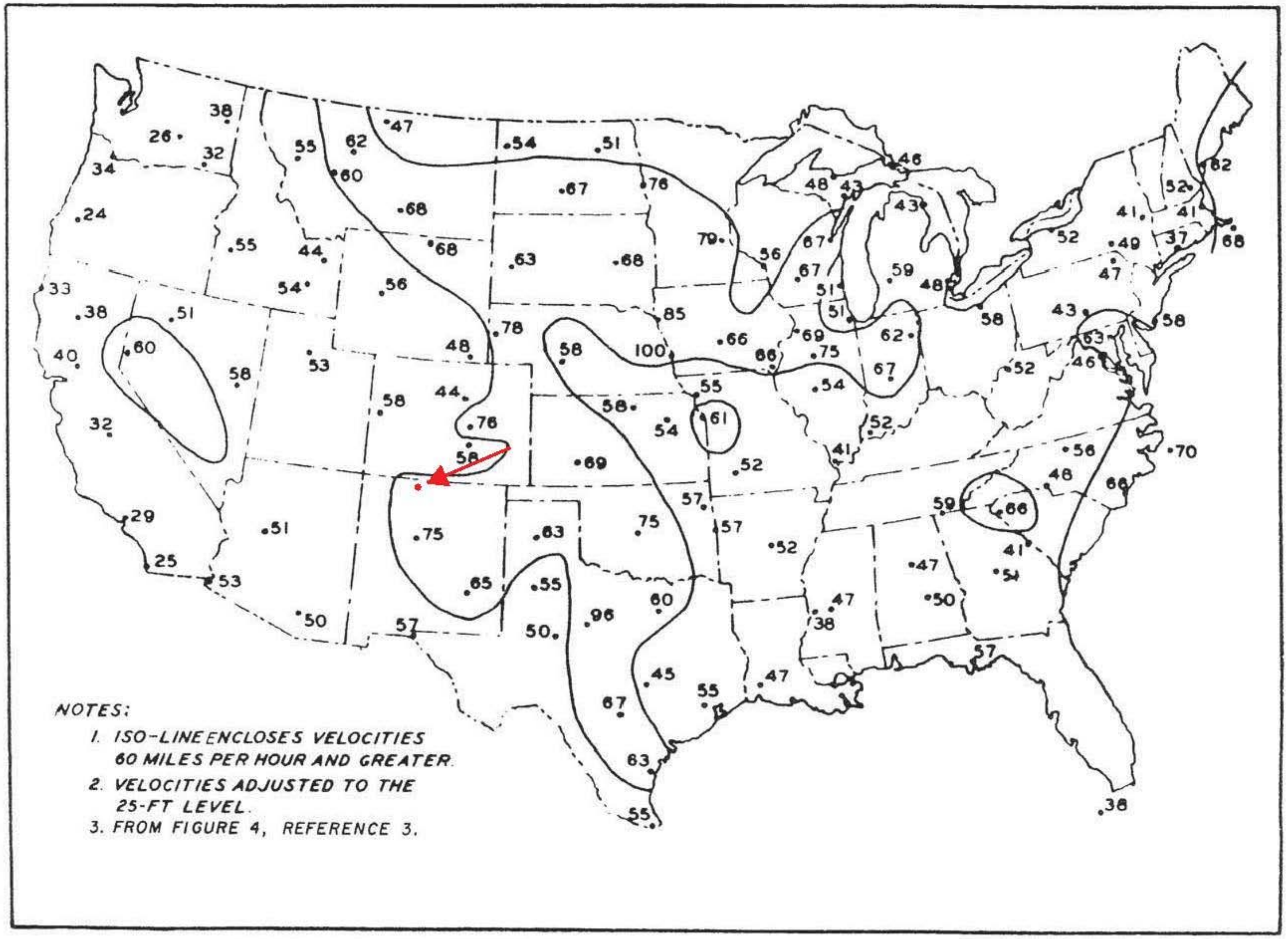


FIGURE 3.-FASTEST MILE OF RECORD-SUMMER

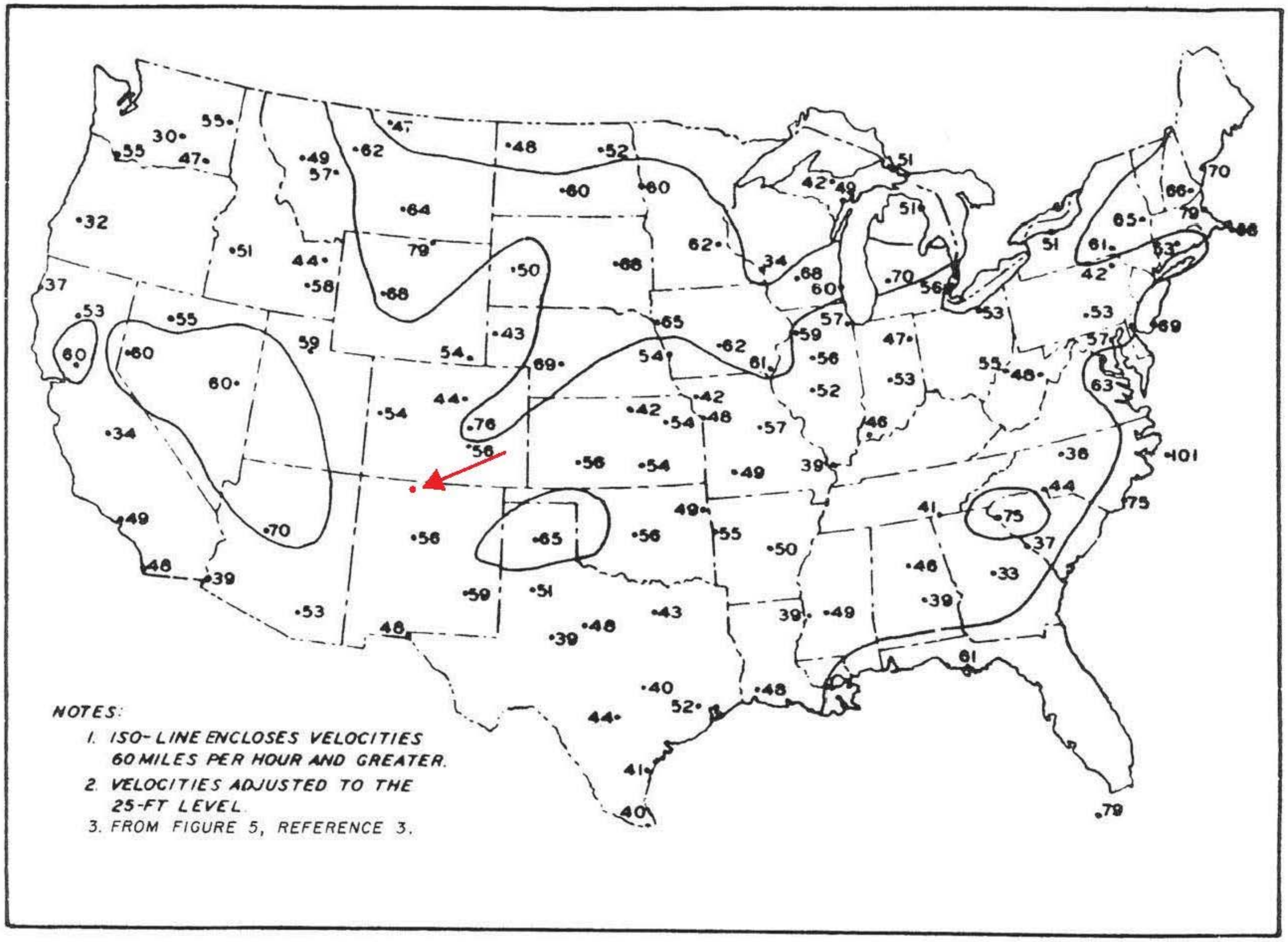


FIGURE 4.-FASTEST MILE OF RECORD-FALL

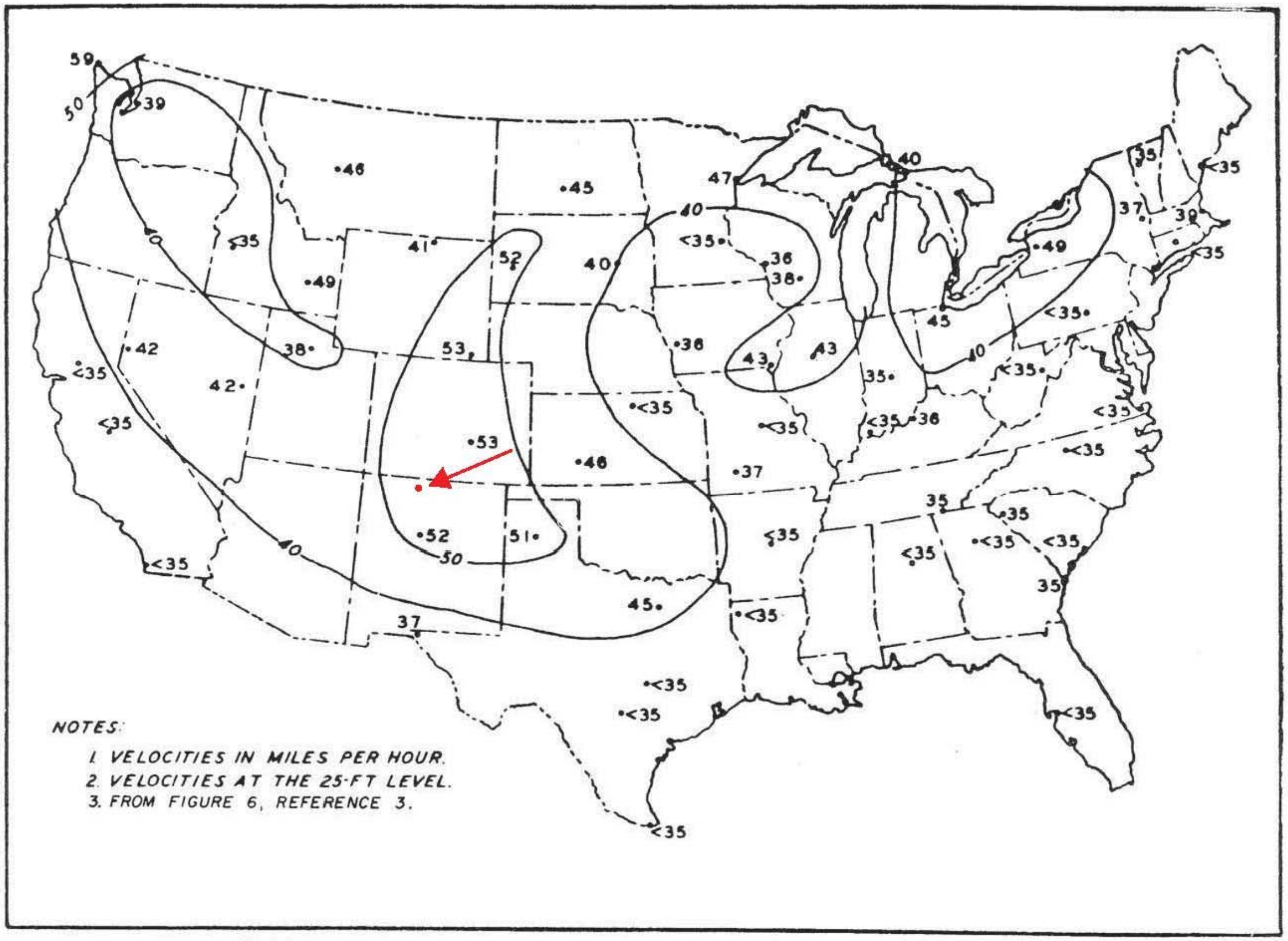


FIGURE 5.- MAXIMUM ONE HOUR VELOCITY - WINTER

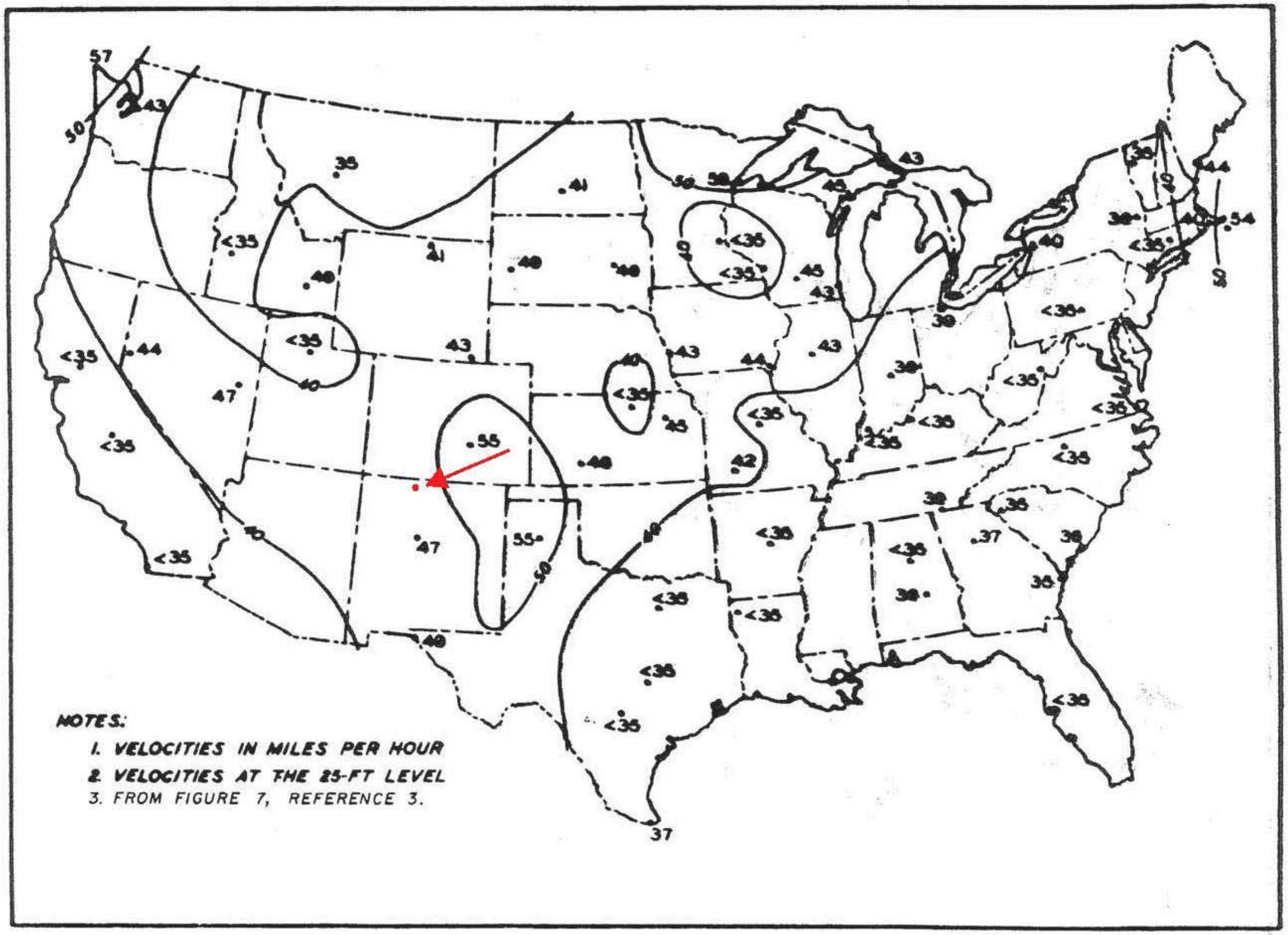


FIGURE 6.-MAXIMUM ONE HOUR VELOCITY - SPRING

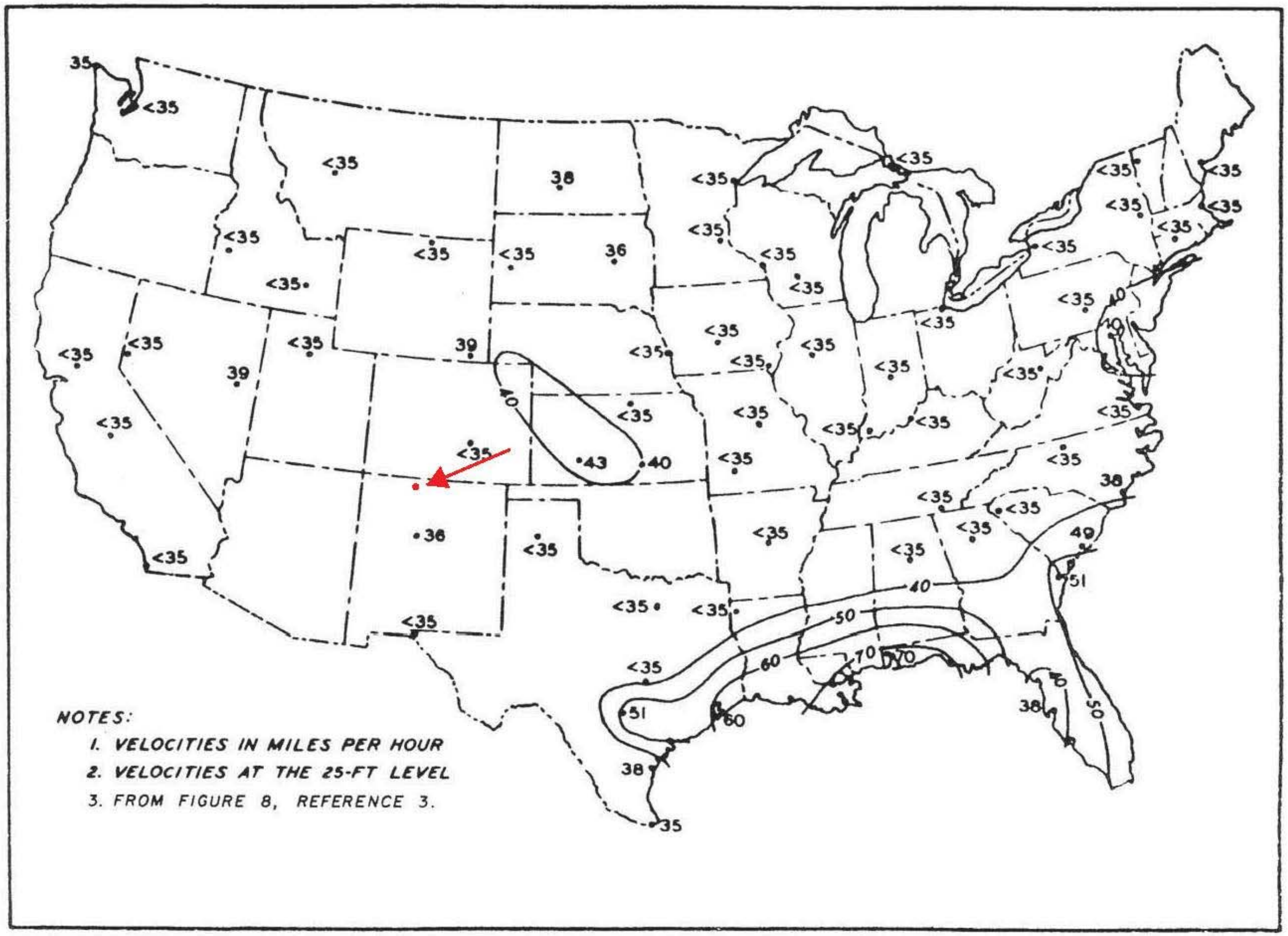


FIGURE 7.-MAXIMUM ONE HOUR VELOCITY - SUMMER

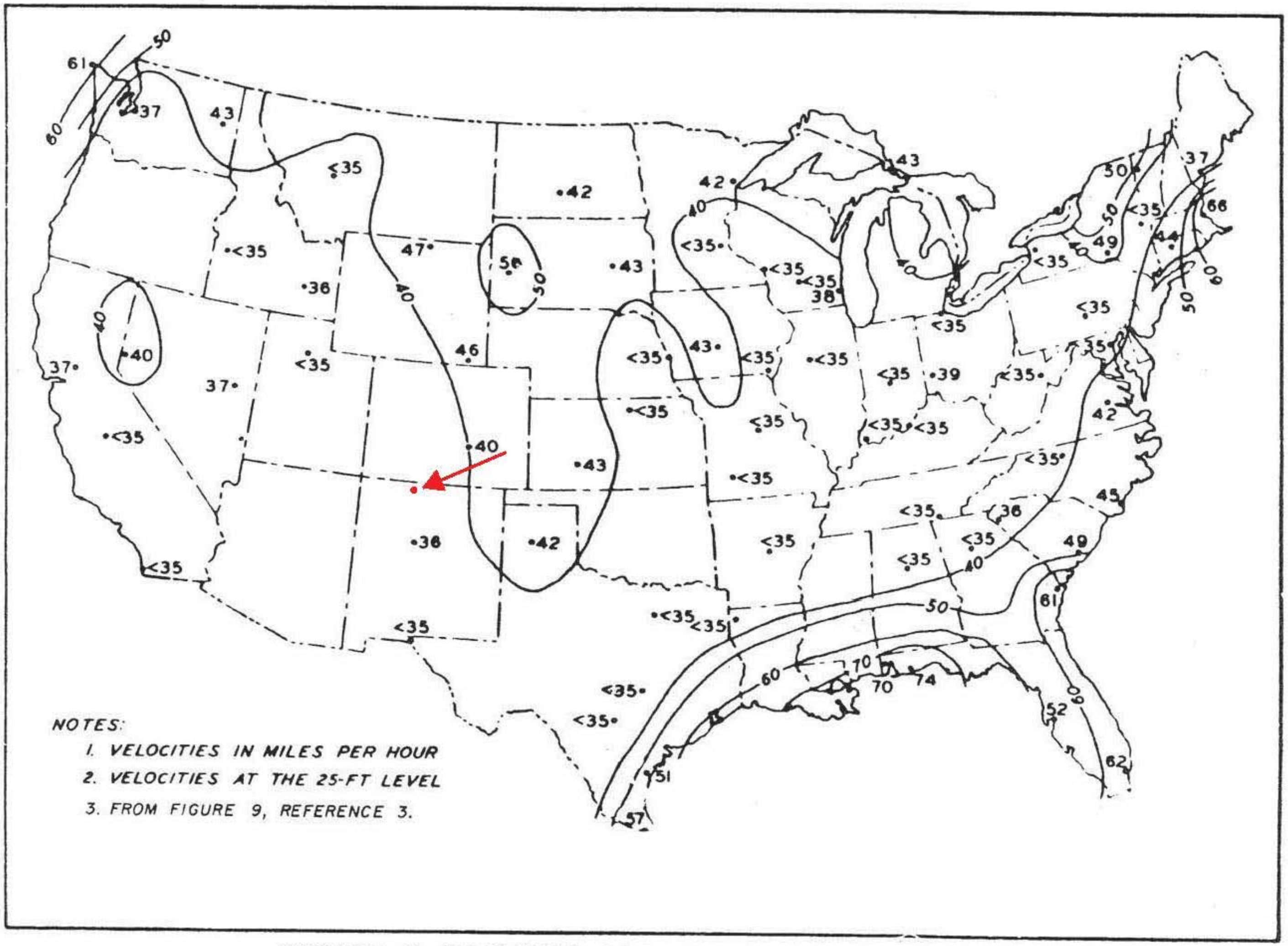


FIGURE 8.-MAXIMUM ONE HOUR VELOCITY-FALL

1. EFFECTIVE FETCH LENGTH CALCULATION

Effective Fetch Length, Equation from USBR ACER TM No.2

Effective Fetch (Fe):

$$Fe = \frac{\sum X_i * \left(Cos^2(\alpha_i)\right)}{\sum Cos(\alpha_i)}$$

Fetch Length at Local Elevation 104' (7,314 NAVD88)

Radial	Angle b/w Central Radial and Radial, α_i	Cos (α_i)	$Cos^2(\alpha_i)$	Radial Length, X_i	$[X_i][Cos^2(\alpha_i)]$
	(Degrees)			(Feet)	
45° North of Central Radi	45	0.71	0.50	455	228
40° North of Central Radi	40	0.77	0.59	472	277
35° North of Central Radi	35	0.82	0.67	494	331
30° North of Central Radi	30	0.87	0.75	521	391
25° North of Central Radi	25	0.91	0.82	558	458
20° North of Central Radi	20	0.94	0.88	605	534
15° North of Central Radi	15	0.97	0.93	665	620
10° North of Central Radi	10	0.98	0.97	745	723
5° North of Central Radi	5	1.00	0.99	1449	1438
Central Radi	0	1.00	1.00	1718	1718
5° South of Central Radi	5	1.00	0.99	1378	1368
10° South of Central Radi	10	0.98	0.97	1134	1100
15° South of Central Radi	15	0.97	0.93	999	932
20° South of Central Radi	20	0.94	0.88	897	792
25° South of Central Radi	25	0.91	0.82	753	619
30° South of Central Radi	30	0.87	0.75	564	423
35° South of Central Radi	35	0.82	0.67	403	270
40° South of Central Radi	40	0.77	0.59	313	184
45° South of Central Radi	45	0.71	0.50	257	129

Σ [Cosine (α_i)] =	16.90	Σ $[X_i][Cos^2(\alpha_i)]$ =	12534

F_e =	**742**	**Feet**
	0.14	**Miles**

2. WIND VELOCITY

Determine Maximum Wind Velocity, Figures 1-4 (1-Minute Duration) and 5-8 (1-Hour Duration) from USBR ACER TM No.2

Maximum Site Wind Speed (Fastest Mile of Record (winter) = 56 MPH, Maximum 1-HR (Winter)=52 MPH) and Duration:

Wind Duration	Over-Land Wind Speed	Over-Water Correction *	Over-Water Wind Speed	Duration
	(MPH)		(MPH)	(MINUTE)
1-Minute (Fastest Mile)	76	1.02	78	1
1-Hour	52	1.02	53	60
2-Hour**	50	1.02	51	120

* Table 2, extrapolated based on a Fe = 0.14 miles

**Adjustment Relationship: 2HR velocity = 0.96*1HR velocity

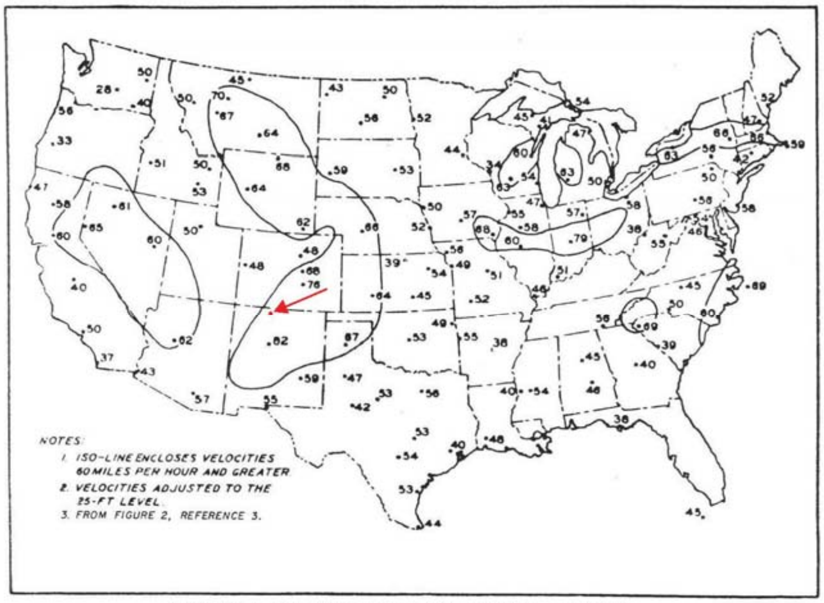


FIGURE 1.-FASTEST MILE OF RECORD-WINTER

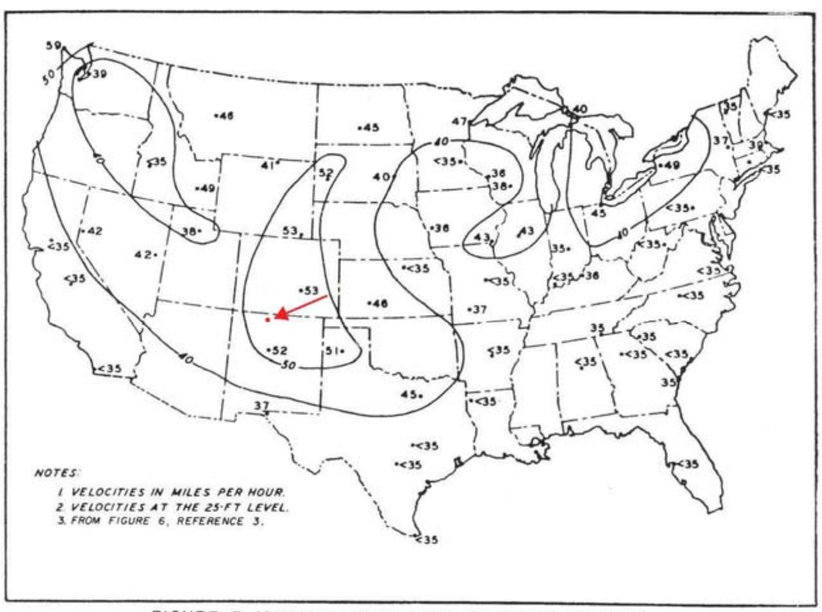


FIGURE 5.-MAXIMUM ONE HOUR VELOCITY-WINTER

3. WIND DURATION

Determine Wind Velocity Durations based on Effective Fetch Length using USBR ACER TM No.2, Figure 9

Wind Speed (25' above water) and Duration, From Figure 9:

Over-Water Wind Speed	Wind Duration*
(MPH)	(MINUTES)
40	5
50	5
60	4
70	4
80	4

*Figure 9, based on a Fe = 0.14 miles

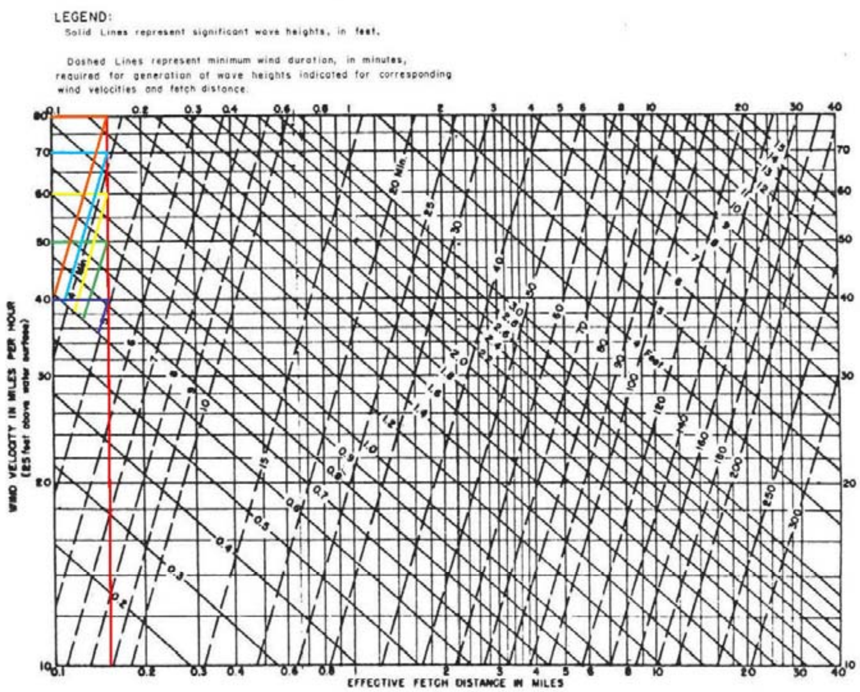
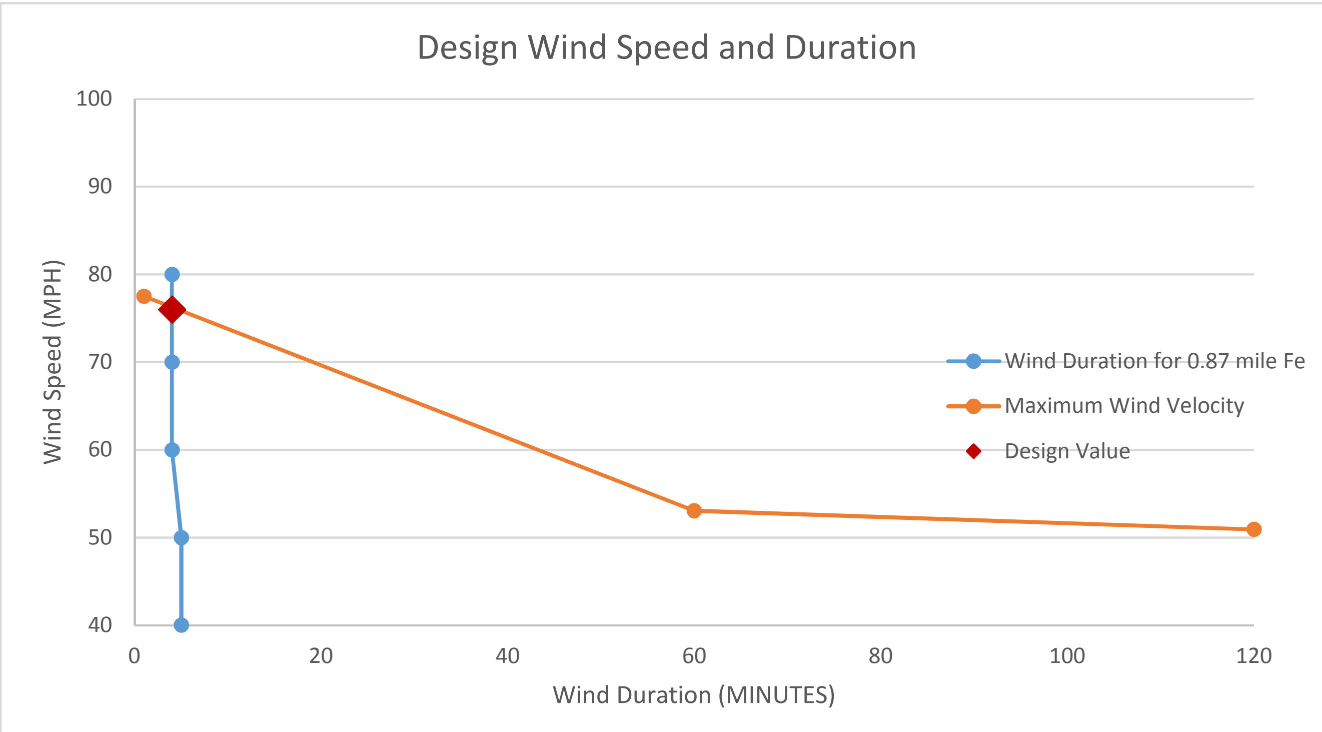


FIGURE 9. - GENERALIZED CORRELATIONS OF SIGNIFICANT WAVE HEIGHTS (H_s) WITH RELATED FACTORS -DEEP WATER CONDITIONS (FROM FIGURE 11, REF. 3)

4. DESIGN WIND VELOCITY AND DURATION

Determine Design Wind Velocity and Duration based on Intersection of Wind Velocity Duration Curves:

	Design Wind Speed (MPH)	Design Wind Duration (MIN)
Design Value	76	4



5. SIGNIFICANT WAVE HEIGHT (Hs)

Determine the Significant Wave Height (Hs) using Figure 9 of the USBR ACER TM No.2

Significant Wave Height:

	Design Wind Speed	Significant Wave Height
	(MPH)	(FEET)
Design Value	76	1.45

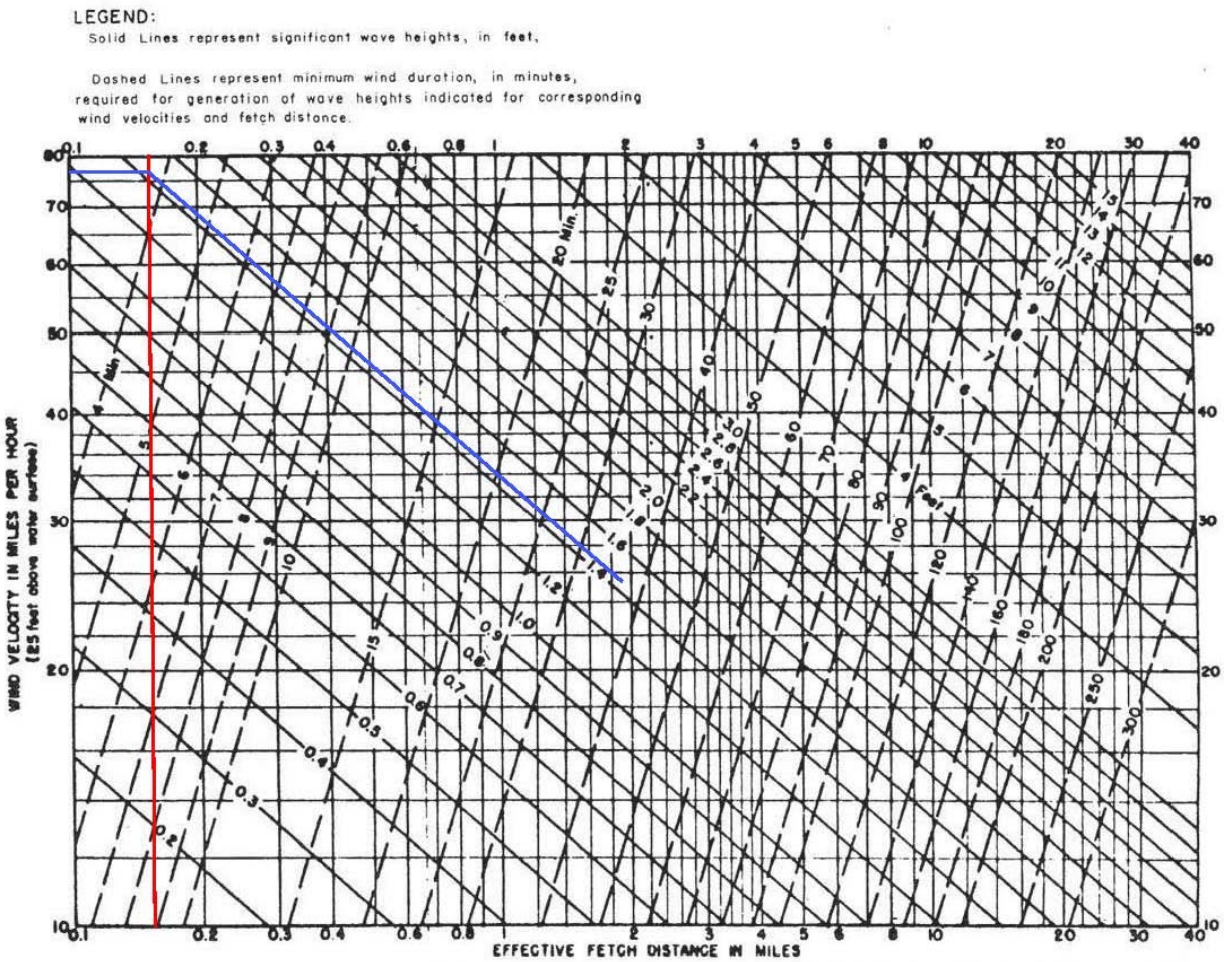


FIGURE 9. - GENERALIZED CORRELATIONS OF SIGNIFICANT WAVE HEIGHTS (H_s) WITH RELATED FACTORS -DEEP WATER CONDITIONS (FROM FIGURE 11, REF. 3)

6. WAVE PERIOD (T)

Determine the Wave Period (T) using Figure 10 of the USBR ACER TM No.2

Wave Period:

	Design Wind Speed	Wave Period, T
	(MPH)	(SEC)
Design Value	76	1.95

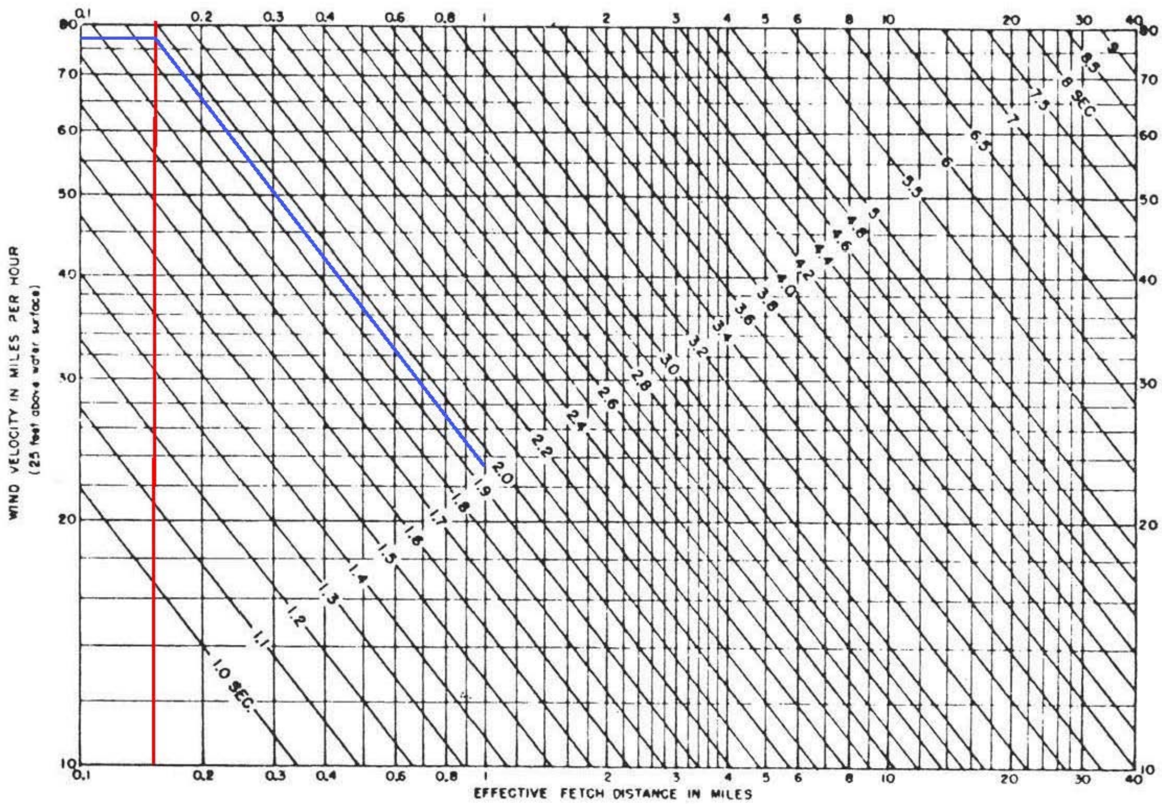


FIGURE 10.- GENERALIZED RELATIONS BETWEEN WAVE PERIODS AND RELATED FACTORS -DEEP WATER CONDITIONS (FROM FIGURE 12, REF. 3)

7. DEEP WATER WAVE LENGTH, L

Determine the Deep Water Wave Length (L) using Equation 2 of the USBR ACER TM No.2

Equation 2: $L = 5.12 * T^2$

L= 19 Feet

Equation 2 is valid when the water is deeper than L/2. The depth of the reservoir, assuming a gage height at the emergency spillway = 26 feet, is greater than half of the deep water wavelength (9.5 feet).

8. DETERMINE THE RUNUP FROM A SIGNIFICANT WAVE (Rs)

Determine the Runup from a significant wave (Rs) using Equation 3 of the USBR TM No. 2

Equation 3: $$R_S = \frac{H_S}{0.4 + \left(\frac{H_S}{L}\right)^{0.5} * \cot(\theta)}$$

COT(θ*) =	3	
Hs =	1.45	Feet
L =	19	Feet

Rs =	1.19	Feet

* 3H:1V Upstream slope from 1937 Dam Drawing

9. DETERMINE THE WIND SETUP (S)

Determine the Wind Setup (S) using Equation 4 of the USBR TM No. 2

Equation 4: $$S = \frac{U^2 * F}{(1400 * D)}$$

Design Wind Velocity, U	76	MPH
Wind Fetch, F=2Fe	0.28	Miles
D*	15	Feet

* Average Depth along central radial: Gage height at ESW / 2 = 29.88'/2 = 15'

S =	0.08	Feet

10. DETERMINE THE NORMAL FREEBOARD REQUIREMENT

Determine the Normal Freeboard Requirement from the relationship described on page 15 of the USBR TM No. 2

$$Normal\ Freeboard\ Requirement = R_S + S$$

Normal Freeboard Requirement =	1.27	Feet

1. EFFECTIVE FETCH LENGTH CALCULATION

Effective Fetch Length is the same for the minimum freeboard as the normal freeboard

Effective Fetch (Fe):	0.14	Miles

2. WIND VELOCITY

Determine REDUCED Wind Velocity, Figures 1-4 (1-Minute Duration) and 5-8 (1-Hour Duration) from USBR ACER TM No.2

Reduced Maximum Site Wind Speed (Original Fastest Mile of Record (Spring) = 55 MPH, Original Maximum 1-HR (Winter)=53 MPH) and Duration:

Wind Duration	REDUCED Over-Land Wind Speed*	Over-Water Correction **	Over-Water Wind Speed	Duration
	(MPH)		(MPH)	(MINUTE)
1-Minute (Fastest Mile)	60.8	1.02	62	1
1-Hour	41.6	1.02	42	60
2-Hour***	40	1.02	41	120

* Reduce Maximum Wind Speed to 80%

** Table 2, based on a Fe = 0.14 miles

***Adjustment Relationship: 2HR velocity = 0.96*1HR velocity

3. WIND DURATION (No change from Normal Pool Calculation because Fe remains the same)

Determine Wind Velocity Durations based on Effective Fetch Length from USBR ACER TM No.2, Figure 9

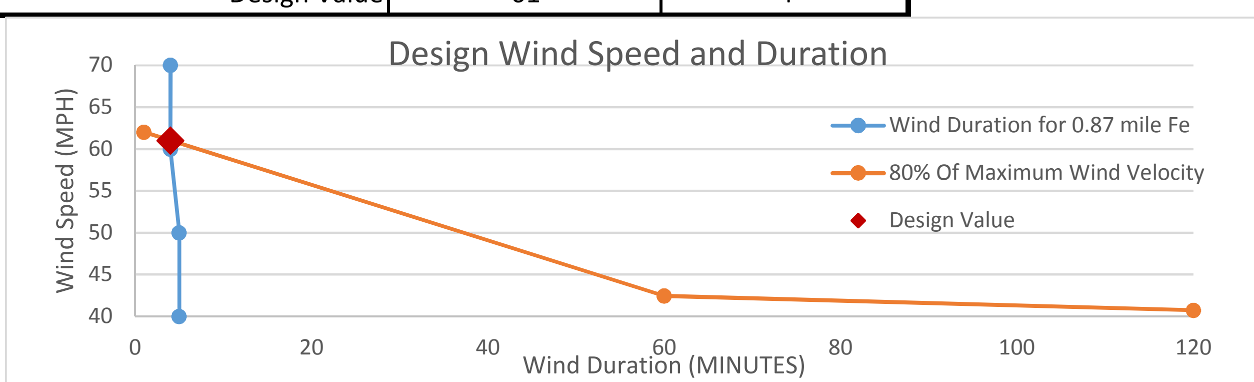
Wind Speed (25' above water) and Duration, From Figure 9:

Over-Water Wind Speed	Wind Duration*
(MPH)	(MINUTES)
40	5
50	5
60	4
70	4
80	4

4. DESIGN WIND VELOCITY AND DURATION

Determine Design Wind Velocity and Duration based on Intersection of Wind Velocity Duration Curves:

	Design Wind Speed	Design Wind Duration
	(MPH)	(MIN)
Design Value	61	4



5. SIGNIFICANT WAVE HEIGHT (Hs)

Determine the Significant Wave Height (Hs) using Figure 9 of the USBR ACER TM No.2

Significant Wave Height:

	Design Wind Speed	Significant Wave Height
	(MPH)	(FEET)
Design Value	61	1.2

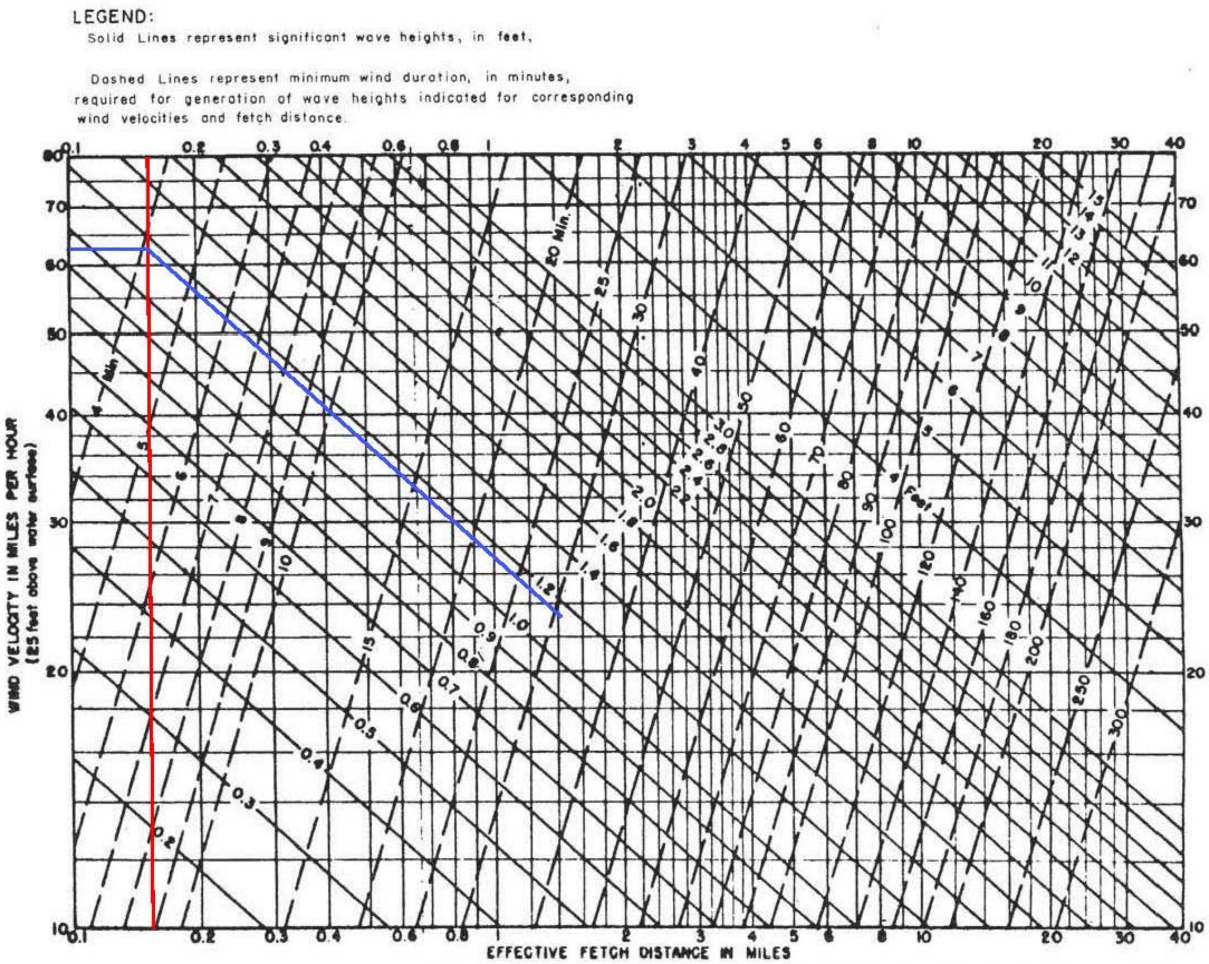


FIGURE 9. - GENERALIZED CORRELATIONS OF SIGNIFICANT WAVE HEIGHTS (H_s) WITH RELATED FACTORS - DEEP WATER CONDITIONS (FROM FIGURE 11, REF. 3)

6. WAVE PERIOD (T)

Determine the Wave Period (T) using Figure 10 of the USBR ACER TM No.2

Wave Period:

	Design Wind Speed	Wave Period, T
	(MPH)	(SEC)
Design Value	49	1.8

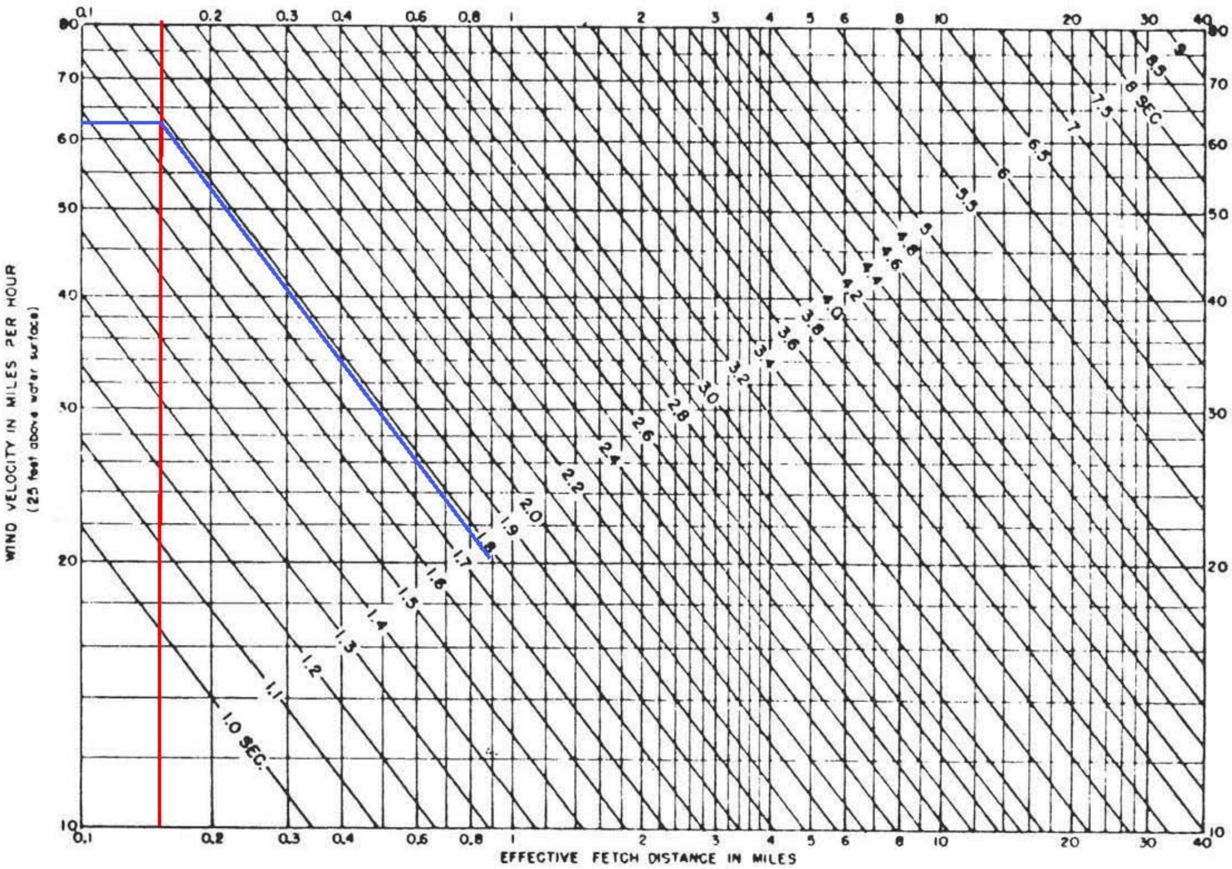


FIGURE 10.- GENERALIZED RELATIONS BETWEEN WAVE PERIODS AND RELATED FACTORS -DEEP WATER CONDITIONS (FROM FIGURE 12, REF. 3)

7. DEEP WATER WAVE LENGTH, L

Determine the Deep Water Wave Length (L) using Equation 2 of the USBR ACER TM No.2

Equation 2: $L = 5.12 * T^2$

L= 17 Feet

Equation 2 is valid when the water is deeper than L/2. The depth of the reservoir, assuming a gage height at the emergency spillway = 26 feet, is greater than half of the deep water wavelength (8.5 feet).

8. DETERMINE THE RUNUP FROM A SIGNIFICANT WAVE (Rs)

Determine the Runup from a significant wave (Rs) using Equation 3 of the USBR TM No. 2

Equation 3: $R_S = \frac{H_S}{0.4+\left(\frac{H_S}{L}\right)^{0.5} * \cot(\theta)}$

COT(θ*) =	3	
Hs =	1.15	Feet
L =	17	Feet

Rs =	0.97	Feet

* 3H:1V Upstream slope from 1962 Dam Reconstruction Drawing

9. DETERMINE THE WIND SETUP (S)

Determine the Wind Setup (S) using Equation 4 of the USBR TM No. 2

Equation 4: $S = \frac{U^2 * F}{(1400 * D)}$

Design Wind Velocity, I	61	MPH
Wind Fetch, F=2Fe	0.3	Miles
D*	15	Feet

* Average Depth along central radial: Gage height at ESW / 2 = 29.88'/2 = 15'

S =	0.05	Feet

10. DETERMINE THE MINIMUM FREEBOARD REQUIREMENT

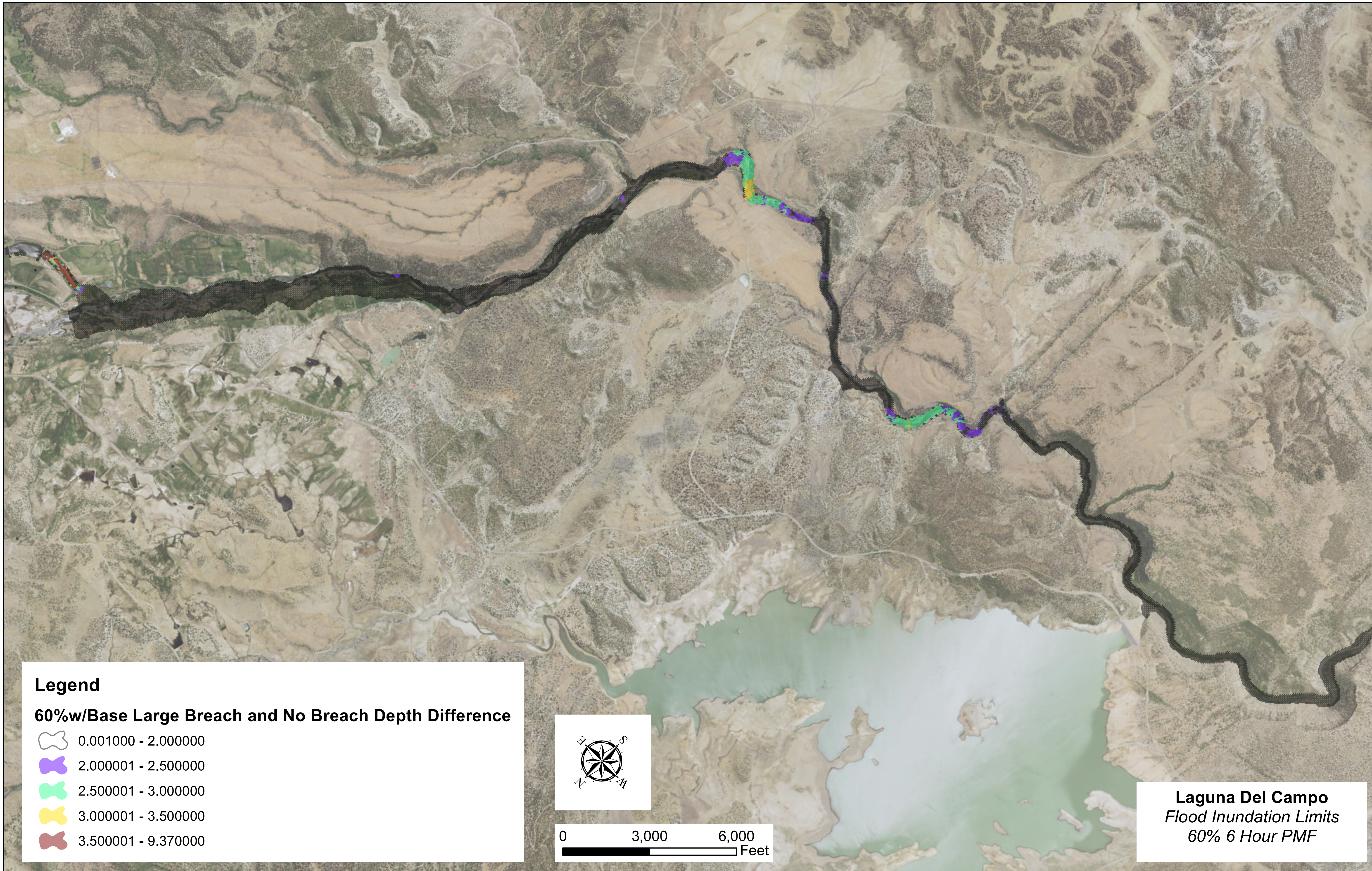
Determine the Minimum Freeboard Requirement from the relationship described on page 15 of the USBR TM No. 2

$$Minimum\ Freeboard\ Requirement = R_S + S$$

Min Freeboard Requirement =	1.02	Feet

Appendix D

Preliminary Incremental Damage Analysis (IDA) Results


Legend
60%w/Base Large Breach and No Breach Depth Difference
0.001000 - 2.000000
2.000001 - 2.500000
2.500001 - 3.000000
3.000001 - 3.500000
3.500001 - 9.370000
0
3,000
6,000
Feet
Laguna Del Campo
Flood Inundation Limits
60% 6 Hour PMF


Legend
100-year FEMA Floodplain
60%w/Base Large Breach and No Breach Depth Difference
0.001000 - 2.000000
2.000001 - 2.500000
2.500001 - 3.000000
3.000001 - 3.500000
3.500001 - 9.370000
0
3,000
6,000
Feet
Laguna Del Campo
Flood Inundation Limits
60% 6 Hour PMF

Appendix E

Opinions of Probable Project Cost

LAGUNA DEL CAMPO DAM
CONCEPTUAL DAM MODIFICATION ALTERNATIVES
NEW MEXICO DEPARTMENT OF GAME AND FISH
ALTERNATIVES ANALYSIS COST OPINION
Alternative No. 1 - Dam Breach with Constructed Wetland

Item No.	Description	Quantity	Unit	Unit Price	Anticipated Total Price
Preparatory Work					
1	Mobilization, Bonds, Insurance & General Conditions (10% of Construction Costs)	1	LS	$103,200	$103,000
2	Storm Water Management - Erosion and Sediment Control	1	LS	$120,000	$120,000
3	Clearing and Grubbing	1	LS	$3,000	$3,000
4	Construction Dewatering	1	LS	$12,000	$12,000
	Subtotal				**$238,000**
Earthwork					
5	Placing Wetland Topsoil	4,300	CY	$27.00	$116,000
6	Excavation	29,600	CY	$8.00	$236,800
7	Install and Compact Fill	5,700	CY	$12.00	$68,400
8	Furnish and Install Grouted Riprap	950	SY	$164.00	$155,800
9	Furnish and Install Soil Installed Riprap	750	CY	$118.00	$88,500
	Subtotal				**$665,500**
Service Spillway					
10	Service Spillway Demolition	1	LS	$23,000	$23,000
	Subtotal				**$23,000**
Outlet Works					
11	Remove Existing Intake Structure and Outlet Works	1	LS	$15,000	$15,000
	Subtotal				**$15,000**
Miscellaneous Items					
12	Wetland Concrete Stoplog Structure	3	EA	$7,500	$22,500
13	Site Reclamation (Includes Wetland Vegetation Planting)	1	LS	$171,000	$171,000
	Subtotal				**$193,500**
14	Unscheduled Items (15% of Listed Items and Mobilization)				**$170,000**
DIRECT CONSTRUCTION SUBTOTAL (DCS)					**$1,305,000**
INDIRECT COSTS					
15	Construction Contingency (15% of Items and Mobilization)				$170,000
16	Final Design Engineering (8% of DCS)				$104,000
17	Bathymetric Survey				$10,000
18	Permitting and Administrative Costs (5% of DCS)				$65,000
19	Construction Administration and Engineering (10% of DCS)				$131,000
TOTAL INDIRECT PROJECT COSTS					**$480,000**
TOTAL 2016 ESTIMATED PROJECT COST					***$1,785,000***

LAGUNA DEL CAMPO DAM
CONCEPTUAL DAM MODIFICATION ALTERNATIVES

NEW MEXICO DEPARTMENT OF GAME AND FISH
ALTERNATIVES ANALYSIS COST OPINION
Alternative No. 2 - Dam Crest Lowering & 100 year Spillway

Item No.	Description	Quantity	Unit	Unit Price	Anticipated Total Price
Preparatory Work					
1	Mobilization, Bonds, Insurance & General Conditions (10% of Construction Costs)	1	LS	$136,260	$136,000
2	Storm Water Management - Erosion and Sediment Control	1	LS	$15,000	$15,000
3	Clearing and Grubbing	1	LS	$5,000	$5,000
4	Reservoir Control	1	LS	$22,400	$22,400
5	Construction Dewatering	1	LS	$12,200	$12,200
	Subtotal				**$190,600**
Earthwork					
6	Stripping and Stockpiling Topsoil	530	CY	$6.00	$3,200
7	Excavation	12,500	CY	$5.00	$62,500
8	Furnish and Place Embankment Fill	100	CY	$12.00	$1,200
9	Furnish and Install Dam Crest Roadbase	120	CY	$99.00	$12,000
10	Furnish and Install Riprap & Bedding	200	CY	$118.00	$23,600
	Subtotal				**$102,500**
Service Spillway					
11	Service Spillway Demolition	1	LS	$23,000	$23,000
12	Furnish and Install Foundation Cutoff Concrete	860	CY	$700	$602,000
13	Furnish and Install Reinforced Structural Concrete	300	CY	$1,450	$435,000
	Subtotal				**$1,060,000**
Outlet Works					
14	Intake Strucutre Modification	1	LS	$5,000	$5,000
15	Furnish and Install 18-inch HDPE pipe liner and Grout Annular Space	1	LS	$80,000	$80,000
16	Furnish and Install Filter Diaphragm	1	LS	$3,500	$3,500
17	Install Terminal Structure	1	LS	$7,500	$7,000
	Subtotal				**$95,500**
Miscellaneous Items					
18	Site Reclamation	1	LS	$50,000	$50,000
	Subtotal				**$50,000**
19	Unscheduled Items (15% of Listed Items and Mobilization)				**$225,000**
DIRECT CONSTRUCTION SUBTOTAL (DCS)					**$1,723,600**
INDIRECT COSTS					
20	Construction Contingency (15% of Items and Mobilization)				$225,000
21	Final Design Engineering (8% of DCS)				$138,000
22	Final Design Investigations				$100,000
23	Topographic Survey				$10,000
24	Permitting and Administrative Costs (5% of DCS)				$86,000
25	Construction Administration and Engineering (10% of DCS)				$172,000
TOTAL INDIRECT PROJECT COSTS					**$731,000**
TOTAL 2016 ESTIMATED PROJECT COST					***$2,454,600***

LAGUNA DEL CAMPO DAM
CONCEPTUAL DAM MODIFICATION ALTERNATIVES
NEW MEXICO DEPARTMENT OF GAME AND FISH
ALTERNATIVES ANALYSIS COST OPINION
Alternative 3a. - RCC Overtopping Protection for 60% PMF

Item No.	Description	Quantity	Unit	Unit Price	Anticipated Total Price
Preparatory Work					
1	Mobilization, Bonds, Insurance & General Conditions (10% of Construction Costs)	1	LS	$442,350	$442,000
2	Storm Water Management - Erosion and Sediment Control	1	LS	$15,000	$15,000
3	Clearing and Grubbing	1	LS	$12,000	$12,000
4	Reservoir Control	1	LS	$22,400	$22,400
5	Construction Dewatering	1	LS	$12,200	$12,200
	Subtotal				**$503,600**
Earthwork					
6	Stripping and Stockpiling Topsoil	1,900	CY	$7.00	$13,000
7	Excavation	42,600	CY	$5.00	$213,000
8	Service Spillway Demolition	1	LS	$23,000.00	$23,000
9	Furnish and Place Embankment Fill	2,200	CY	$12.00	$26,000
10	Furnish and Place Riprap	1,100	CY	$95.00	$105,000
11	Furnish and Place RCC Bedding	5,600	CY	$94.00	$526,400
	Subtotal				**$906,400**
RCC Overtopping					
12	Furnish and Place Upstream/Downstream Cutoff Wall Concrete	3,100	CY	$700	$2,170,000
13	Furnish and Place RCC for Dam	8,600	CY	$120	$1,032,000
14	Furnish and Place Structural Concrete	100	CY	$1,450	$145,000
	Subtotal				**$3,347,000**
Outlet Works					
15	Intake Structure Modification	1	LS	$5,000	$5,000
16	Furnish and Install 18-inch HDPE pipe with grouted annular space	1	LS	$80,000	$80,000
17	Furnish and Install Filter Diaphragm	1	LS	$3,500	$3,500
18	Install Terminal Structure	1	LS	$7,000	$7,000
	Subtotal				**$95,500**
Site Reclamation					
19	Ditch Headgate Relocation	1	LS	$10,000	$10,000
20	Site Reclamation	1	LS	$3,000	$3,000
	Subtotal				**$13,000**
21	Unscheduled Items (15% of Listed Items and Mobilization)				**$730,000**
DIRECT CONSTRUCTION SUBTOTAL (DCS)					**$5,595,500**
INDIRECT COSTS					
22	Construction Contingency (15% of Items and Mobilization)				$730,000
23	Final Design Engineering (8% of DCS)				$448,000
24	Final Design Investigations				$100,000
25	Survey				$10,000
26	Permitting and Administrative Costs (5% of DCS)				$280,000
27	Construction Administration and Engineering (10% of DCS)				$560,000
TOTAL INDIRECT PROJECT COSTS					**$2,128,000**
TOTAL 2016 ESTIMATED PROJECT COST					***$7,723,500***

LAGUNA DEL CAMPO DAM
CONCEPTUAL DAM MODIFICATION ALTERNATIVES

NEW MEXICO DEPARTMENT OF GAME AND FISH
ALTERNATIVES ANALYSIS COST OPINION
Alternative 3b. - RCC Overtopping Protection for 100% PMF

Item No.	Description	Quantity	Unit	Unit Price	Anticipated Total Price
Preparatory Work					
1	Mobilization, Bonds, Insurance & General Conditions (10% of Construction Costs)	1	LS	$442,460	$442,000
2	Storm Water Management - Erosion and Sediment Control	1	LS	$15,000	$15,000
3	Clearing and Grubbing	1	LS	$16,000	$16,000
4	Reservoir Control	1	LS	$22,400	$22,400
5	Construction Dewatering	1	LS	$12,200	$12,200
	Subtotal				**$507,600**
Earthwork					
6	Stripping and Stockpiling Topsoil	1,900	CY	$7.00	$13,000
7	Excavation	38,110	CY	$5.00	$190,550
8	Service Spillway Demolition	1	LS	$23,000.00	$23,000
9	Furnish and Place Embankment Fill	2,200	CY	$12.00	$26,000
10	Furnish and Place Riprap	800	CY	$95.00	$76,000
11	Furnish and Place RCC Bedding	7,100	CY	$94.00	$667,400
	Subtotal				**$996,000**
RCC Overtopping					
12	Furnish and Place Upstream/Downstream Cutoff Wall Concrete	2,700	CY	$700	$1,890,000
13	Furnish and Place RCC for Dam	9,800	CY	$120	$1,176,000
14	Furnish and Place Structural Concrete	130	CY	$1,450	$188,500
	Subtotal				**$3,254,500**
Outlet Works					
15	Intake Structure Modification	1	LS	$5,000	$5,000
16	Furnish and Install 18-inch HDPE pipe with grouted annular space	1	LS	$80,000	$80,000
17	Furnish and Install Filter Diaphragm	1	LS	$3,500	$3,500
18	Install Terminal Structure	1	LS	$7,000	$7,000
	Subtotal				**$95,500**
Site Reclamation					
19	Ditch Headgate Relocation	1	LS	$10,000	$10,000
20	Site Reclamation	1	LS	$3,000	$3,000
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21	Unscheduled Items (15% of Listed Items and Mobilization)				**$730,000**
DIRECT CONSTRUCTION SUBTOTAL (DCS)					**$5,596,600**
INDIRECT COSTS					
22	Construction Contingency (15% of Items and Mobilization)				$730,000
23	Final Design Engineering (8% of DCS)				$448,000
24	Final Design Investigations				$100,000
25	Survey				$10,000
26	Permitting and Administrative Costs (5% of DCS)				$280,000
27	Construction Administration and Engineering (10% of DCS)				$560,000
TOTAL INDIRECT PROJECT COSTS					**$2,128,000**
TOTAL 2016 ESTIMATED PROJECT COST					***$7,724,600***

Appendix F

Site Photos

Laguna Del Campo Dam

Site Visit March 15, 2016

Photo 1 - Downstream Dam Slope (Facing South)

Photo 2- Downstream Dam Slope (facing north)

Laguna Del Campo Dam

Site Visit March 15, 2016

Photo 3 - View of Outlet Works Discharge Channel from Dam Crest

Photo 4- Outlet Works Gate Operator

Laguna Del Campo Dam

Site Visit March 15, 2016

Photo 5 - Spillway Approach Channel and Fish Screen

Photo 6 - Spillway Crest and La Puente Ditch Headgate

Laguna Del Campo Dam

Site Visit March 15, 2016

Photo 7 - Spillway Exit Chute

Photo 8 - Reservoir Looking Upstream

Laguna Del Campo Dam

Site Visit March 15, 2016

Photo 9 - Spillway Exit Channel Looking Upstream

Photo 10 - La Puente Ditch Looking Upstream

Laguna Del Campo Dam

Site Visit March 15, 2016

Photo 11 - Outlet Works Discharge Looking Upstream

Photo 12 - North Dike Looking Downstream (West)

Laguna Del Campo Dam

Site Visit March 15, 2016

Photo 13 - Low Area at Upstream End of Reservoir Looking East

Appendix G

Meeting Summaries

Laguna Del Campo Dam Spillway Alternatives
Project Kickoff Meeting

March 23, 2016

Meeting participants:

NMDGF	**Wheeler**	**NMOSE**
Russell Benjamin	Steve Jamieson	David Heber
Jack Young	Todd Lewis	Charles Thompson
USFWS	Todd Street	
Robert Baca		

1) **New Mexico Department of Game & Fish (NMDGF)**
2) **W. W. Wheeler & Associates, Inc. (Wheeler)**
3) **New Mexico Office of the State Engineer (NMOSE)**
4) **U.S. Fish & Wildlife Service (USFWS)**

1.0 Introductions and Review Meeting Agenda

The meeting was started with a review of the agenda and introductions by the meeting participants. A Powerpoint presentation used during the meeting to summarize key meeting topics is attached for additional information.

2.0 Review Project Execution Plan / Communications

- Russell Benjamin is the NMDGF project manager and should be copied on all communications. E-mail is the preferable communication method.
- Questions to fisheries personnel and surrounding property owners should be routed through Russell Benjamin.
- A summary of any outside communications should be provided to Russell Benjamin.
- The alternatives conference will be conducted by webinar. Wheeler should select a webinar service and coordinate a test webinar with NMDGF and USFWS prior to the first webinar.
- Jack Young will provide cultural resources evaluations for NMDGF for the project. He indicated there are no known cultural concerns for modifying the spillway. A cultural resource evaluation will not be required in the project scope.

- Robert Baca will execute a contract modification to remove the cultural resources evaluation from the project scope.
- Wheeler invoices should be submitted to Kevin Arnold of USFWS Region 2 via the Internet Payment Platform (IPP) system. Robert Baca will provide Wheeler with Kevin Arnold's contact information.
- NMOSE will not be heavily involved in the project review until a final design is submitted to their office for review and approval. Charles Thompson and David Heber should be kept in the loop and are available for questions. David Heber indicated that informal input or review should not be construed as NMOSE approval.

3.0 Review Available Background Information

- NMDGF will provide plat files for property boundaries.
- A low-level outlet dive inspection or video does not exist
- The Emergency Action Plan was updated in December 2015.
- Russell Benjamin indicated that a video inspection of the low-level outlet is scheduled to be completed after July 1.

4.0 Review Preliminary Design Criteria

- Residual freeboard should be included in the design. Residual freeboard should be determined based on wave run up and calculated using the USBR method per NMOSE guidance.
- A second spillway should be referred to as "auxiliary" versus "emergency".
- NMOSE or NMDGF do not have a recommend trigger elevation or service spillway flow to initiate flow in the auxiliary spillway.
- Any modification to the diversion headgate located in the spillway should match capacity of the existing diversion.
- Work outside of the NMDGF property boundaries should not be considered. Acquiring additional land through easement or acquisition will be very difficult and will complicate project permitting.
- The irrigation system south (left looking downstream) of the reservoir generally operates from March through October.
- Reservoir storage volume is approximately 3 percent of Probable Maximum Flood (PMF) volume. Wheeler recommends conducting a preliminary incremental damage assessment (IDA) prior to evaluating alternatives to determine if the Inflow Design Flood (IDF) can be reduced to a percentage of the PMF. This could result in significant savings in spillway improvement costs.
- Roddy Gallegos and Russell Benjamin should be consulted regarding property ownership as it relates to the adjacent irrigation system or potential land acquisition.
- The dam was historically used for irrigation, historical use will be a consideration when evaluating minimum required reservoir storage.

- It was agreed that Wheeler will complete a preliminary incremental damage assessment (IDA) within the original project budget, however a schedule extension will be required.
  - The Project must be completed by June 30 per NMDGF.
  - Wheeler will provide Robert Baca a contract modification e-mail addressing the schedule extension.

5.0 Review of Potential Spillway Alternatives

- A side channel south of the existing spillway will require replacing portions of irrigation ditch and is likely not feasible.
- A side channel spillway north of spillway will be limited by property constraints and may not be feasible.
- Low or no maintenance is a key NMDGF priority for spillway design.
  - This limits the viability of fuse plug spillway fuse gates, or other gated spillways.
- A labyrinth spillway may be a good low maintenance alternative.
- Renovation of the existing spillway may require relocation of the irrigation headgate to a point upstream of the spillway.
- The east pond forebay is a settling pond to enhance wildlife in the reservoir

6.0 Review Action Items

- Wheeler - Coordinate a webinar test before the next workshop.
- Wheeler - Provide a meeting summary to all participants.
- Wheeler - Provide Robert Baca with a Task Order modification e-mail.
- Wheeler – Finalize the Project Execution Plan (PXP) based on comments received on the draft by Friday, March 25.
- Wheeler - Schedule the Primary Alternatives Selection Workshop after completing the preliminary IDA work.
- NMDGF - Check on availability of LIDAR data in the reservoir and downstream of the dam.
- NMDGF - Provide Wheeler with an updated copy of the Emergency Action Plan.
- NMDGF - Determine the maximum allowable reservoir drawdown during construction based on water rights or fisheries criteria for the reservoir.
- USFWS – Robert Baca will provide Kevin Arnold’s contact information.

Laguna Del Campo Dam Alternatives Evaluation Kick-off Meeting

W. W. WHEELER & ASSOCIATES, INC.

Project Objective

- Prepare alternative preliminary designs and cost opinions to modify Laguna Del Campo Dam to meet current State of New Mexico Dam Safety Regulations:
  - Spillway Modifications
  - Other Modifications ?

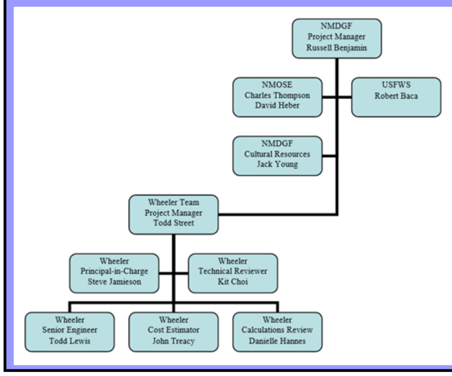
W. W. WHEELER & ASSOCIATES, INC.

Meeting Agenda

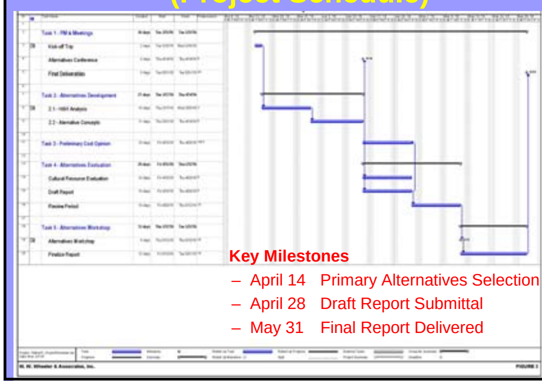
- Introductions/Review Agenda
- Project Execution Plan
- Available Background Information
- Preliminary Design Criteria
- Potential Spillway Alternatives
- Project Administration & Communications
- Review Action Items
  - Who Does What By When
- Schedule Next Workshops

W. W. WHEELER & ASSOCIATES, INC.

Project Execution Plan
(Project Organization Chart)



Project Execution Plan
(Project Schedule)



Key Milestones

- April 14 Primary Alternatives Selection
- April 28 Draft Report Submittal
- May 31 Final Report Delivered

Project Execution Plan

- **Budget - $43,988**
- **Deliverables**
  - March 7 Project Execution Plan
  - March 16 Kick-off Meeting
  - March 23 Kick-off Meeting Summary
  - April 14 Primary Alternatives Workshop
  - April 21 Primary Alternatives Workshop Summary
  - April 28 Draft Report Submittal
  - May 12 Draft Report Workshop
  - May 19 Draft Report Workshop Summary
  - May 31 Final Report Deliverable

W. W. WHEELER & ASSOCIATES, INC.

Project Execution Plan (Administration & Communications)

- **Formal Communication between**
  - Russell Benjamin & Todd Street
- **Monthly Invoices Submitted to USFWS IPP**
  - Approved by Russell Benjamin & Robert Baca
- **Cultural Resources Evaluations**
  - Completed by Jack Young ?
- **Other Procedures ?**

W. W. WHEELER & ASSOCIATES, INC.

Available Background Information

- **Key Reports**
  - Phase 1 Inspection Report, 1978
  - NMOSE Inspection Reports
    - (2009, 2011, 2014, 2015)
  - Breach Analysis Report, 2012
  - Operations & Maintenance Manual, 2012
- **Key Drawings**
  - As-Let Drawings, 1937
  - Reservoir Contour Map, 1938
  - Spillway Repair Drawing, 1979

W. W. WHEELER & ASSOCIATES, INC.

Other Available Information

- **Digital Topographic Information**
  - USGS National Elevation Database n37w107 1/3 arc-second Digital Elevation Model, 2013
  - NRCS SSURGO Soil Survey Geographic Database for Rio Arriba area, New Mexico, 2013
- **Existing Computer Models**
  - HEC-HMS model of the Laguna Del Campo Dam basin (taken from the 2012 Breach Analysis Report)
  - FLO-2D breach model of the area downstream of Laguna Del Campo Dam to El Vado Reservoir (also taken from the 2012 Breach Analysis Report)

W. W. WHEELER & ASSOCIATES, INC.

Other Available Information

- Outlet works video ?
- August 2015 dive inspection ?
- LiDAR data and other site topography ?
- Geotechnical reports ?
- Other information ?

W. W. WHEELER & ASSOCIATES, INC.

Key Pertinent Data

- Construction Date: 1937
- Dam Type : Zoned embankment w/ puddled core
- Dam Height: 36 feet
- Normal Storage: 99.6 acre-feet at spillway crest
- Maximum Storage: 177.5 acre-feet at dam crest
- Hazard Classification: High
- Spillway: 28-foot-wide concrete
- Outlet Works:
  - 185 feet long, 2-foot x 2-foot concrete conduit

W. W. WHEELER & ASSOCIATES, INC.

Key H&H Data

- Drainage Area: 5.75 square miles
- Spillway Capacity: 1,185 ft^3/s at the dam crest (Elevation 104.0 feet)
- Probable Maximum Flood
  - Peak inflow: 19,846 ft^3/s
  - Storm Volume: 3,588.0 acre-feet (11.7 inches total)
  - Runoff Volume: 3,526.7 acre-feet (11.5 inches excess)
  - Rainfall Temporal Distribution: EM 1110-2-1411
  - Maximum Overtopping Depth: 2.5 feet
  - Overtopping Duration: 5 hours, 36 minutes

W. W. WHEELER & ASSOCIATES, INC.

Preliminary Design Criteria

- Preliminary designs consistent with OSE Dam Safety Rules and Regulations
- Spillway(s) designed to safely pass the PMF
  - No residual freeboard ?
  - Emergency spillway trigger elevations ?
- Diversion required from existing spillway
- No outlet works modifications components included in the rehabilitation alternatives
- No embankment maintenance components included in the embankment modifications

Key Site Visit Observations

- Site constrained by property boundaries
- Existing spillway condition is extremely poor
- Construction water management questions
  - Minimum reservoir pool (water rights)
  - Bypass flow requirements
- Hazard classification
- Wetlands

Revised Key Design Criteria

- No construction outside of NMDGF property?
- Potential for reduced IDF?
  - Incremental damage assessment
  - Reduced hazard classification
- Reduction in normal storage?

- Potential significant cost savings

Potential Spillway Alternatives

- **Optimized Spillway & Embankment Enlargement**
- **Embankment Overtopping**
- **Side Channel Spillway**
- **Other Potential Options**
  - Fuse gate spillway
  - Fuse plug spillway
  - Labyrinth spillway

W. W. WHEELER & ASSOCIATES, INC.

Spillway/Embankment Optimization

Overtopping Protection

W. W. WHEELER & ASSOCIATES, INC.

Laguna Del Campo Dam
Spillway Alternatives Selection Meeting

Meeting Date: May 5, 2016

Meeting participants:

NMDGF	**USFWS**	**Wheeler**
Russell Benjamin	Robert Baca	Steve Jamieson
		Todd Lewis
		Todd Street

1) **New Mexico Department of Game & Fish (NMDGF)**
2) **W. W. Wheeler & Associates, Inc. (Wheeler)**
3) **U.S. Fish & Wildlife Service (USFWS)**

1.0 Introductions and Review of Meeting Agenda

- The meeting began with a review of project objective, goals of the meeting and the meeting agenda. The PowerPoint presentation used during the meeting to convey alternatives and communicate initial findings is included with this meeting summary for reference purposes.

2.0 Progress Update

- An initial site visit, NMOSE document search, preliminary Incremental Damage Assessment (IDA), and preliminary spillway hydraulic evaluation have been completed.

3.0 Schedule Update

- The project is currently on schedule; the task order will end on June 30.
- The detailed project schedule is included within the attached PowerPoint presentation.

4.0 Preliminary Incremental Damage Assessment

- A preliminary IDA has been completed. Initial results from this assessment indicate a likely 60% reduction in the PMP flood.

  - Incremental depth requirements cannot be achieved in the small channel section between the Laguna Del Campo Dam and Rio Chama.
- Based on discussions with NMOSE, if a structure were constructed in the future, immediately downstream of the dam, the dam would again be out of compliance with NMOSE rules. For this reason, NMDGF expressed concern with using the 60% PMP as a design point in the spillway alternatives analysis.
- NMOSE requested that alternatives capable of conveying the 100% PMP flood be considered.

5.0 Discussion of Spillway Alternatives

- Four potential spillway design alternatives were presented: a side channel spillway, full height inline labyrinth spillway, a roller-compacted concrete (RCC) overtopping spillway and a dam breach.
- Russell materials can provide soil fill and concrete. They will likely accept disposal material.

6.0 Primary Spillway Alternative Selection

- An extension of the north dike to contain the flood pool on NMDGF property is acceptable provided it is constructed within property boundaries.
- The existing spillway will be removed under all alternatives.
- NMOSE indicated that a project costing in excess of 4 to 5 million dollars will not be feasible.
- Meeting participants mutually agreed that a side channel spillway is likely too expensive to and has too many complications to be viable alternative.
- Based on Wheeler's initial evaluation, a full height labyrinth would also be too expensive to be a viable alternative.
- An overtopping RCC spillway should be considered for both the 60% and 100% PMP storms.
  - Constructing an overtopping spillway capable of conveying the 100% PMP food will require a reduction in the Laguna Del Campo normal operating pool.
  - NMDGF indicated that a 2 to 4 foot reduction in the normal operating pool is acceptable for the 100% PMP RCC overtopping spillway alternative.
- NMDGF would like to consider both a full breach of the dam and a reduction in dam height to remove the dam from NMOSE jurisdiction.
  - Under both the breach and size reduction alternatives, the existing headgate leading to the La Puenta Ditch from the Laguna Del Campo Reservoir will no longer be operable due to the reduced operating pool elevation.
  - This existing diversion can likely be relocated to a point upstream of the Laguna Del Campo Reservoir and will be addressed as a separate project.
- With a size reduction in the dam, NMDGF would like to convert the upstream forebay pond into a wetland.

- With a dam breach alternative, NMDGF would like to create a series of constructed wetlands in place of the existing reservoir.

7.0 Next Steps and Action Items

- The three alternatives selected for evaluation and creation of cost opinions are:
    1. An RCC overtopping spillway for both the 60% and 100% PMP storms.
    2. A full breach of the dam with the inclusion constructed wetlands in the current reservoir footprint.
    3. A reduction in the size of Laguna Del Campo Dam to remove it from NMOSE jurisdiction.
- Wheeler will provide Russ with a CD of background documents obtained from NMOSE.
- Wheeler will develop price curves for different reservoir storage reductions under overtopping alternatives.
- Wheeler requested a one-week schedule extension to address the change of project direction from spillway renovation to altered consideration of a breach or storage reduction.
- A Draft Report workshop will be scheduled on June 9.
- A draft report will be delivered on May 26 and a final report will be delivered on June 28.

Laguna Del Campo Dam Alternatives Selection Meeting

Project Objective

- Prepare alternative preliminary designs and cost opinions to modify Laguna Del Campo Dam to meet current State of New Mexico Dam Safety Regulations

Meeting Goals

- Finalize selection of three primary spillway rehabilitation alternatives to pass the Inflow Design Flood
- Answer key remaining conceptual design criteria questions

Meeting Agenda

- Introductions / Review Agenda
- Progress Update
- Schedule Update
- Preliminary Incremental Damage Assessment
- Review Design Criteria
- Discuss Spillway Alternatives
- Primary Spillway Alternative Selection
- Next Steps and Action Items

Progress Update

- Initial Site Visit and kickoff meeting
- NMOSE Document Search
- Preliminary Incremental Damage Assessment
- Preliminary spillway hydraulics to define alternatives that meet project design criteria

Main Findings

- All options are constrained by property boundaries
- No geotechnical information is available
- Outlet works condition is a major unknown
- Good potential exists to reduce the IDF to 60% PMP or lower

Project Schedule

- **Key Upcoming Dates**
  - May 19: Deliver draft alternatives report
  - June 2: Draft report workshop, receive comments from NMDGF
  - June 7: Due date for comments on draft report
  - June 30: Task Order ends

Preliminary IDA Results

- **FLO-2D breach versus no-breach scenarios for ten percent increments of full PMP**
- **Incremental impacts of breach compared**
  - Incremental depth increase of less than 2 feet
  - Isolated increases within limits of Rio Chama 100-year floodplain were neglected
- **Results show a likely reduction of IDF to 60% of PMP**
- **Significant impacts in drainage between reservoir and Rio Chama**
- **Complete IDA Study will be required for approval of reduced IDF**
- **Revision of Rio Chama hydrology estimates could result in a further reduction of the IDF**

Preliminary IDA Map

Summary of Design Criteria

- NMOSE Rules and Regulations
- Improvements within property boundaries
- Easements are not desirable
- La Puenta ditch capacity and alignment must be maintained
- Maintain existing normal storage
- Spillway required to convey the IDF
  - One foot of residual freeboard
  - Evaluate 60% PMP and 100% PMP alternatives (where feasible)

List of Potential Alternatives

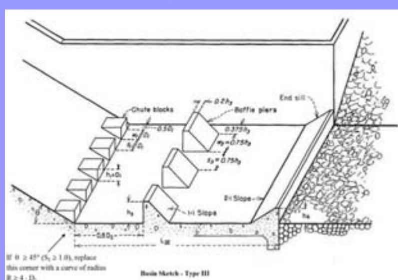
A. Side channel spillway on left (south) abutment (60% PMP)
B. Full height inline labyrinth spillway (60% PMP or 100% PMP)
C. RCC inline overtopping spillway (60% PMP or 100% PMP with reduced storage)
D. Breach dam

Common Design Elements

- Extension of northern dike to contain flood pool
- Outlet works repair or replacement
- Replace existing service spillway structure with new diversion to the La Punta ditch

A – Side Channel Spillway 60% PMP

A – Side Channel Spillway Typical Stilling Basin Schematic



- USBR Type III, which is similar to the specified SAF Type

A – Side Channel Spillway

- 342 foot long vertical faced ogee crest weir wall
- 50 foot wide, 11 foot deep rectangular concrete spillway chute
- Peak outflow 11,820 cfs during 60% PMP
- 60% PMP design only
- 1.0% (upper) and 16.5% (lower) chute slopes
- St. Anthony Falls type concrete stilling basin
- Challenges
  - Significant modification of La Puenta ditch required
  - Chute hydraulics and energy dissipation

B – Full Height Inline Labyrinth 100% PMP

B – Full Height Inline Labyrinth 60% PMP

B – Full Height Inline Labyrinth

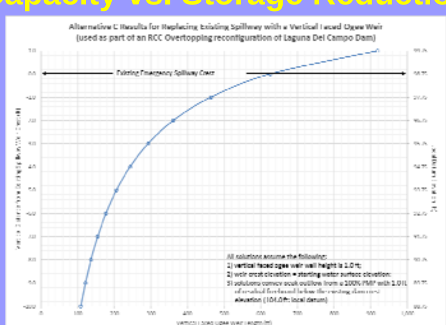
- 100% labyrinth design
  - 258 foot wide, 117 foot long, 26 foot high
  - Peak outflow 19,790 cfs during 100% PMP
- 60% labyrinth design
  - 155 foot wide, 78 foot long, 26 foot high
  - Peak outflow 11,750 cfs during 60% PMP
- Slab with cutoff wall downstream of weir
- Maintains existing La Puenta ditch alignment
- Outlet works replacement
- Challenges
  - Downstream grading and major dam excavation
  - Significant coffer dam or reservoir draining for construction

C – RCC Overtopping Spillway 60% PMP

C – RCC Overtopping Spillway

- 493 foot long vertical faced ogee weir crest
- Roller compacted concrete (RCC) dam face
- Peak outflow 10,960 cfs during 60% PMP
- 60% PMP or 100% PMP design
- Challenges
  - 100% PMP design will requires reduced storage
  - Energy dissipation and downstream scour

C – RCC Overtopping Spillway Capacity vs. Storage Reduction



D – Breach Dam

- **Breach dam following published NMOSE guidelines**
  - Excavate to natural grade
  - Breach cross section must convey the 100-year, 24-hour storm peak discharge without attenuation
  - Sediment control plan required
  - Create constructed wetlands in reservoir footprint
- **Remove dam from NMOSE jurisdiction**
  - Less than 25 foot high and 50 acre-feet of storage
  - Reduce dam crest elevation to 92 feet (local datum)
  - Replacement spillway for 100-year, 24-hour storm event required (recommended)
- **Both options will eliminate the La Puenta ditch headgate**

Summary of Alternatives

	Key Design Components	A - 60% PMP Side Channel Spillway	B1 -60% PMP Full Height Labyrinth	B2 - 100% PMP Full Height Labyrinth	C1 - 60% PMP RCC Overtopping	C2 - 100% PMP RCC Overtopping	D - Breach
1	Pass 100% PMP			X		X	
2	Remove Existing Spillway	X	X	X	X	X	X
3	Repair Low Level Service Outlet	X			X	X	
4	Replace Outlet Works		X	X			
5	Relocate La Puenta Headgate	X	X	X	X	X	
6	Eliminate La Puenta Ditch Headgate						X
7	Modify La Puenta Ditch	X					
8	Large Spillway Chute and Stilling Basin	X					
9	Permanent Storage Reduction					X	
10	Upstream Dike Extension	X	X	X	X	X	

Conceptual Design Criteria Questions

- **Select three alternatives to develop opinion of cost**
- **Maximum service spillway flow**
- **Target project budget**
- **NMDGF property borrow areas**
- **Outlet conduit condition**
- **Is a dike extension acceptable**
- **Are permanent storage restrictions acceptable**
- **Acceptable reservoir elevation during construction**

Next Steps

- May 9 – Selection of alternatives and response to key conceptual design questions
- May 12 – Meeting Summary
- May 19 – Draft alternatives report

Laguna Del Campo Dam Spillway Alternatives
Draft Report Review Meeting

June 13, 2016

Meeting participants:

NMDGF	**USFWS**	**Wheeler**
Russell Benjamin	Robert Baca	Steve Jamieson
		Todd Lewis
		Todd Street

1) **New Mexico Department of Game & Fish (NMDGF)**
2) **W. W. Wheeler & Associates, Inc. (Wheeler)**
3) **U.S. Fish & Wildlife Service (USFWS)**

1.0 Review Meeting Agenda

- The meeting was started with a review of the project objectives and the meeting agenda. A PowerPoint presentation used during the meeting to summarize key meeting topics is attached for additional information.

2.0 Progress Update

- The draft alternatives report was submitted to NMDGF and USFWS for review on June 2.

3.0 Schedule Update

- Project is on schedule; the final report is scheduled to be delivered on June 28.
- The Task Order will end June 30.

4.0 Review Evaluated Alternatives

- Wheeler provided a review of the three primary alternatives and the associated opinions of probable cost for each alternative.
    1. Dam Breach
    2. Lower Dam
    3. RCC Overtopping Spillway

5.0 Recommendations and Discussion

- In the draft report, Wheeler recommended pursuing Alternative1, breach the dam, because it will address dam safety concerns in a cost effective manner while providing a valuable ecological resource to NMDGF. Other alternatives result in a cost per-acre-foot of storage that is significantly higher than typically observed.

- NMDGF indicated they prefer Alternative 2 because it will maintain a small recreational pond and create wetlands on site. It is also significantly less expensive than the RCC overtopping spillway alternative. The final report will be edited to document this preferred alternative.
- NMDGF expressed concern about the large contingencies presented in the cost opinions.
- Wheeler indicated the contingencies are generally standardized by the AACE Cost Estimate Classification System and the presented opinions of cost are considered Class 4, Concept Study or Feasibility Level. There are several unknowns associated with the project which reduce accuracy of the costs. These unknowns include accurate topographic information, no geotechnical information, outlet works condition, and unknown acceptable reservoir water levels during construction.
- It was agreed that the discussion of the cost accuracy range will be removed from the report.
- NMDGF expressed concern that the RCC alternative costs are higher than anticipated and do not compare well to other recent NMDGF dam rehabilitation projects.
- Wheeler indicated the costs are based on standard material unit costs and project multipliers. The RCC overtopping spillway costs are generally higher due to the lack of attenuation in the reservoir and restrictive property constraints. It is also difficult to compare the cost of one dam to another because each has its own unique site constraints and dimensions.
- It was agreed that the opinions of cost for alternatives would be reduced to 15 percent to match contingency values typically used by NMDGF.
- Wheeler will review the opinions of cost to identify if there are other areas where the cost may be reduced.

6.0 Next Steps and Action Items

- NMDGF and USFWS will provide any additional comments by June 17, 2016
- Comments discussed during the review meeting will be addressed and a final report will be delivered on or about June 28, 2016.

Laguna Del Campo Dam Draft Report Review

Project Objective

- Prepare alternative preliminary designs and cost opinions to modify Laguna Del Campo Dam to meet current State of New Mexico Dam Safety Regulations

Meeting Goals

- Review Draft Laguna Del Campo Dam Rehabilitation Alternatives Report
- Get comments from NMDGF and FWS

Meeting Agenda

- Review Agenda
- Progress Update
- Schedule Update
- Description of Primary Alternatives
- Opinions of Probable Cost
- Alternatives Analysis Conclusions and Discussion
- Next Steps and Action Items

Progress and Schedule Update

- Draft Alternatives Report submitted - June 2
- Final NMDGF and FWS Comments - June 17
- Final Report delivery - June 28
- Task Order ends - June 30

Review of Design Criteria

- NMOSE Rules and Regulations
- Improvements within property boundaries
- Easements are not desirable
- La Puente Ditch capacity and alignment must be maintained
- Maintain existing normal storage
- Spillway required to convey the IDF
  - One foot of residual freeboard
  - Evaluate 60% PMP and 100% PMP alternatives (where feasible)

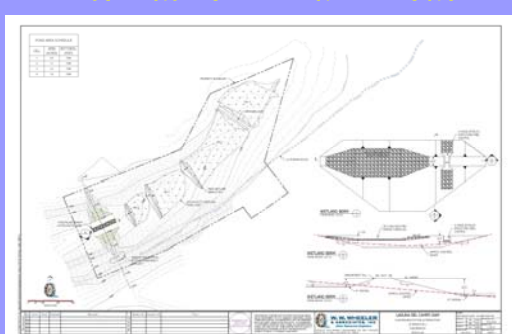
Evaluated Alternatives

- **Alternative 1 – Dam Breach with Constructed Wetlands**
- **Alternative 2 – Lower Dam to Remove It from NMOSE Jurisdiction**
- **Alternative 3 – RCC Overtopping Spillway**
  - Alternative 3a – 60%PMF design
  - Alternative 3B – 100% PMF design

Alternative 1 – Dam Breach

- **Decommission dam by constructing 100-foot wide breach to natural ground elevation**
  - Low flow channel through breach
- **Create four constructed wetland ponds**
  - Total wetland area approximately 5 acres
  - 12 foot high berms
  - Stoplog low level outlet and grouted riprap overflow
- **Final design will be dependent on reservoir basin topography**
  - Consider topographic and bathymetric surveys

Alternative 1 – Dam Breach



Alternative 2 – Lower Dam

- **Lower dam to remove it from NMDGF jurisdiction**
  - 12 foot reduction in dam crest to elevation 7302
  - 16.4 acre feet of storage at proposed spillway crest
- **New 24-hour, 100-year spillway**
  - 85-foot-wide spillway crest at elevation 7296
  - 3,139 cfs spillway capacity
  - Provides one of foot residual freeboard

Alternative 2 – Lower Dam

- **Rehabilitate Outlet Works**
  - Slip line with 20" Diameter HDPE and grout annular space
  - Replace gate and modify operator
- **Create Wetland in upstream Forebay Pond**
  - Provide outlet control in upstream pond and adjust WSEL for wetland conditions
  - May be space for additional constructed wetland at upstream end of reservoir
- **Relocate La Puente Ditch Headgate**
  - Gate should be relocated to a point upstream of reservoir

Alternative 2 – Lower Dam

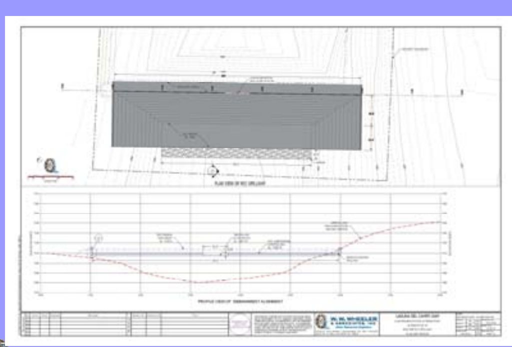
Alternative 3a – 60% PMF RCC Overtopping Spillway

- RCC overtopping spillway capable of passing 60% of PMF
  - 493 foot wide crest width at elevation 7309.75
  - 450 cfs, 2-foot-deep x 50-foot-wide service flow notch elevation 7307.75
  - 11,836 cfs, capacity with one foot of residual freeboard
  - Maintains Existing Storage
- Energy Dissipation
  - 50-foot long level RCC slab
  - Downstream concrete cutoff wall

Alternative 3a – 60% PMF RCC Overtopping Spillway

- Relocate La Puente Ditch Headgate
  - Remove existing spillway
  - Move La Puente gate upstream in reservoir
- Rehabilitate Outlet Works
  - Slip line with 20" Diameter HDPE and grout annular space
  - Replace gate and maintain existing operator elevation
- Extend North Dike
  - Approximate 700-foot extension of north dike to contain flood pool

Alternative 3a – 60% PMF RCC



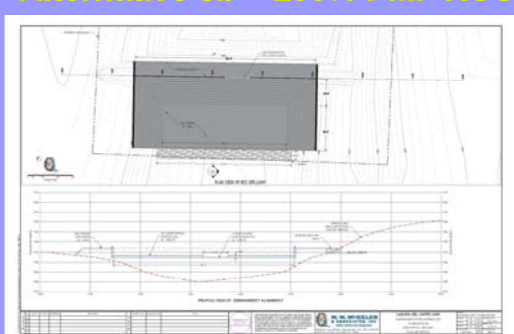
Alternative 3b – 100% PMF RCC Overtopping Spillway

- **RCC overtopping spillway capable of passing 100% of PMF**
  - 361 foot wide crest width at elevation 7306.75
  - 450 cfs, 2-foot-deep x 50-foot-wide service flow notch at elevation 7304.75
  - 4-foot reduction in normal operating water surface elevation and 26 acre-foot storage reduction
  - 19,784 cfs, capacity with one foot of residual freeboard
- **Energy Dissipation**
  - 80-foot long level RCC slab
  - Downstream concrete cutoff wall

Alternative 3b – 100% PMF RCC Overtopping Spillway

- **Relocate La Puente Ditch Headgate**
  - Additional survey is required to determine if La Puente Ditch Headgate can be relocated within reservoir
- **Rehabilitate Outlet Works**
  - Slip line with 20-inch diameter HDPE and grout annular space
  - Replace gate and lower operator by 4 feet
- **Extend North Dike**
  - Approximate 700-foot extension of north dike to contain flood pool

Alternative 3b – 100% PMF RCC



Comparison of Alternatives

Parameter	Alternative 1	Alternative 2	Alternative 3a	Alternative 3b
Maintains Existing Storage Capacity			x	
Permenantly Reduced Storaged Capacity		x		x
No Storage	x			
Pass the full PMF				x
Created Wetlands	x	x		
Remove / Abandon Existing Spillway	x	x	x	x
Outlet Works Rehabilitation		x	x	x
Relocate La Puente Ditch Headgate in Reservoir			x	x
Relocate La Puente Ditch Diversion Upstream of Reservoir	x	x		
Upstream Dike Extension			x	x
Remove Dam from NMOSE Jurisdiction	x	x		

Opinion of Probable Cost

Item Description	Alternative 1 Breach	Alternative 2 Reduced Crest	Alternative 3a 60% RCC	Alternative 3b 100% RCC
Direct 2017 Construction Costs	$1,305,000	$1,723,280	$5,595,500	$5,596,550
Indirect 2017 Construction Costs	$622,000	$919,000	$2,735,000	$2,736,000
Total 2017 Construction Costs	$1,927,000	$2,642,280	$8,330,500	$8,332,550

Conclusions

- **Alternative 1**
  - Provides most cost effective solution to dam safety concerns while creating valuable resource
- **Alternative 2**
  - High cost per acre-foot due to need for new spillway
  - Potential for combination with Alternative 1
- **Alternative 3**
  - High cost per acre foot
  - Significantly higher total cost than Alternative 1 or 2
  - Can pass 60% PMF while maintaining storage
  - Can pass 100% PMF with 26 acre-foot storage reduction

Recommendations

- Alternative 1
  - Most cost effective alternative
  - Will eliminate dam safety concerns
  - Difficult to justify cost per acre-foot of other alternatives

Next Steps

- June 17 – NMDGF and FWS to provide comments on draft report
- June 20 – Meeting Summary
- June 28 – Final Alternatives Report