Yakima River Basin Study

Thorp to Wymer Conveyance Technical Memorandum

U.S. Bureau of Reclamation
Contract No. 08CA10677A ID/IQ, Task 4.7

Prepared by

HDR Engineering, Inc

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region
Columbia-Cascades Area Office

State of Washington
Department of Ecology
Office of Columbia River

February 2011

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1.0 Introduction

This technical memorandum describes the design criteria, geology, facilities, and property easement needs for a possible project that would divert additional flow from the Yakima River to the proposed Wymer reservoir for storage. The Wymer Upstream Conveyance project is located in the Kittitas Valley between Thorp and Wymer near the City of Ellensburg in central Washington. Figure 1 shows general project location.

The purpose of this project is to divert up to 1,000 cubic feet per second (cfs) of additional flow from the Yakima River and convey it through the Kittitas Reclamation District (KRD) North Branch Canal into the proposed Wymer reservoir for storage. This water would subsequently be used to meet Roza Irrigation District demands, instream flow requirements, and/or other downstream diversion needs.

The project begins with a river diversion and pump station on the Yakima River near Thorp and ends at a tunnel outlet to the proposed Wymer reservoir just east of the Yakima River at Wymer. The flow would be conveyed around the north and east sides of the Kittitas Valley through an enlarged KRD North Branch Canal, then to the southwest via a new siphon and tunnel through the Manastash Ridge to the Wymer reservoir.

A new pump station at Thorp would pump the water through a new transmission main into an upgraded KRD canal system. Near the south end of the valley at Wippel, where the main canal divides into three canals, a new siphon would convey the water across the valley into a new tunnel passing through the Manastash Ridge to the Wymer reservoir.

Any options that are selected to move forward would need additional analysis during final design.

2.0 Design Criteria

2.1 Flow Transfer Rate

The flow criteria selected for the project would convey approximately 1,000 cfs of additional flow from the Yakima River to the Wymer Reservoir for storage and downstream irrigation use. The 1,000 cfs capacity was established based on the desire to have adequate pumping capacity to fill Wymer reservoir during late winter/early spring high runoff periods and to reduce current high irrigation demand driven flows in the river between Thorp and Roza Dam.

2.2 Thorp Site Selection

The conceptual pump station site, approximately 1.7 miles northwest of Thorp (see Figure 2, was selected for the following reasons:

- Proximity to, and on the same side of the Yakima River as, the existing KRD North Branch Canal.
- Ease of access to a major highway (Highway 10 for this site).
- A stable section of the Yakima River, with the lowest point of the river bed along the accessible bank.

- Relatively flat area with room for construction of the intake and pump station.
- Reasonable alignment for the discharge pipeline up a gradual slope to the canal.
- Relatively close (3 miles) to a high-voltage transmission line corridor.

A drainage channel that crosses the pump station site would have to be rerouted to the river north of the site or incorporated into the site design.

2.3 Yakima River Diversion and Intake

The following Yakima River flow information and design criteria were used for the Yakima River diversion and intake conceptual design:

- Flows Near the Diversion – Based upon average daily flow data from 1990 to present for the Bureau of Reclamation gauge about six miles upstream of the diversion site (YRWW); the flows in the Yakima River upstream of diversion site have typically varied between approximately 600 cfs (exceeded 90 percent of the time) and 3,900 cfs (exceeded 10 percent of the time). The minimum, average, and maximum recorded flows were 256 cfs, 1961 cfs, and 21,384 cfs (January 8, 2009) respectively. These recorded flows are similar to longer term average daily flows recorded 15 miles upstream from USGS gauge 12479500 at Cle Elum, Washington from 1949 through 1990. Flows are typically lowest in October and November and highest from June through August.
- River Elevation – The river elevation varies with flow volume, but for this conceptual-level analysis, based upon USGS mapping of the site, the normal river elevation during pumping was assumed to be approximately elevation 1650.
- Adjustable Diversion Dam – The diversion would be an adjustable height dam to pass high flows without upstream impacts while providing the ability to divert flow into the Thorp pump station intake.
- Self-Cleaning Trash Rack – A self-cleaning trash rack paralleling the stream bank would be required to keep large debris out of the fish screens. The trash rack would be a standard bar screen meeting Reclamation standards.
- Fish Screening – The facility would require fish screens to prevent fish from entering the pump station intake. The dual stainless steel wedge wire V-screens would be designed for 1,000 cfs capacity with a 0.4 feet per second (fps) approach velocity, 1.75 millimeters or less clear slot openings, and a 2 fps sweeping velocity.
- Fish Screen Cleaning – An automatic horizontal-motion brush-cleaning system would sweep the screens clean of any floating or suspended debris that accumulates on the screen surface.
- Downstream Fish Bypass – A fish bypass system would allow fish that collect in the screen area to bypass the facility. The system would be designed for flows of 25 cfs past each screen (50 cfs total) to a fish bypass channel discharging below the diversion dam.
- Upstream Fish Passage – Upstream fish passage would accommodate the upstream movement of fish when the adjustable-height dam is used to divert water to the pump

station. A vertical-slot fish ladder would be located on the east end of the dam to provide upstream fish passage.

2.4 Thorp Pump Station Capacity

The pump station is configured with a six 200-cfs pumps that would be able to pump from a minimum of approximately 200-cfs up to a firm capacity of 1,000 cfs. The firm capacity assumes that one of the six pumps is on standby or out of service. A pump station discharge pipeline would convey the 1,000 cfs flow to the KRD North Branch Canal.

2.5 Pump Station and Pipeline Hydraulics

The preliminary hydraulic analysis results in a 144-inch diameter, 4,200-foot-long transmission main between the pump station and the high point on the ridge at Station 42+00 and a 144-inch diameter, 6,200-foot-long gravity pipe from the high point to the KRD North Branch Canal. The pipeline should be designed for normal static pressures to a maximum of 500 feet of head (217 pounds per square inch [psi]) at the pump station. The gravity pipeline should be designed for static pressures up to a maximum of 80 feet (35 psi) at the crossing under Highway 97 and Dry Creek. About 20 feet of head would be needed at the high point on the ridge to “drive” the gravity flow through the pipe to the North Branch Canal. The velocity in the full pipe at 1,000 cfs would be 8.8 fps. Surge analysis would be required to determine dynamic and surge pressure design criteria for the pipeline.

2.6 KRD North Branch Canal

The existing KRD North Branch Canal and structures would be enlarged to convey current local irrigation flow plus the additional 1,000 cfs from the pump station at Thorp to Wippel near the southern end of the Kittitas Valley. From there flow would enter new conveyance piping and a tunnel to the Wymer reservoir. Section 5 of this memorandum discusses property acquisition that would be required to accommodate the wider canal and larger canal structures.

It is assumed that no new diversions would be built along the canal and that existing turnouts would continue to divert the same volume of water as they currently do for local valley irrigation. It is likely that approximately half of the existing North Branch Canal check structures would need to be reconstructed in the new, larger canal to maintain the original hydraulic gradeline for flows into the lateral canals during low flow conditions. This would include removal of stop logs when the canal is being used to convey the local irrigation flow along with the added 1,000 cfs.

The North Branch Canal water surface drops about 60 feet in elevation from the Thorp pump station discharge location just downstream of the Little Dry Creek siphon to the downstream end of the Little Johnson siphon just above the Wippel diversion.

To preserve the viability of the existing local diversions and lateral canal hydraulics, the higher-capacity canal, tunnels, and siphons are conceptually designed to maintain the existing hydraulic gradeline as much as possible. Canal velocities vary depending on the slope of each canal segment. Significant variations from this criterion would likely require major modifications to the North Branch and lateral canal system, including canal route modifications. If this project is selected to move forward, detailed design of canal features such as drains, wasteways, roadway crossings, and control structures would be completed during the next phases of the project.

2.7 Wymer Siphon and Tunnel

The new siphon and tunnel from Wippel to the proposed Wymer reservoir are sized to convey up to the additional 1,000 cfs flow with a design flow maximum velocity of 8 fps. The preliminary alignment was selected to minimize the length of the siphon and tunnel to the Wymer Reservoir.

3.0 Geology

The geology of the area that includes the Thorp pipeline, North Branch Canal, and the Wymer siphon and tunnel alignments is shown on the USGS geologic map of the East Half of the Yakima Quadrangle (Schuster 1994) and in a USGS hydrogeologic report (Jones et al. 2006). The Washington Division of Geology and Earth Resources (2005) published the same geologic mapping information in the form of a GIS dataset layer. Figure 3 shows the geology along the project features.

As summarized in Jones et al. (2006), the Yakima River Basin is part of the Yakima Fold belt, which is a highly folded and faulted region underlain by various consolidated rocks, ranging in age from Precambrian to Tertiary, and unconsolidated materials and volcanic rocks of Quaternary age. In the Yakima River Basin, the headwater areas in the Cascade Range include metamorphic, sedimentary, and intrusive and extrusive igneous rocks. The central, eastern, and southwestern parts of the basin are composed of basalt lava flows of the Columbia River Basalt Group (CRBG) with some intercalated sediments that are discontinuous and weakly consolidated. The lowlands are underlain by unconsolidated and weakly consolidated valley-fill composed of glacial, glacio-fluvial, lacustrine, and alluvium deposits that exceed 1,000 feet thick in places. Wind-blown deposits, called loess, occur locally along the lower valley.

The Thorp pipeline alignment passes through surface geologic units: alluvial fan (af), alluvium (al), alpine outwash (QFao and Qaow), volcaniclastic rocks (Tvc), and continental sedimentary Thorp gravel (Tstg), indicating that the pipeline excavation would predominantly encounter silty sand, sand, gravel and cobbles, and some rock.

The existing North Branch Canal is located around the perimeter of the valley, passing between the alluvium (al) and the CRBG geologic units.

The Wymer siphon alignment passes through surface geologic units: alluvial fan (af), loess (Qloess), continental sedimentary Ellensburg formation (Tse), and CRBG consisting of Wanapum basalt and Grande Ronde basalt. The tunnel alignment primarily passes through surface geologic units of CRBG consisting of Wanapum basalt and Grande Ronde basalt, as well as mass wasting deposits (Qls).

Based on the geologic information reviewed, it appears possible that the tunnel alignment and the shafts could be located essentially within the basalt bedrock. However, geology at the depth of the proposed tunnel is not available and would require more specific tunnel geology information during future project design phases. It also appears that most of the siphon alignment could be located within the alluvial fan and loess deposits with some rock excavation near the transition to the tunnel section. The feasibility of these significant structures would need to be investigated by conducting detailed, site-specific geotechnical and geological investigations.

4.0 Facilities Description

This section provides a description of the conceptual facilities required to convey water approximately 22 miles from the Yakima River near Thorp southwest to the proposed Wymer dam site.

In summary, this project includes the following components:

- Yakima River diversion near Thorp.
- Fish-screened intake with upstream and downstream fish passage.
- 1,000-cfs pump station at Thorp.
- Approximately 2-mile-long pipeline from the Thorp pump station to the KRD North Branch Canal.
- Approximately 30 miles North Branch Canal capacity upgrades to 1,000 cfs.
- Approximately 3-mile siphon, 3.2-mile tunnel, and 3,850-foot pipeline from the KRD North Branch Canal at Wippel to the Wymer reservoir.

Primary access to the project area would be via Interstate 90 and Highway 10 to the Thorp area, and Highway 821 and Interstate 82 to the Wymer area. Local roads provide access to the North Branch Canal between Thorp and Wippel and the south end of the Kittitas Valley.

4.1 Yakima River Diversion Dam

Figure 4 shows the Yakima River diversion and Thorp pump station site plan. Depending on stream hydraulics, it is likely that a diversion weir would be required in the Yakima River to divert flow into the Thorp intake. The river at this potential weir site is approximately 200 feet wide. The weir is assumed to be a permanent 200-foot-long, 4-foot-high shaped concrete structure across the river with a stop log system or hinged crest (Bascule) gates that could be used to temporarily raise the dam crest elevation an additional 5 feet (to a total of 9 feet) when needed to divert flow into the pump station intake. Assuming a continuing 1-foot of flow over the raised crest, the water surface behind the raised dam during pumping would then be at approximately elevation 1660.

The gates are lowered, or the stop logs removed, when not needed for diversion to pumping and/or to allow passage of high flows in the river. The east end of the diversion structure would contain a fish ladder for upstream fish passage and the downstream fish passage discharge structure.

The river and intake hydraulics should be further investigated during the next phase of preliminary design to determine if it would be feasible to avoid construction of the diversion dam by lowering the fish screen and pump station intake structures.

4.2 Intake and Fish Screens

Figure 5 shows the pump station intake, fish screens, and pump station. The pump station intake would be located upstream of the Yakima River diversion on the left (east) bank of the river approximately 1.7 miles northwest of Thorp. As described below, the intake structure would include a trash rack to exclude large debris, fish screens meeting federal and state agency requirements, sediment-handling capabilities, and downstream and upstream fish passage.

4.2.1 Trash Rack

A 190-foot-long, 10-foot-high trash-rack structure would be located along the left (east) bank of the river in front of the fish screen forebay to prevent large debris from damaging the fish screen and fish screen cleaning mechanisms. To promote self cleaning, the vertical, 8-inch-deep trash rack bars would be spaced on 8-inch centers at a 45-degree angle with the front of the bars pointing downstream. The 8-foot-high trash-rack panels would be supported by a 10-foot-high concrete structure that also supports a walkway along the top of the structure. The walkway would be used to access the trash rack for inspection and maintenance.

4.2.2 Sediment Handling

The area behind the screen and in front of the fish-screen structure would be depressed and sloped to channel and would remove sediment that may collect in front of the fish screens. A 48-inch sediment-flushing gate on a headwall at the lowest downstream point of the sediment basin could be opened to flush sediment through a 48-inch-diameter pipe and discharge the flow back to the river downstream of the diversion dam. It is also expected that sediments could be manually removed from the forebay area as needed, using pressurized water from a hydrant next to the forebay area.

4.2.3 Fish Screens

The fish screen design concept is intended to comply with federal and state fisheries agencies criteria for a 1,000-cfs fish screen. The approximately 140-foot-wide, 235-foot-long concrete fish screen structure would be angled back from the streambank and trash rack to create a settling forebay in front of the screen structure.

The screen system is arranged in a twin V-shape to fit on the site, promote self-cleaning, and allow downstream fish passage. The screen criteria approach velocity is 0.4 fps, resulting in a total screen area of 2,500 square feet. Using an assumed minimum 5-foot water depth on the screens results in a screen length of 125 feet for each of the four screens. Each 125-foot-long screen section would consist of 10 equally sized panels that could be removed for repair and replaced with a spare panel using a monorail and hoist system. The screen material would be stainless steel wedge wire or profile bar with an open slot width of 1.75 millimeters or less.

Individually adjustable flow-control baffles behind each screen panel would maintain uniform velocities through the screen panels. Water-surface elevations and flow rates would be measured upstream and downstream of the screens to monitor compliance with agency requirements and to determine head losses through the screens, which would vary as the screens plug with debris.

The screens would be cleaned with vertical brushes that automatically sweep horizontally along the length of the screen. The cleaning cycle would be activated by a water surface elevation difference through the screens of 1.2 inches or less. Screen-cleaning cycles could also be timed to occur more frequently or be activated manually.

The fish screens would discharge into flow transition boxes, then through two 15-foot-wide conduits that convey the flow to a pump station forebay. Stop logs in front of each conduit would allow the forebay to be isolated from the intake structure, if needed.

4.2.4 Fish Bypass System

Each V-screen channel would narrow to guide fish to a bypass channel that transports fish and small floating debris in front of the screens. A minimum 2 fps sweeping velocity results in approximately 25 cfs flowing through the V channel in front of the screens (50 cfs total) into flow bypass ramps at the narrow end of the converging screen assemblies. The bypass ramp transitions the uniform screen sweeping flow velocity into bypass channels that converge to a single channel that then discharges into the plunge pool at the downstream end of the fish ladder below the east end of the diversion structure. The bypass channels flow at a minimum depth of 9 inches, with velocities of 6 to 20 fps.

4.2.5 Upstream Fish Passage

The upstream fish-passage system would be located on the east end of the diversion dam in the lowest point of the river bed. The concrete, vertical-slot fish ladder would be designed for a minimum flow of 10 cfs to assist in maintaining debris-sweeping velocities downstream in front of the trash rack.

4.3 Thorp Pump Station

The Thorp pump station would pump up to 1,000 cfs of water from the Yakima River intake through approximately 2 miles of steel pipeline to the KRD North Branch Canal.

4.3.1 Pump Station Forebay

A concrete transitional forebay would connect the two intake-structure conduits to the pump station clearwell. The 85-foot-long forebay would gradually widen and deepen from elevation 1645 at the intake-structure conduits to elevation 1630 at the pump station clearwell to provide a smooth transition of flow from the intake into each of the pump suction bells in the clearwell. The forebay would include measures for handling and removing sediment.

4.3.2 Pump Station Building

The pump station building would be a 200-foot-long, 70-foot-wide concrete and steel structure containing six 200-cfs, vertical turbine pumps. A bridge crane would run the length of the 40-foot-tall building. The pump motor floor is assumed to be approximately at elevation 1670. A motor floor access driveway on each end of the building would facilitate loading and unloading of equipment using the building bridge crane.

To contain the pumps and keep the pump bowls submerged, the pump station clearwell floor would be approximately 40 feet below the pump motor floor at elevation 1630. The pump station clearwell water surface elevation would vary between elevation 1660 and 1655 depending on flow in the river and losses through the trash rack, fish screens and forebay.

The pump station would contain forebay gates to isolate each pump bay, if needed, and pump control valves on the pump discharge manifold. Discharge piping would continue under the electrical room to a valve vault containing discharge piping isolation butterfly valves.

A 50-foot-wide, 150-foot-long electrical room in a lower building immediately adjacent to the pump station building would contain all of the pump station electrical power and control panels.

4.3.3 Pumps and Motors

The 200-cfs, vertical-turbine pumps would be selected based on the total dynamic head (TDH) of the pumping system. The static head from the intake water surface at approximately elevation 1660 to the discharge pipeline high point at elevation 2120 is approximately 460 feet. The design set points for the pumps would be for an approximate average TDH of the average static plus the hydraulic losses in the pumping suction and discharge systems. A pump selection TDH of 475 feet (206 psi) is based on a conceptual-level hydraulic analysis of the discharge piping, valve, and pipeline losses.

The pump station capacity would vary with changes in the TDH and pump efficiencies as the river elevation changes. The pumps would be equipped with soft motor starters to reduce power-system impacts. Using combined pump and motor efficiency of 85 percent results in a pump motor capacity of approximately 12,500 horsepower.

4.3.4 Power

An electrical substation and switchyard at the north end of the pump station would accept power from the grid and transform it to the voltages needed for the 12,500-horsepower motors. A major east-west, high-voltage transmission power line corridor about 3 miles north of the proposed pump station site could serve as a power source for the pump station.

4.3.5 Flow Metering and Pump Operation

The pump station would contain flow meters on each pump and automated data acquisition and control systems to operate the pumps. In addition to local manual operation, the pump station could be remotely monitored and automatically controlled or operated under a pre-programmed plan.

4.3.6 Hydraulic Surge Control

Because of the large water volumes being pumped through a long transmission pipeline, extensive measures would be required to control and minimize surge pressures in the event of a rapid change in flow due to a power failure or other reasons. Although this study did not include a surge analysis, the conceptual plans and estimates include provisions for vacuum and air-release valves, pump-control valves, and surge tanks. The most significant provisions are for six surge-control tanks and pump-control valves as shown in Figure 5.

4.3.7 Security

The diversion dam, intake, and pump station would be a large and complex facility requiring significant perimeter security. It is expected that security measures would include fencing, intrusion sensors, remote camera monitoring, and building alarm systems.

4.4 Pump Discharge Manifolds and Transmission Pipeline

Figure 6 shows the pipeline plan and Figure 7 shows the pipeline profile. Each pump would discharge through a 66-inch-diameter pipe that includes a pump-control valve in the pump station and pump isolation valve in an exterior valve vault. Two sets of three pump-discharge pipes would combine so each set of three pipes connects to one of two 108-inch-diameter steel pipes.

These two pipes then would combine to flow into a 10,400-foot-long, 12-foot-diameter steel pipeline to convey the flow to the KRD North Branch Canal. The first 4,200 feet of the transmission pipeline would be aligned to the northeast to cross under Highway 10, and then climb a ridge with a ground-surface high point of approximately elevation 2160. Since the high-point ridge is relatively narrow at about 800 feet, the ridge would be excavated to reduce the pipeline high point by about 40 feet to elevation 2120 to reduce total pumping head by about 9 percent.

The pipeline alignment would continue to the northeast as a gravity-flow pressure pipe for another 6,200 feet. The alignment would extend down the eastern slope of the ridge then as an inverted siphon under Highway 97 and Dry Creek to discharge into a new structure adjacent to the KRD North Branch Canal just downstream of the existing North Branch Little Dry Creek Siphon. The discharge location was selected to avoid increasing the sizes of the North Branch Tunnel No. 3 and the existing siphon.

At the end of each pumping season the first 4,200 feet of the transmission pipeline could be slowly drained back into the Yakima River through a drain valve and pipe at the pump station. The gravity portion of the pipeline could be drained into Dry Creek. A set of combination air release/vacuum valves would be located at the pipeline high points to allow movement of air into and out of the pipeline.

4.5 Discharge Structure at KRD North Branch Canal

The transmission pipeline would discharge to the Thorp North Branch Canal discharge structure at approximately elevation 2080 (see Figure 8). The flow from the pipe would discharge into a 125-foot-long hydraulic transition structure next to the North Branch Canal and then flow over a weir from the discharge structure into the adjacent canal. The weir discharge structure would be protected by a security fence surrounding the area and/or a concrete slab cover and bar rack.

4.6 KRD North Branch Canal

Figure 9 is an aerial map showing segments of the KRD North Branch Canal system from Thorp to Wippel. Approximately 31 miles of the canal and canal structures would be upgraded to convey the additional 1,000 cfs of flow from the Thorp pump station pipeline to the division of the North Branch Canal at Wippel. The capacity of the existing North Branch Canal gradually decreases as lateral canals divert water from the main canal to meet existing local valley irrigation system demands. The canal capacity varies from approximately 1,000 cfs at the upstream northern end near Thorp to approximately 200 cfs at Wippel. Therefore, the required percentage increase in canal capacity varies from a 100 percent increase at the upper end (1,000 cfs to 2,000 cfs) to approximately a 500 percent increase at the lower end (200 cfs to 1,200 cfs).

Resizing the canal to convey the additional flow would also likely impact 39 existing bridges that cross the canal, two tunnels, two siphons, and many of the existing diversion structures.

Approximately 6 miles southeast of Kittitas, Washington, near the intersections of Larsen, Pumping Plant and Wippel Creek roads, the North Branch Canal divides into three canals that serve the south Kittitas Valley: Pumped Ditch (highest elevation), Gravity Ditch (medium elevation), and Turbine Ditch (lowest elevation).

To divert the flow to Wymer a new hydraulic diversion and control structure would be located upstream of the existing flow control structure at Wippel. Up to 1,000 cfs of flow would be diverted into a siphon, tunnel and pipeline that would discharge at the proposed Wymer reservoir for storage. The current local service flow would be left in the main canal to be divided into the three existing canals to serve south valley irrigation needs (as it is now).

4.6.1 Existing North Branch Canal Characteristics

Canal construction would include widening and deepening of approximately 29.7 miles of the North Branch Canal and replacing or paralleling 1.2 miles of canal structures consisting of two siphons and two tunnels. Existing canal and canal structure information provided by the KRD is summarized in the tables below. The segment numbers in the tables correspond to numbers shown on Figure 9. Table 1 shows the approximate North Branch Canal water surface elevations at the beginning (Canal Section 6 near Thorp) and the end (Canal Section 52 at the Wippel diversion) of the affected reach. A more detailed tabulation of existing North Branch Canal information is shown in Appendix B.

Table 1. KRD North Branch Canal Water Surface Elevation Data

CANAL SECTION ID	LOCATION	APPROXIMATE WATER SURFACE ELEVATION (FT)
6	At Thorp pump station discharge (at start of affected canal reach)	2,075
52	At Wippel diversion (at end of affected canal reach)	2,018

Table 2 summarizes the canal parameters provided by KRD. For example, canal sections 6 through 11 have the same length, bottom width, depth, slope, flow rate and velocity, while section 12 is unique. Ranges are given where the parameters are similar.

Table 2. Existing KRD North Branch Canal Basic Dimensions and Hydraulic Parameters

CANAL SECTION IDS	LENGTH (FT)	CANAL BOTTOM WIDTH (FT)	DEPTH (FT)	SLOPE (FT PER 100 FT)	FLOW RATE (CFS)	VELOCITY (FPS)
6-11	17,000	30	8.2	0.015	926	2.7
12	466	12	9.8	0.030	1,320	5.6
13-21	16,435	28	7.5	0.017	775	2.7
18	1,034	9	7.2	0.050	775	6.0
19 and 21	17,178	28	7.5	0.017	775	2.7
20	1,164	15	7.5	0.057	775	4.0
22-27	29,652	24 to 28	6.4 to 7.2	0.015 to 0.017	515 to 690	2.4 to 2.7
28-36	35,465	20 to 24	5.2 to 6.2	0.020 to 0.015	325 to 455	2.2 to 2.4
37-52	38,206	6 to 20	4.2 to 4.8	0.023 to 0.100	200 to 290	2.2 to 6.0

4.6.2 North Branch Canal Hydraulic Analysis

The canal would need to be widened and deepened to approximately maintain the current hydraulic gradeline between Thorp and Wippel. Using similar canal slopes and velocities, the existing cross-sectional area of the North Branch Canal would need to be approximately doubled at the Thorp end, then gradually increased to up to six times at the Wippel end. Figure 10 shows representative comparative cross-sections of existing and improved canal cross-sections in areas near Thorp (larger existing canal) and near Wippel (smaller existing canal).

Preliminary calculations indicate the following dimensional changes would increase capacity as required while minimizing the increase in width and depth:

- At the upstream end, increase canal depth from 8.2 feet to 10.2 feet and increase canal bottom width from 30 feet to 45.3 feet.
- At the downstream end, increase canal depth from 4.2 feet to 9.2 feet and increase canal bottom width from 15 feet to 22.5 feet.

To maintain the current hydraulic gradeline, the canal's physical and hydraulic characteristics need to be maintained as much as possible. Modifications to some items may have major or minor consequences. The following list includes canal characteristics that should be maintained or minimally modified:

- Longitudinal Slope – The longitudinal slope along the canal should match the existing slope as much as possible to maintain the viability of the existing lateral canals system.
- Canal Surface Type – KRD provided a Manning's Roughness Coefficient (n) for each canal segment. Most of the canal is unlined with a Manning's coefficient of 0.0225 or slightly higher in some sections. Some short lined sections have a coefficient of 0.0140. It may be necessary to line some of the unlined canal segments to increase the canal capacity in some areas.
- Side Slopes – Canal side slopes should remain the same where possible. However, side slope modification may be required to balance earthwork cut and fill volumes and minimize cut slopes on steeper hillsides.
- Limiting Impact – Local features such as control structures and energy dissipation features should be maintained where possible, or modified to limit impacts to upstream and downstream canal sections.

4.6.3 Existing Diversions

KRD maps of the North Branch Canal show that there are 29 existing lateral canal diversions. If most of the expansion of existing canals occurs on the uphill side of the canal and the hydraulic gradeline remains about the same as it is now, modifications to most of the diversion structures may be minimal. However, for cost-estimating purposes it is assumed that modifications such as raising weirs or adjusting gates would be required and some existing diversions may need to be completely rebuilt. Also, based on a review of the canal aerial mapping, three major diversion structures spanning the canal would have to be reconstructed.

The main canal also would need to be modified to allow existing diversions and lateral canals to operate under the current lower flow conditions when the canal is not conveying the additional 1,000 cfs. Main canal check structures would keep the canal water levels at the existing hydraulic gradeline during normal irrigation operations. Check structure stop logs would then be removed or gates opened when the North Branch Canal is conveying the additional 1,000 cfs. A more detailed hydraulic analysis of each existing diversion and lateral canal would be needed before main canal check structures can be located and designed.

4.6.4 Canal Maintenance Roads

Maintenance roads along the canal would need to be reconstructed if they are impacted by excavation or other construction issues. The cost estimates that are outlines in a separate technical memorandum assume reconstructing all existing maintenance roads along the canal.

4.6.5 Bridges

A review of the aerial mapping of the North Branch Canal between the Thorp pipeline discharge and Wippel showed that 39 bridges cross the canal within that 31-mile-long reach. These include 23 that appear to be small, single-lane, local-use bridges and 16 larger county road bridges with at least two lanes. For this conceptual analysis, cost estimates assume that all 39 bridges would have to be extended or, more likely, replaced to span the new, wider canal. Other roads crossing at bored tunnels (including I-90) would not need to be reconstructed.

4.7 North Branch Canal Structures

Table 3 summarizes the information KRD provided for North Branch Canal tunnels and siphon structures. Copies of original plan and profile drawings of these structures are included in Appendix B.

Table 3. KRD North Branch Tunnel and Siphon Data

STRUCTURE NAME	MILE	LENGTH[1] (FT)	CHARACTERISTICS	CAPACITY (CFS)
Badlands Tunnel No. 4	NB11.1	594	11 ft horseshoe shaped tunnel	775
Big Johnson Siphon	NB31.5	1,858	6 ft diameter tunnel	280
Little Johnson Siphon	NB32.8	284	6 ft diameter tunnel	280
Tunnel No. 5	NB33.5	3,562	6.5 ft horseshoe shaped tunnel	280

[1]Length includes transition structures.

4.7.1 Badlands Tunnel No. 4

Badlands Tunnel No. 4 is located at the east end of Smithson Road at North Branch Canal Station 585+28. Constructed in 1929, the approximately 11-foot-diameter, horseshoe-shaped tunnel is 482 feet long and has a capacity of approximately 775 cfs. The overall structure is 594 feet long, including the concrete-lined canal transitions at each end. The water surface through the tunnel varies from about elevations 2069.5 to 2068.2. Presuming that the existing tunnel is in good enough condition to remain in service for local flows, a new, parallel, 13-foot-diameter tunnel, approximately 600-foot-long (including concrete lined canal transitions at each end), would be designed to convey the additional 1,000 cfs through the same reach. If it is determined that the existing tunnel is not in good condition and should be replaced, a new tunnel designed to carry the total capacity of 1,775 cfs would be 16.3 feet in diameter. Figure 11 shows comparative cross-sections of the existing and new Badlands Tunnel No. 4.

For this design concept, cost estimates assume that the old tunnel would be replaced with a new parallel tunnel for the entire 1,775 cfs capacity. The existing tunnel could remain in service while the new tunnel is being built and continue operating to allow one tunnel to be taken out of service during low-flow periods. If the old tunnel is left in service, flow-control structures would be required at the ends of the tunnels.

4.7.2 Big Johnson Siphon

Constructed in 1930, the Big Johnson Siphon is located between North Branch Canal stations 1665+09 and 1683+51. The siphon crosses under Johnson Creek, Interstate 90 (approximately Milepost 120), Boylston Road, and the Old Milwaukee Railroad grade (now the Iron Horse Trail) trestle. The 6-foot-diameter siphon pipe is 1,815 feet long with an existing capacity of 280 cfs. The approximate water surface gradeline elevations through the siphon vary from elevation 2043 at the upstream end to 2034 at the downstream end.

A new parallel, 13-foot-diameter siphon would convey the new higher flow of 1,280 cfs. The tunnel segment of the siphon crossing under I-90 and Boylston Road would be approximately 850 feet long. The existing siphon could be kept in service while the new siphon is being built. The old siphon could be either abandoned or kept in place to allow the large siphon to be taken out of service during low flow periods. If the old siphon is left in service, flow-control structures would be required at the ends of the siphons.

Figure 12 shows comparative cross-sections of the existing and new Big Johnson Siphon.

4.7.3 Little Johnson Siphon

The Little Johnson Siphon is located about a mile downstream of the Big Johnson Siphon between North Branch Canal stations 1735+46 and 1738+70. The 6-foot-diameter, 284-foot-long siphon pipe has an existing capacity of 280 cfs.

A new parallel, 13-foot-diameter siphon would convey the new full-flow capacity of 1,280 cfs. This new siphon section through the unnamed small drainage could be constructed using conventional open-trench construction. The existing siphon could be abandoned or kept in place to allow the large siphon to be taken out of service during low-flow periods. If the old siphon is left in service, flow-control structures would be required at the ends of the siphons.

Figure 12 shows comparative cross-sections of the existing and new Little Johnson Siphon.

4.7.4 Tunnel No. 5

Constructed in 1930, Tunnel No. 5 is a 3,470-foot-long, 6.7-foot-wide, horseshoe-shaped tunnel with an existing capacity of 280 cfs. There are 42-foot and 50-foot-long, concrete-lined canal transitions on each end of the tunnel resulting in a total structure length of 3,562 feet. The tunnel portal North Branch Canal stations are 1771+30 to 1806+00. The water surface is at approximately elevation 2028.5 at the upstream end and elevation 2019.8 at the downstream end of the siphon.

A new, parallel, 13-foot-diameter tunnel would convey the full capacity of 1,280 cfs. It would be the same length as the old tunnel (3,470 feet) and would require similar concrete-lined transitions between the tunnel and canal. Depending on its condition, the existing tunnel could be abandoned or kept in place to allow the new, large tunnel to be taken out of service during low-flow periods. If the old tunnel is left in service, flow-control structures would be required at the ends of the tunnels.

Figure 11 shows comparative cross-sections of the existing and new Tunnel No. 5.

4.7.5 Construction Access and Power

The primary construction access would be via local roads to and from I-90 and the canal maintenance roads.

During construction, low-voltage power from local service lines is available in some locations, but the remote nature of the canal would require generators in many locations.

4.7.6 Metering and Controls

The canal would use flow-metering and controls systems similar to those already in use.

4.7.7 Security

The discharge and diversion structure facilities could require some perimeter security, including fencing or other more sophisticated measures.

4.8 Cross-Valley Siphon and Tunnel to Wymer

A new diversion would be constructed upstream of the existing flow-splitting system at Wippel to divert the 1,000 cfs into a siphon pipeline that would cross the south end of the Kittitas Valley. The siphon would then connect to a tunnel through the Manastash Ridge to convey the flow to the proposed Wymer reservoir. Figure 13 (aerial photo background) and Figure 14 (contour background) show plan views of the proposed alignment.

4.8.1 Hydraulic Analysis

The average water surface in the KRD North Branch Canal at the Wippel diversion structure is approximately elevation 2,018. The canal levels are expected to be similar when the Thorp pump station is pumping. The maximum water level elevation in the canal is assumed to be elevation 2019 for design purposes. The design flow maximum velocity is between 8 and 9 fps.

The siphon pipeline should be designed for pressures up to a maximum of 304 feet (132 psi), which corresponds to a maximum water level in the canal at elevation 2019 and the low point of the siphon at pipe invert at elevation 1716 at Badger Creek. This corresponds to a ground-surface at elevation 1735 with 6 feet of cover over the 150-inch-diameter pipeline.

The tunnel should be designed for pressures up to a maximum of 127 feet (55 psi), which corresponds to a conservative maximum 2019 ft hydraulic gradeline at the siphon-to-tunnel connection structure and a tunnel invert at elevation 1893 at the tunnel-to-penstock connection structure. The hydraulic analysis resulted in a 150-inch siphon, tunnel, and penstock with approximately 225 feet of hydraulic head at the end of the Wymer pipeline.

4.8.2 Wippel Diversion

The new, larger North Branch Canal would discharge into a siphon pipeline through the Wippel diversion at approximately weir elevation 2,014. Figure 15 shows a plan and sections for the Wippel diversion structure.

A check structure in the canal with removable stop logs for flow adjustment would divert flow into a 130-foot-long siphon intake structure located next to the North Branch Canal. The intake would be just upstream of the existing flow split to the KRD Pump, Gravity, and Turbine ditches. The Wippel diversion weir elevation would need to be coordinated with the hydraulics of the existing flow splits to the three ditches.

The diversion structure would be protected by a bar rack to prevent entry into the structure. To prevent excess water from entering the structure, a bypass weir would allow overflows into the existing wasteway to Badger Creek. It is likely that this wasteway would need to be enlarged for the increased canal flows.

4.8.3 Cross-Valley Siphon

At the south end of the Kittitas Valley, a 15,850-foot-long, 150-inch-diameter steel siphon pipeline would convey 1,000 cfs from the North Branch Canal Wippel diversion to the Wymer Tunnel. The combined siphon and tunnel alignment was selected as the shortest route between the south end of the North Branch Canal and the northernmost arm of the proposed Wymer reservoir. The siphon pipeline would cross under valley farmlands and Badger Creek. The low point would be at approximately ground-surface elevation 1735 at Badger Creek. Figure 16 shows the siphon profile.

The downstream end of the siphon would connect to the Wymer Tunnel at approximately ground-surface elevation 2020 between the Pump Ditch and the Gravity Ditch in the southwestern corner of the Kittitas Valley. The tunnel connection location and elevation was selected for a combination of hydraulic, terrain, and geologic criteria, including the possible use of the Gravity Ditch for overflows.

If necessary, most of the siphon pipeline could be drained from the low point into Badger Creek at the end of each season or for internal inspection.

4.8.4 Cross-Valley Siphon to Wymer Tunnel Portal

The siphon pipeline would discharge into the tunnel at a connecting portal structure at approximately siphon invert elevation 1990. The invert of the tunnel is approximately elevation 1,970. In addition to serving as the permanent connecting structure, the portal would likely be a retrieval portal for a tunnel boring machine used to construct the tunnel to Wymer. The connection structure would be enclosed to prevent unauthorized entry into the structure and would be vented to allow air into and out of the structure to vent the siphon and tunnel. Figure 17 shows a plan and section of the Wymer Tunnel Portal.

4.8.5 Wymer Tunnel

An approximately 12.5-foot-diameter, 16,750-foot-long tunnel would extend from the end of the siphon-to-tunnel connection portal to the tunnel-to-pipeline portal. Figure 18 shows the tunnel profile.

It is anticipated that most of the tunnel would be bored or excavated through the rock of the Manastash Ridge. Specific site geologic boring information is not available, but for this conceptual analysis, the siphon and tunnel alignment were selected as the shortest routes between the North Branch Canal Diversion and the northernmost arm of the proposed Wymer reservoir.

The tunnel would be likely be excavated using a tunnel boring machine (TBM), but could also be excavated using drill and blast methods. In either case, the finished inside dimensions would be approximately 12.5 feet in diameter for a circular tunnel or about 12 feet wide for horseshoe-shaped tunnel. Construction and lining methods would have to be determined after a more detailed geologic and structural analysis.

The tunnel profile is shown in Figure 18 with a 0.0046 ft/ft slope from the siphon to Wymer pipeline connection structure. The actual depth and slope of the tunnel would depend on the geology along the alignment and the direction chosen for mining or TBM excavation. To allow for gravity-flow drainage during tunneling it is advantageous to excavate in a positive grade direction and make the portals as shallow as possible while still tunneling in competent rock. This current alignment assumes that mining would start at the Wymer reservoir portal. It is possible the tunnel spoils could be used for part of the Wymer dam construction.

All of these characteristics and design criteria would have to be determined and refined after more information is obtained from a geotechnical boring program along the alignment. For this analysis, it was assumed that the tunnel would be partially unlined rock (50 percent) and partially lined with shotcrete, formed in place or precast concrete segments. It would also be expected that rock bolting may be required in some tunnel sections.

4.8.6 Wymer Tunnel-to-Pipeline Connection

The tunnel would connect to a pipeline to the Wymer reservoir at a tunnel-to-pipeline connection structure at approximately elevation 1,893. The connection structure would be enclosed to prevent unauthorized entry into the pipeline.

4.8.7 Wymer Pipeline

The final section of pipeline to the Wymer reservoir would be 3,850 feet long and 12 feet in diameter. Figure 18 shows the pipeline profile. The steel pipeline parallels and discharges into Scorpion Coulee Creek, then daylights at ground-surface elevation 1,740, which is the proposed high-water level of Wymer reservoir. Scorpion Coulee Creek would serve as the outlet channel into the reservoir. The tunnel and penstock could be dewatered for maintenance and inspection by draining them into the Wymer reservoir. The design of the penstock and outlet channel and their terminal locations would need to be coordinated with the water levels in the reservoir.

4.8.8 Wymer Pipeline Discharge Structure

Figure 19 shows a preliminary plan for the Wymer pipeline discharge structure. With the large variation in the water-surface elevation of the Wymer reservoir, hydropower energy recovery of the intermittent flow at the pipeline outlet into the reservoir may not be economically feasible. If energy recovery is not feasible, the pipeline outlet could discharge into a concrete baffled outlet, then through a baffled apron drop structure to a rock riprap-lined stilling basin located some distance down the reservoir bank. As the reservoir fills these structures would be slowly inundated by the rising water. This cycle would repeat itself each time the reservoir is drawn down and refilled.

If hydropower energy recovery is not going to be installed at the pipeline outlet, the tunnel grade could be modified to shorten the tunnel and pipeline to discharge the water further up the Scorpion Creek drainage. These options should be further reviewed during the next phase of design.

4.8.9 Optional Energy Recovery

Electrical power could potentially be generated in the future by using the increased flows in the KRD North Branch Canal. The pipeline discharge location at Wymer was selected to accommodate the possible addition of an optional hydropower turbine to utilize approximately 225 feet of available hydraulic head.

4.8.10 Sediment Handling

All of these conveyance facilities are downstream of the Thorp pump station and canal diversions. Therefore, all of these facilities can be drained as needed during the off-season for routine maintenance and sediment removal.

4.8.11 Construction Access and Power

The primary construction access for the cross-valley siphon and tunnel to Wymer reservoir would be via local roads to and from I-82 and Highway 821. The work on the tunnel and penstock would be coordinated with construction of the Wymer reservoir.

For construction power, low-voltage power from local service lines is available in some locations, but the remote nature of the tunnel would require generators in most locations.

4.8.12 Metering and Controls

The siphon, tunnel and penstock should have flow meters and automated data acquisition systems. In addition to local manual operation, the system would be designed to be remotely monitored and controlled.

4.8.13 Security

It is expected that transition structures would be fenced for perimeter security and bar screened as necessary to prevent entry.

5.0 Property Easements and Purchases

The Kittitas County Assessor’s website was used to compile property ownership information and data needed to estimate the cost of easements for all structures, pipelines, tunnels, and the expanded canal. Data was compiled by using GIS tools on the website and redrawing the proposed facilities on a parcel map. Data was then collected for each parcel along the route and combined with parcel data from other surrounding parcels not on the route to determine realistic property values.

For this conceptual study, the property analysis is based on the following assumptions:

- Most of additional canal property would be on uphill non-arable land.
- Parcels where the pipelines cross open space would need a 50-foot permanent easement and a 100-foot temporary construction easement.
- A 50-foot temporary easement would be needed for canal construction.
- Ten acres would be needed for the Thorp pump station and diversion dam; two acres each for the Thorp pump station discharge and Wippel diversion structures; and about four acres for the siphon-to-tunnel connection structure.

Cost estimates for the Wymer Conveyance Project will be outlined in a separate memorandum.

6.0 Considerations for Final Design

6.1 Special Considerations

Special considerations for implementing this project are as follows:

- Determining the feasibility of all of the project concepts.
- Permitting and constructing a new diversion dam on the Yakima River at Thorp.
- Minimizing impacts to the Yakima River.
- Providing adequate power to the Thorp pump station.
- Enlargement of the KRD North Branch Canal without major changes to the hydraulics of the existing systems.
- Reconstruction of existing bridges, canal structures, and diversions along the canal.
- Construction of a long siphon and tunnel between the Wippel diversion and the Wymer reservoir.
- Powering the Wymer tunneling operation.

6.2 General Considerations

General considerations for implementing this project are as follows:

- Confirm the overall system operational criteria and project hydraulics for existing and future flows with additional surveying as required.
- Conduct a more detailed review of the impacts of enlarging of the KRD North Branch Canal on the lateral canal systems and structures.
- Obtain more detailed geotechnical information for the entire length of the project, including a geotechnical exploration program for critical areas, structures, and tunnels.
- Further evaluate the existing canal profile, cross slopes, and structures to determine if excavating the canal to the larger cross-section is practical and constructible – especially in areas with steep side slopes.

- Explore permitting and engineering requirements for constructing a new diversion dam on the Yakima River.
- Perform a more detailed analysis of potential hydropower energy recovery facilities at the Wymer outlet.
- Further evaluate the feasibility and costs for getting high-voltage electrical power to the Thorp pump station.
- Further investigate and refine design for fish screens and bypass system at the Yakima River diversion and intake.

6.3 Cost Estimates

Cost estimates for the Wymer project will be outlined in a separate memorandum.

7.0 References

1. Schuster, J.E. (1994). "Geologic Map of the East Half of the Yakima 1:100,000 Quadrangle, Washington", Washington Division of Geology and Earth Resources, Open File Report 94-12, June.
2. Jones, M.A., Vaccaro, J.J., and Watkins, A.M. (2006). "Hydrogeologic Framework of Sedimentary Deposits in Six Structural Basins, Yakima River Basin, Washington", Prepared in Corporation with the Bureau of Reclamation, Washington State Department of Ecology, and Yakama Nation, U.S. Geological Survey Scientific Investigations Report 2006-5116, 24 p.
3. Washington Division of Geology and Earth Resources (2005), Digital 1:100,000-scale geology of Washington State, version 1.0: Washington Division of Geology and Earth Resources, Open File Report 2005-3, scale 1:100000.
4. Golder Associates, Inc., "Appraisal Assessment of the Yakima River Pump Exchange Alternative Delivery System for Roza and Sunnyside Valley Irrigation Districts", Technical Series No. TS-YSS-11, U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, October 2006.
5. "Yakima River Basin Storage Alternatives Appraisal Assessment", Technical Series No. TS-YSS-8, U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, May 2006.
6. North Branch Canal Siphon and Tunnel Drawings, Yakima Project – Washington, Kittitas Division, U.S. Department of the Interior, Bureau of Reclamation, Denver Colorado, May 1929 through January 1930.

8.0 List of Preparers

NAME	BACKGROUND	RESPONSIBILITY
HDR ENGINEERING, INC.		
Jim Peterson	Professional Engineer	Task Manager
Keith Goss	Professional Engineer	Task Engineer
Sri Rajah	Professional Engineer	Task Engineer
Stan Schweissing	Professional Engineer	QC Reviewer

Appendix A

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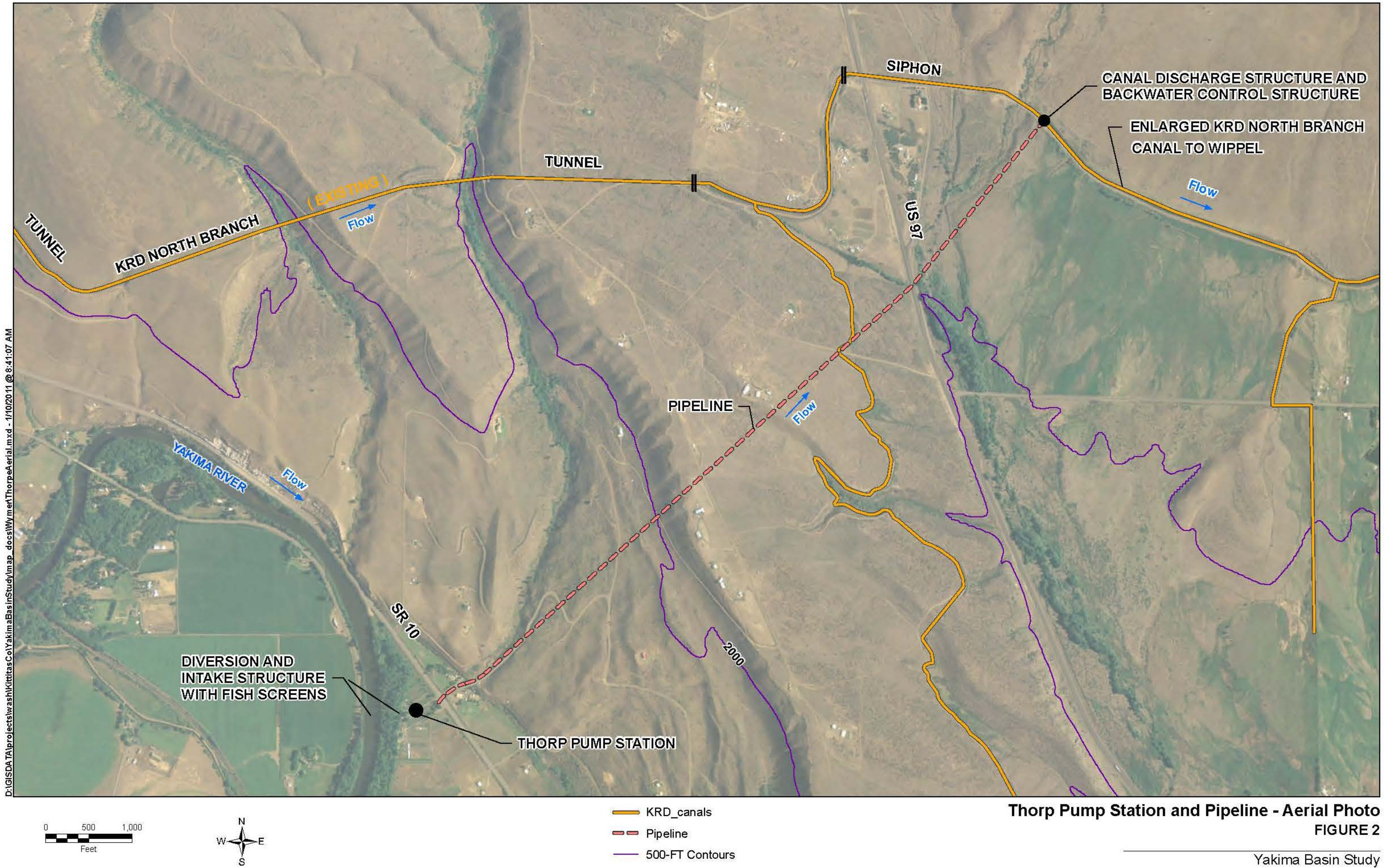
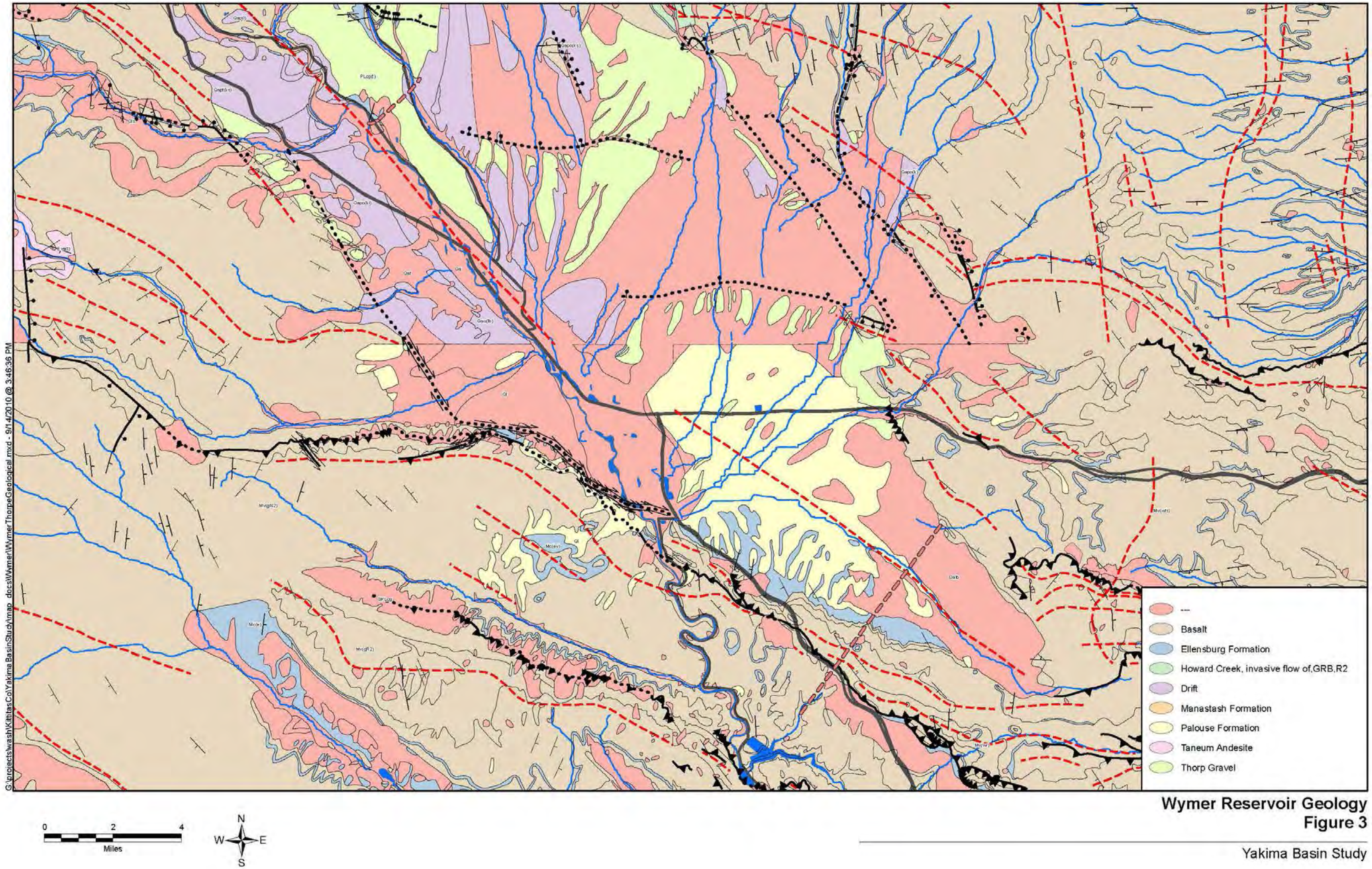
Wymer System Vicinity
FIGURE 1

Yakima Basin Study



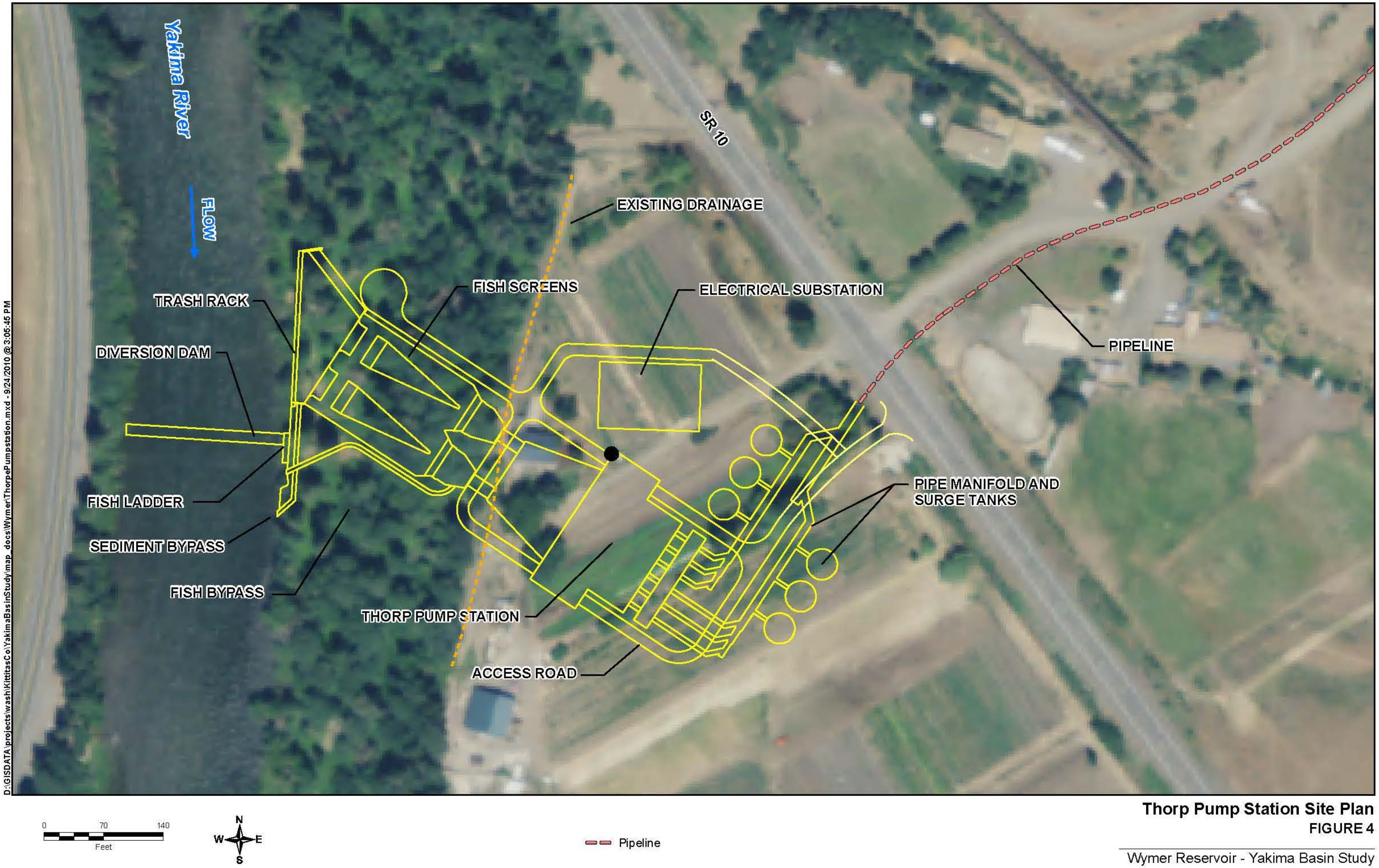
Thorp Pump Station and Pipeline - Aerial Photo
FIGURE 2

Yakima Basin Study



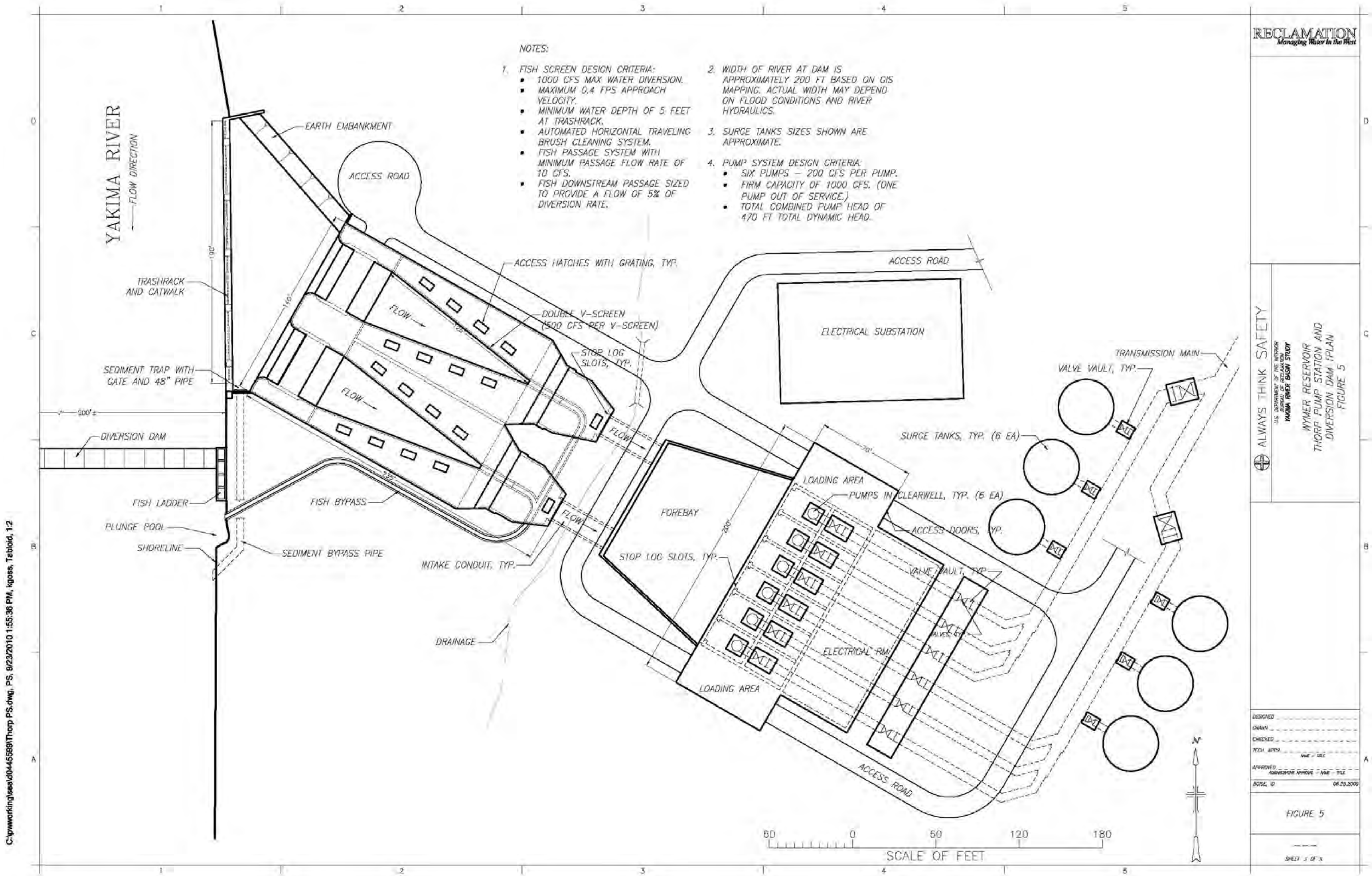
Wymer Reservoir Geology
Figure 3

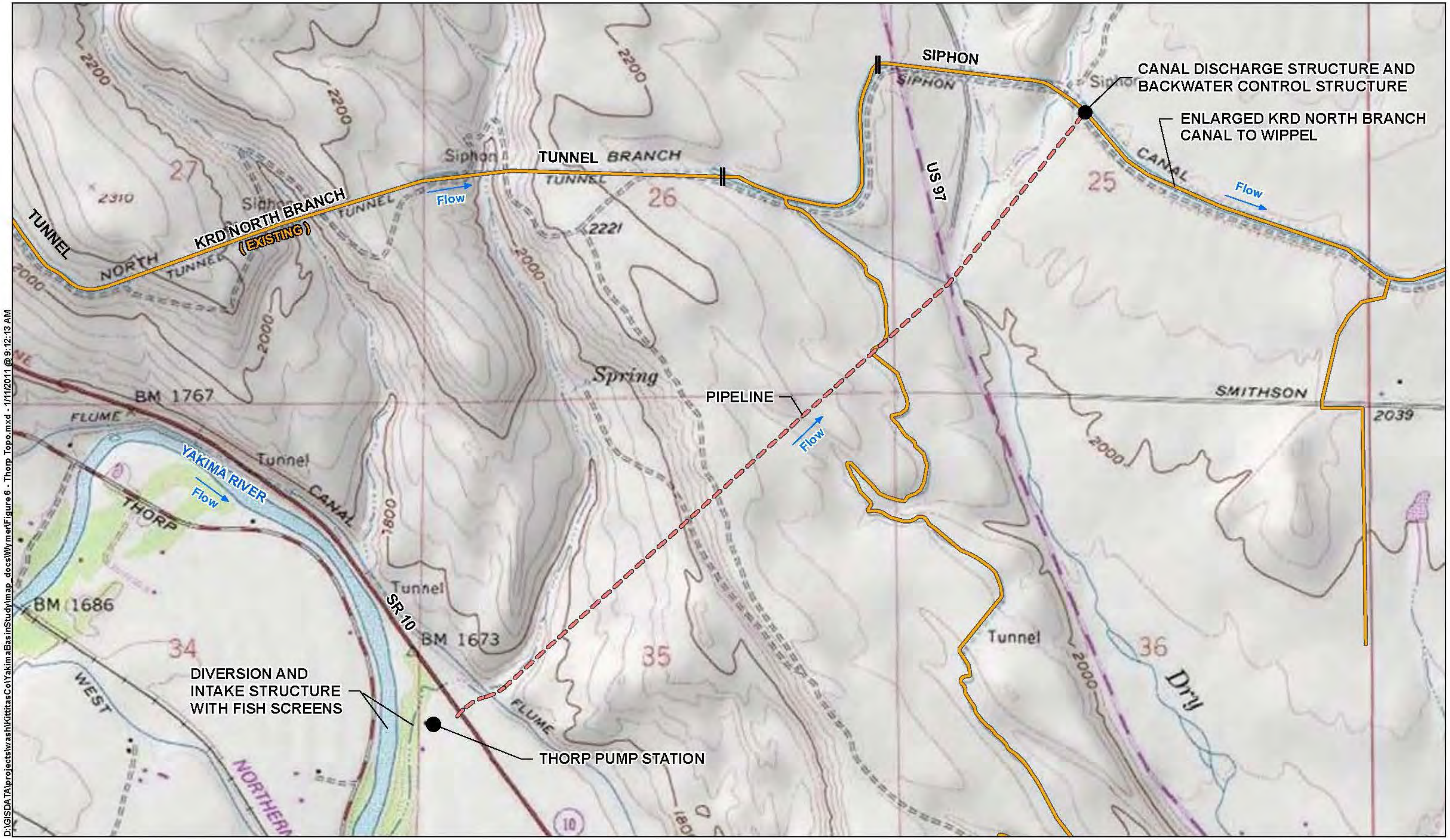
Yakima Basin Study



Thorp Pump Station Site Plan
FIGURE 4

Wymer Reservoir - Yakima Basin Study


NOTES:
1. FISH SCREEN DESIGN CRITERIA:
• 1000 CFS MAX WATER DIVERSION.
• MAXIMUM 0.4 FPS APPROACH VELOCITY.
• MINIMUM WATER DEPTH OF 5 FEET AT TRASHRACK.
• AUTOMATED HORIZONTAL TRAVELING BRUSH CLEANING SYSTEM.
• FISH PASSAGE SYSTEM WITH MINIMUM PASSAGE FLOW RATE OF 10 CFS.
• FISH DOWNSTREAM PASSAGE SIZED TO PROVIDE A FLOW OF 5% OF DIVERSION RATE.
2. WIDTH OF RIVER AT DAM IS APPROXIMATELY 200 FT BASED ON GIS MAPPING. ACTUAL WIDTH MAY DEPEND ON FLOOD CONDITIONS AND RIVER HYDRAULICS.
3. SURGE TANKS SIZES SHOWN ARE APPROXIMATE.
4. PUMP SYSTEM DESIGN CRITERIA:
• SIX PUMPS – 200 CFS PER PUMP.
• FIRM CAPACITY OF 1000 CFS. (ONE PUMP OUT OF SERVICE.)
• TOTAL COMBINED PUMP HEAD OF 470 FT TOTAL DYNAMIC HEAD.
YAKIMA RIVER
FLOW DIRECTION
EARTH EMBANKMENT
ACCESS ROAD
TRASHRACK AND CATWALK
SEDIMENT TRAP WITH GATE AND 48" PIPE
200'±
DIVERSION DAM
FISH LADDER
PLUNGE POOL
SHORELINE
SEDIMENT BYPASS PIPE
FISH BYPASS
INTAKE CONDUIT, TYP.
DRAINAGE
ACCESS HATCHES WITH GRATING, TYP.
DOUBLE V-SCREEN (500 CFS PER V-SCREEN)
STOP LOG SLOTS, TYP.
FLOW
ACCESS ROAD
ELECTRICAL SUBSTATION
FOREBAY
STOP LOG SLOTS, TYP.
LOADING AREA
PUMPS IN CLEARWELL, TYP. (6 EA)
ACCESS DOORS, TYP.
VALVE VAULT, TYP.
ELECTRICAL RM.
LOADING AREA
ACCESS ROAD
SURGE TANKS, TYP. (6 EA)
VALVE VAULT, TYP.
TRANSMISSION MAIN
SCALE OF FEET
60 0 60 120 180
N
RECLAMATION
Managing Water in the West
ALWAYS THINK SAFETY
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN STUDY
WYMER RESERVOIR
THORP PUMP STATION AND
DIVERSION DAM PLAN
FIGURE 5
DESIGNED
DRAWN
CHECKED
TECH. APPR.
APPROVED
BOISE, ID
FIGURE 5
C:\pwworking\sed\d0445599\Thorp PS.dwg, PS, 9/23/2010 1:55:36 PM, kgoss, Tabloid, 1:2



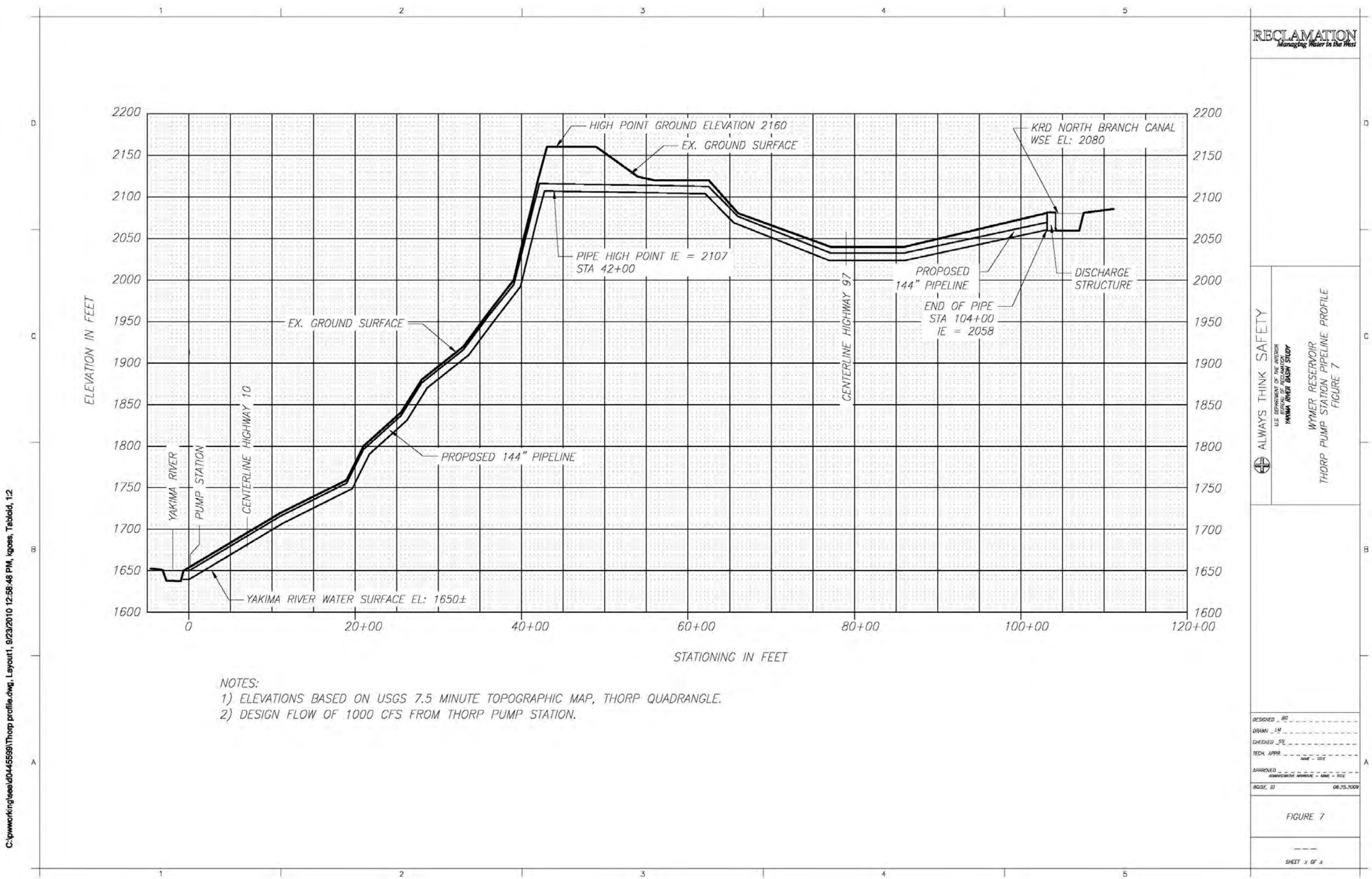
0 510 1,020 Feet

USGS TOPO MAP
40' CONTOUR INTERVAL

KRD_canals
Pipeline

Thorp Pump Station and Pipeline - Topography
FIGURE 6

Yakima Basin Study


HIGH POINT GROUND ELEVATION 2160
EX. GROUND SURFACE
KRD NORTH BRANCH CANAL
WSE EL: 2080
PIPE HIGH POINT IE = 2107
STA 42+00
PROPOSED
144" PIPELINE
DISCHARGE
STRUCTURE
END OF PIPE
STA 104+00
IE = 2058
CENTERLINE HIGHWAY 97
EX. GROUND SURFACE
CENTERLINE HIGHWAY 10
PROPOSED 144" PIPELINE
YAKIMA RIVER
PUMP STATION
YAKIMA RIVER WATER SURFACE EL: 1650±
ELEVATION IN FEET
STATIONING IN FEET
2200
2150
2100
2050
2000
1950
1900
1850
1800
1750
1700
1650
1600
0
20+00
40+00
60+00
80+00
100+00
120+00
NOTES:
1) ELEVATIONS BASED ON USGS 7.5 MINUTE TOPOGRAPHIC MAP, THORP QUADRANGLE.
2) DESIGN FLOW OF 1000 CFS FROM THORP PUMP STATION.
RECLAMATION
Managing Water in the West
ALWAYS THINK SAFETY
WYMER RESERVOIR
THORP PUMP STATION PIPELINE PROFILE
FIGURE 7
FIGURE 7
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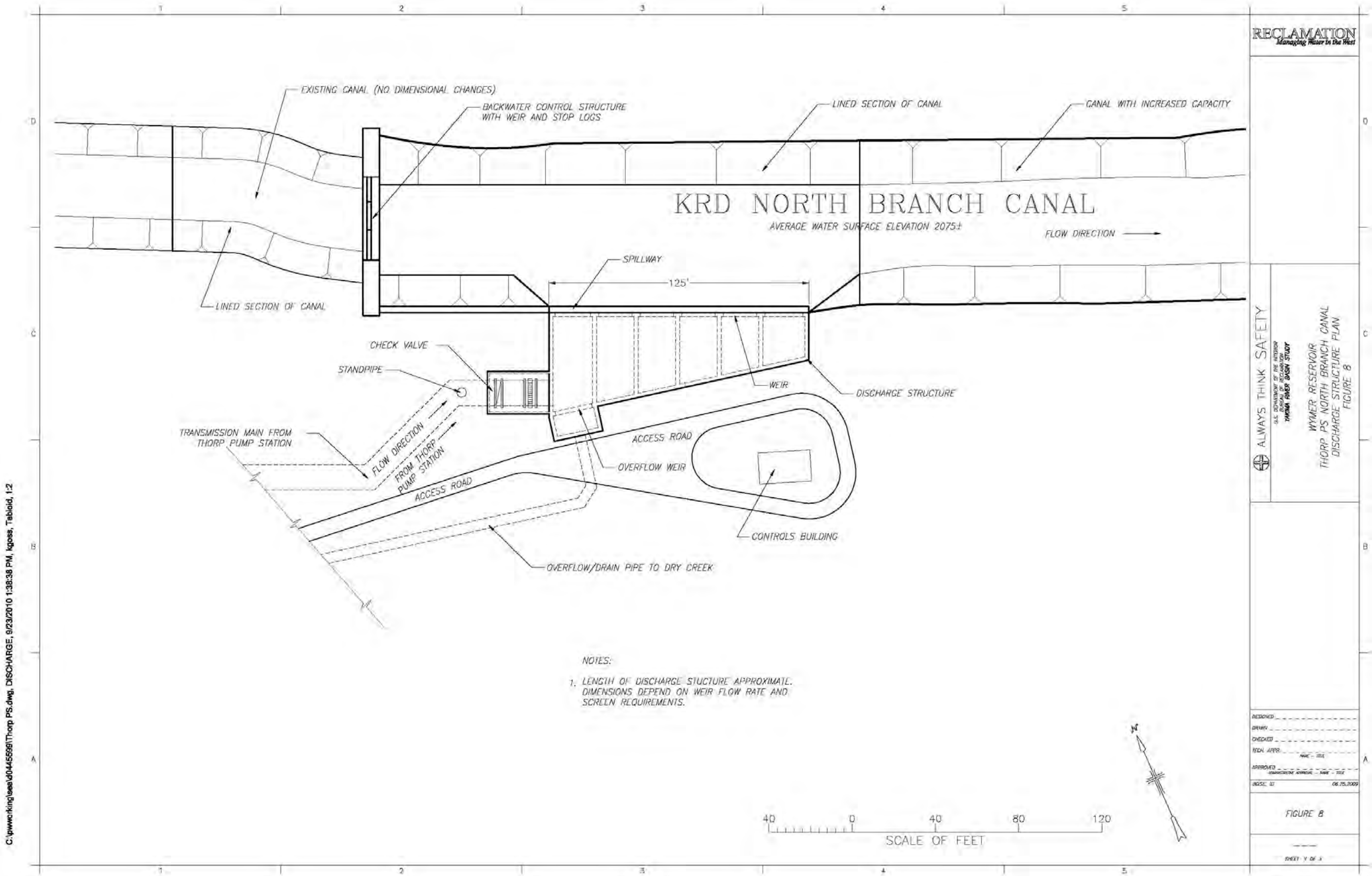
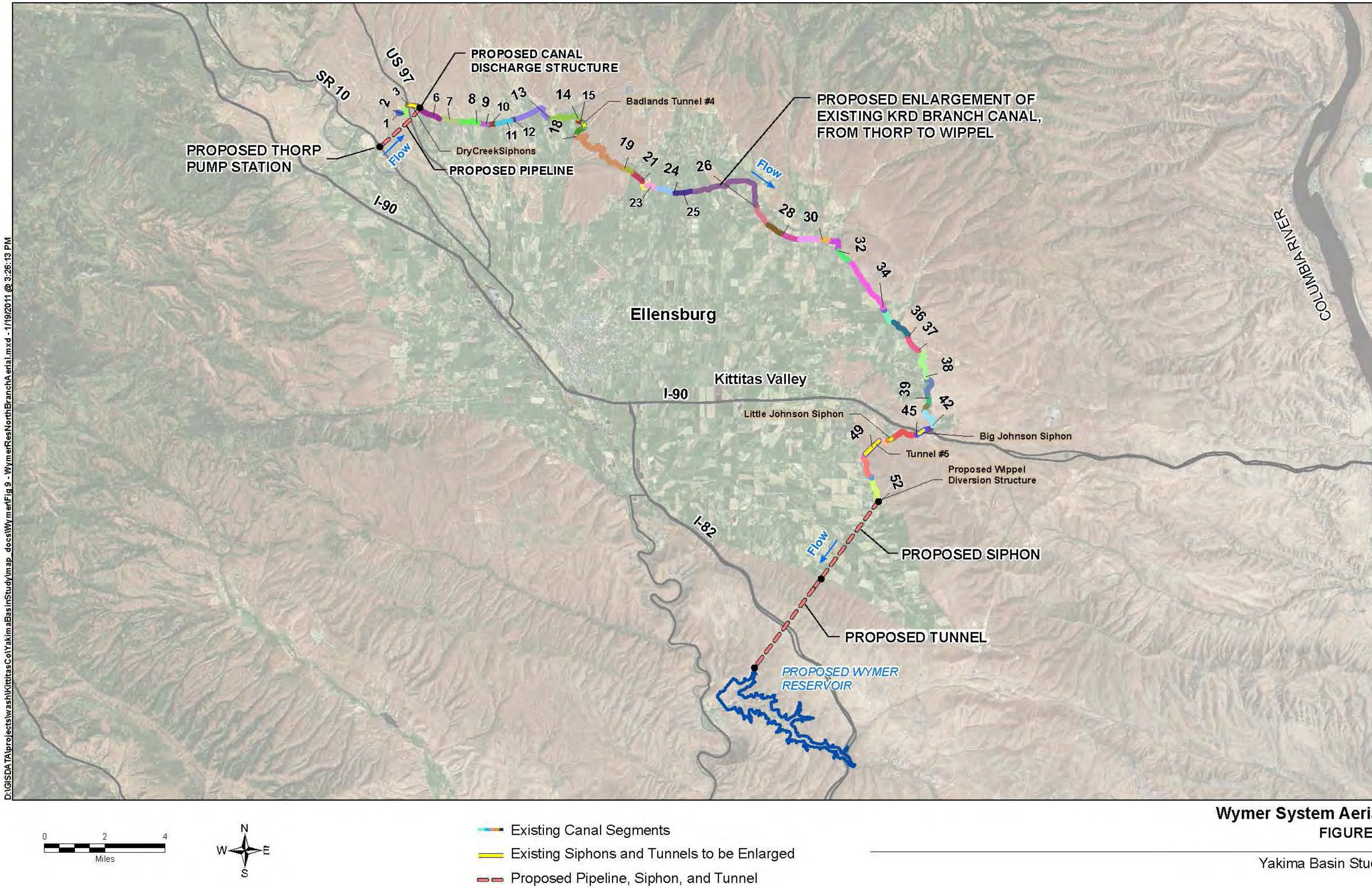


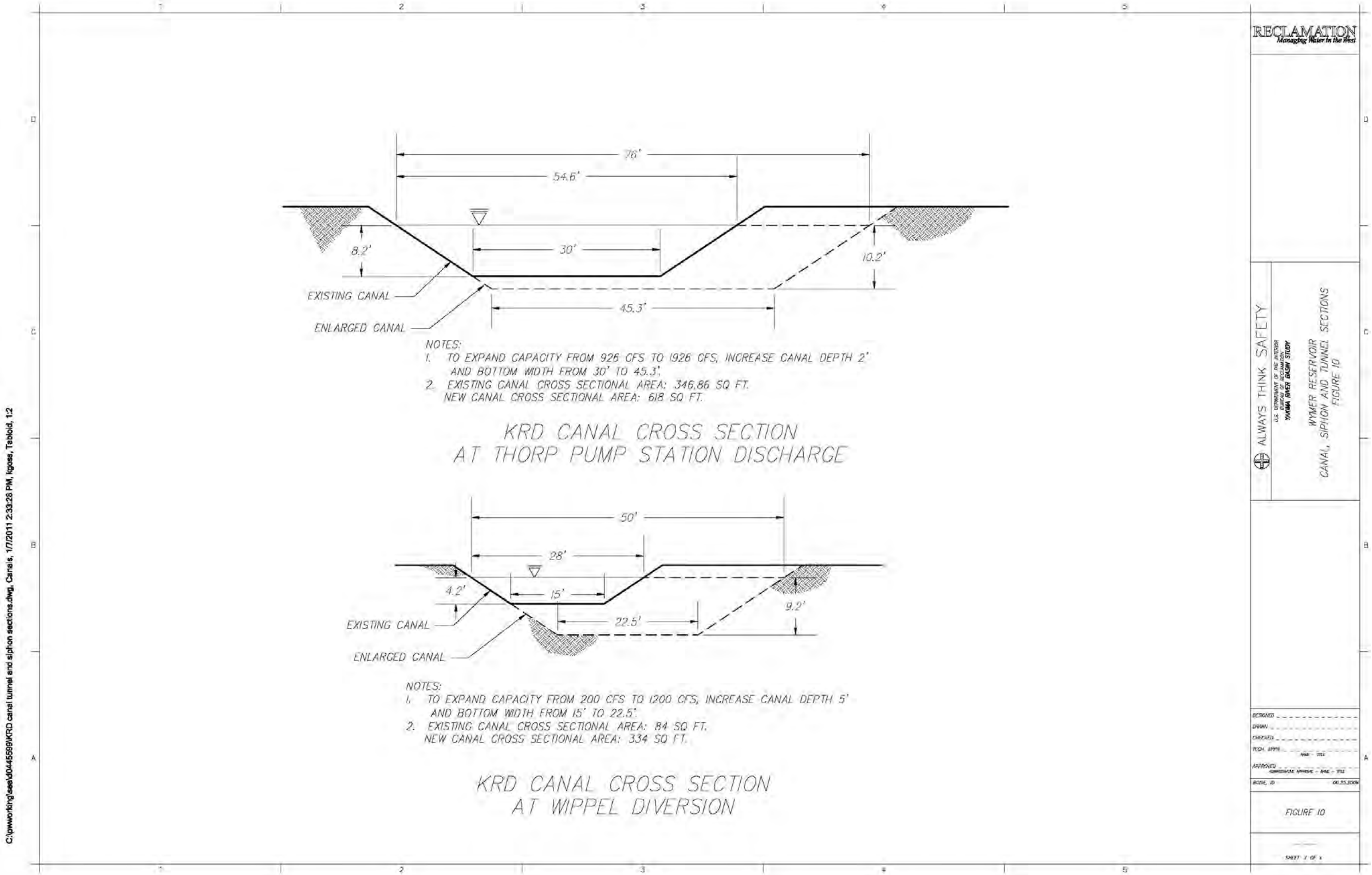
RECLAMATION
Managing Water in the West
EXISTING CANAL (NO DIMENSIONAL CHANGES)
BACKWATER CONTROL STRUCTURE
WITH WEIR AND STOP LOGS
LINED SECTION OF CANAL
CANAL WITH INCREASED CAPACITY
KRD NORTH BRANCH CANAL
AVERAGE WATER SURFACE ELEVATION 2075±
FLOW DIRECTION
SPILLWAY
125'
LINED SECTION OF CANAL
CHECK VALVE
STANDPIPE
WEIR
DISCHARGE STRUCTURE
TRANSMISSION MAIN FROM
THORP PUMP STATION
FLOW DIRECTION
FROM THORP
PUMP STATION
ACCESS ROAD
ACCESS ROAD
OVERFLOW WEIR
CONTROLS BUILDING
OVERFLOW/DRAIN PIPE TO DRY CREEK
NOTES:
1. LENGTH OF DISCHARGE STUCTURE APPROXIMATE.
DIMENSIONS DEPEND ON WEIR FLOW RATE AND
SCREEN REQUIREMENTS.
40 0 40 80 120
SCALE OF FEET
N
ALWAYS THINK SAFETY
WYMER RESERVOIR
THORP PS NORTH BRANCH CANAL
DISCHARGE STRUCTURE PLAN
FIGURE 8
FIGURE 8
C:\pwworking\sea\d0445699\Thorp PS.dwg, DISCHARGE, 9/23/2010 1:38:38 PM, kgoss, Tabloid, 1:2

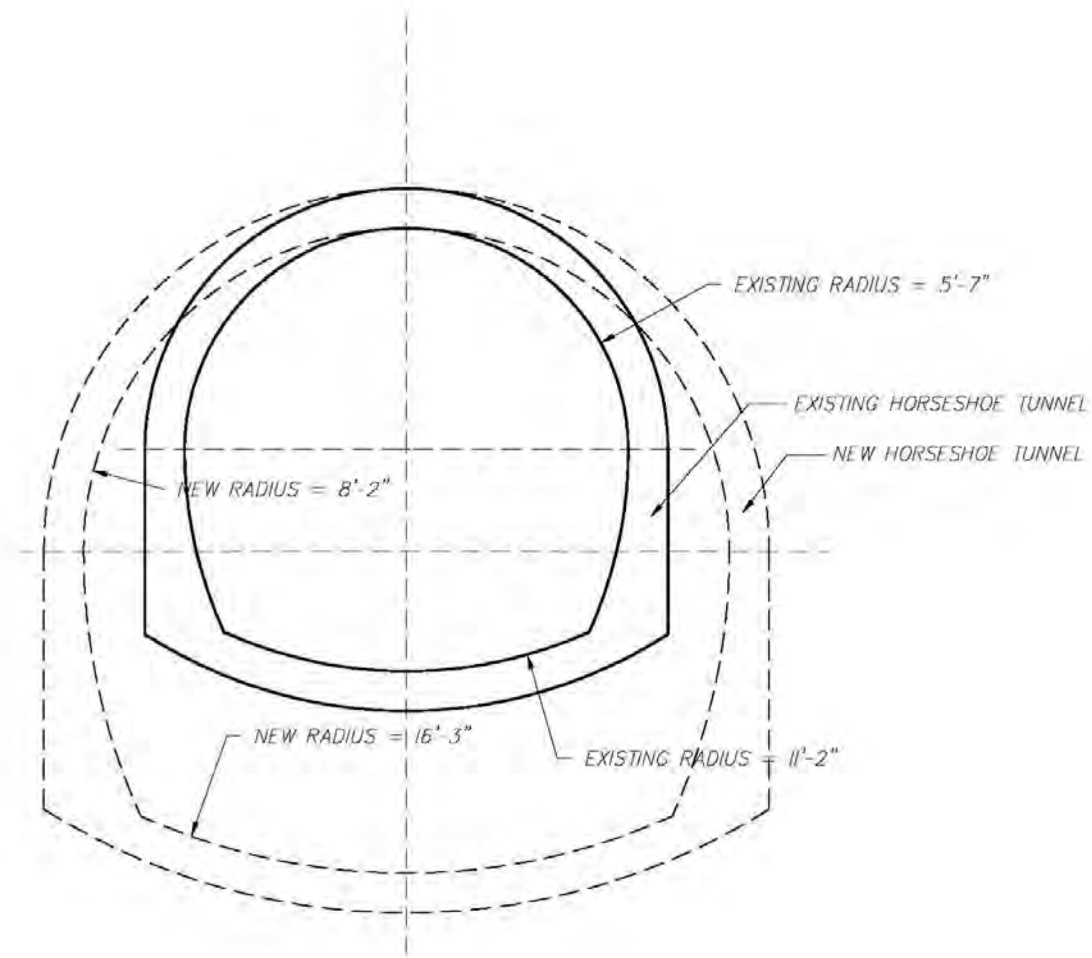


Wymer System Aerial
FIGURE 9

Yakima Basin Study

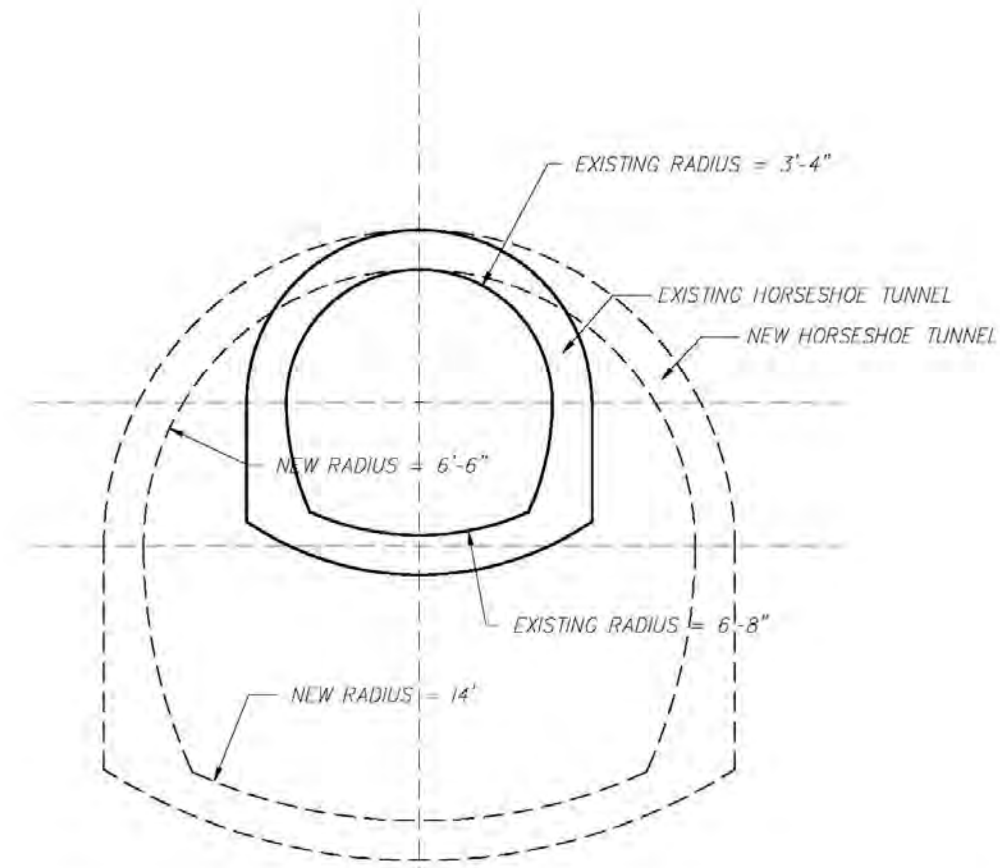
)


RECLAMATION
Managing Water in the West
76'
54.6'
8.2'
30'
10.2'
45.3'
EXISTING CANAL
ENLARGED CANAL
NOTES:
1. TO EXPAND CAPACITY FROM 926 CFS TO 1926 CFS, INCREASE CANAL DEPTH 2' AND BOTTOM WIDTH FROM 30' TO 45.3'.
2. EXISTING CANAL CROSS SECTIONAL AREA: 346.86 SQ FT.
NEW CANAL CROSS SECTIONAL AREA: 618 SQ FT.
KRD CANAL CROSS SECTION
AT THORP PUMP STATION DISCHARGE
50'
28'
4.2'
15'
9.2'
22.5'
EXISTING CANAL
ENLARGED CANAL
NOTES:
1. TO EXPAND CAPACITY FROM 200 CFS TO 1200 CFS, INCREASE CANAL DEPTH 5' AND BOTTOM WIDTH FROM 15' TO 22.5'.
2. EXISTING CANAL CROSS SECTIONAL AREA: 84 SQ FT.
NEW CANAL CROSS SECTIONAL AREA: 334 SQ FT.
KRD CANAL CROSS SECTION
AT WIPPEL DIVERSION
ALWAYS THINK SAFETY
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN STUDY
WYMER RESERVOIR
CANAL, SIPHON AND TUNNEL SECTIONS
FIGURE 10
DESIGNED
DRAWN
CHECKED
TECH. APPR.
APPROVED
BOISE, ID
FIGURE 10
C:\pwworking\sea\d0445599\KRD canal tunnel and siphon sections.dwg, Canals, 1/7/2011 2:33:28 PM, kgoss, Tabloid, 1:2



NOTES:
1. TO EXPAND CAPACITY FROM 775 CFS TO 1775 CFS, INCREASE RADIUS OF TUNNEL FROM 5'-7" TO 8'-2" AND MODIFY SLOPE FROM 0.000825 TO 0.000395 (EQUAL TO 0.20 FT OVER 594 FT LENGTH OF PIPE.)
2. EXISTING TUNNEL CROSS SECTIONAL AREA: 103.48 SQ FT.
NEW TUNNEL CROSS SECTIONAL AREA: 207.66 SQ FT.

BADLANDS TUNNEL No. 4 CROSS SECTION



NOTES:
1. TO EXPAND CAPACITY FROM 280 CFS TO 1280 CFS, INCREASE RADIUS OF TUNNEL FROM 3'-4" TO 6'6" AND MODIFY SLOPE FROM 0.00244 TO 0.00047 (EQUAL TO 7.02 FT OVER 3562 FT LENGTH OF PIPE.)
2. EXISTING TUNNEL CROSS SECTIONAL AREA: 37.23 SQ FT.
NEW TUNNEL CROSS SECTIONAL AREA: 160.23 SQ FT.

TUNNEL No. 5 CROSS SECTION

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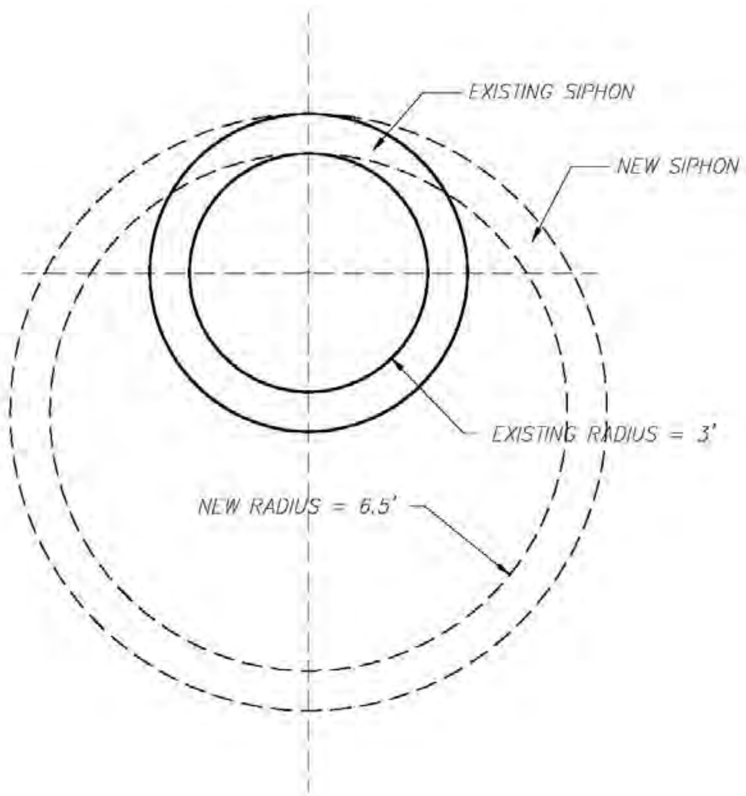
YAKIMA RIVER BASIN STUDY

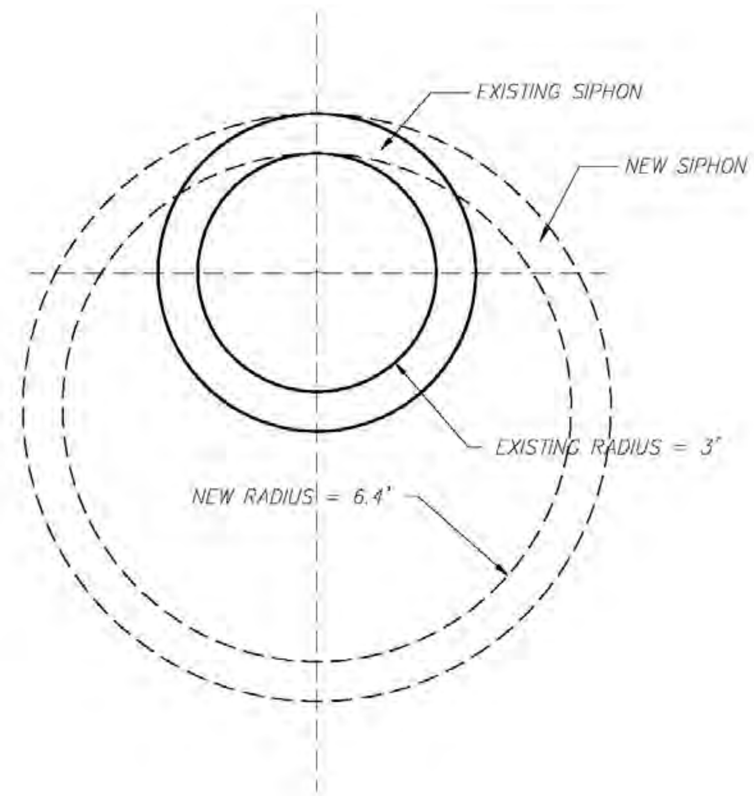
WYMER RESERVOIR
CANAL, SIPHON AND TUNNEL SECTIONS
FIGURE 11

FIGURE 11

C:\pwworking\sea\d0445589\KRD canal tunnel and siphon sections.dwg, Tunnels, 9/14/2010 8:10:39 AM, kgoss, Tabloid, 1:2

RECLAMATION
Managing Water in the West





NOTES:
1. TO EXPAND CAPACITY FROM 280 CFS TO 1280 CFS, INCREASE RADIUS OF PIPE FROM 3' TO 6.5' AND MODIFY SLOPE FROM 0.00371 TO 0.00058 (EQUAL TO 5.81 FT OVER 1858 FT LENGTH OF PIPE.)
2. EXISTING TUNNEL CROSS SECTIONAL AREA: 28.27 SQ FT.
NEW TUNNEL CROSS SECTIONAL AREA: 133.15 SQ FT.

BIG JOHNSON SIPHON CROSS SECTION

NOTES:
1. TO EXPAND CAPACITY FROM 280 CFS TO 1280 CFS, INCREASE RADIUS OF PIPE FROM 3' TO 6.4' AND MODIFY SLOPE FROM 0.00627 TO 0.00053 (EQUAL TO 1.63 FT OVER 284 FT LENGTH OF PIPE.)
2. EXISTING TUNNEL CROSS SECTIONAL AREA: 28.27 SQ FT.
NEW TUNNEL CROSS SECTIONAL AREA: 128.42 SQ FT.

LITTLE JOHNSON SIPHON CROSS SECTION

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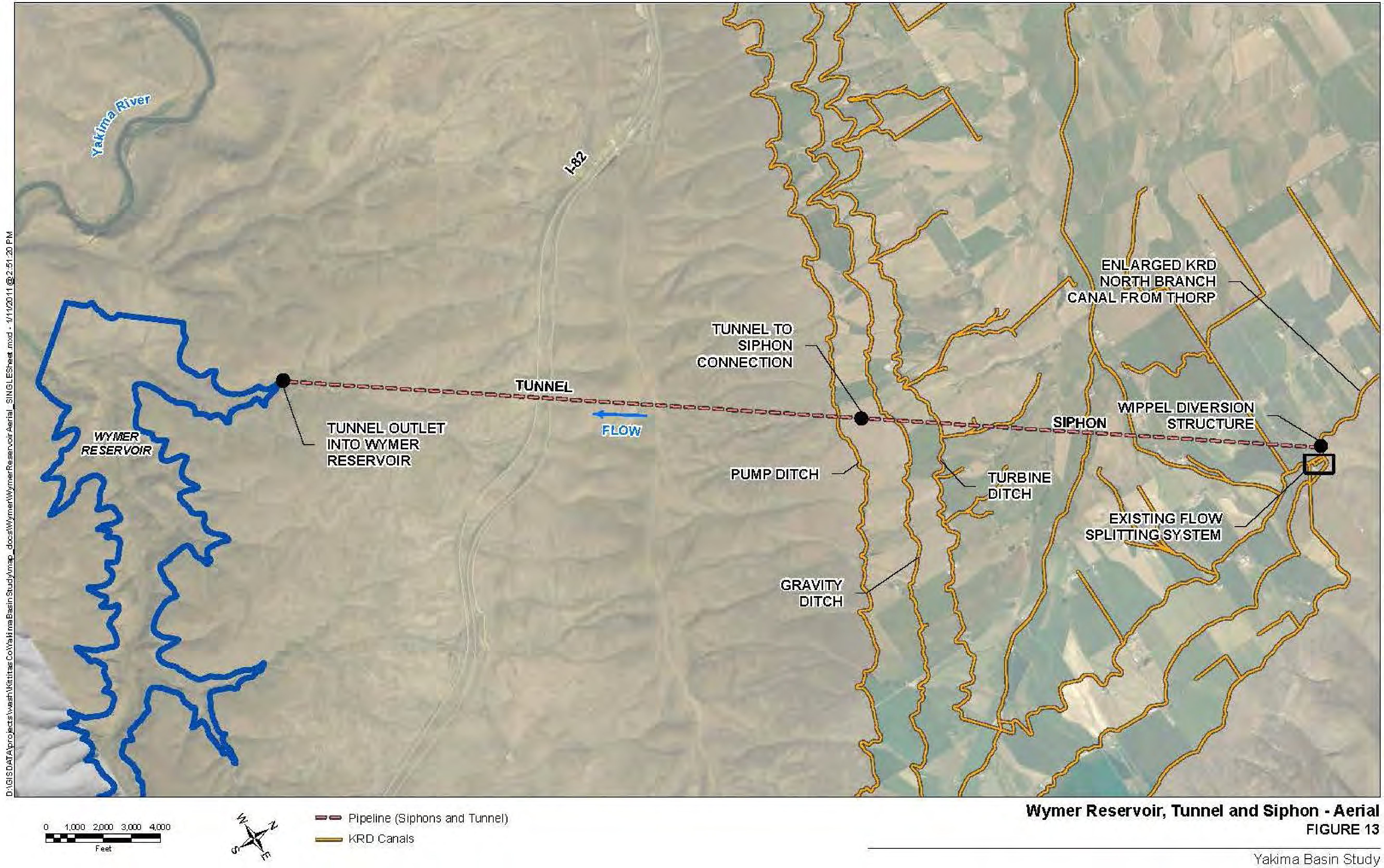
YAKIMA RIVER BASIN STUDY

WYMER RESERVOIR
CANAL, SIPHON AND TUNNEL SECTIONS
FIGURE 12

FIGURE 12

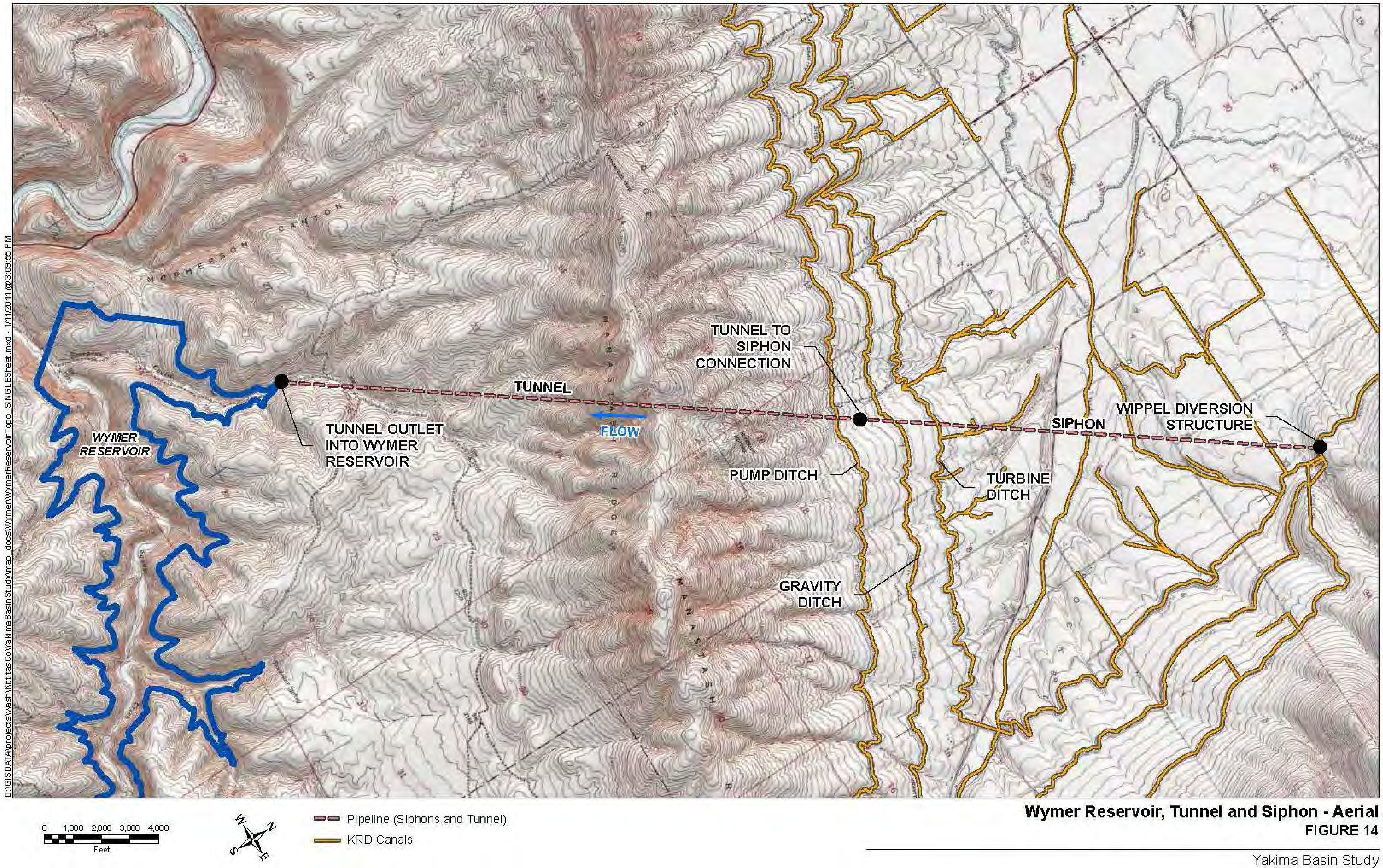
SHEET 1 OF 1

C:\pwworking\sea\d0445599\KRD canal tunnel and siphon sections.dwg, Siphons, 9/14/2010 8:11:47 AM, kgoss, Tabloid, 1:2



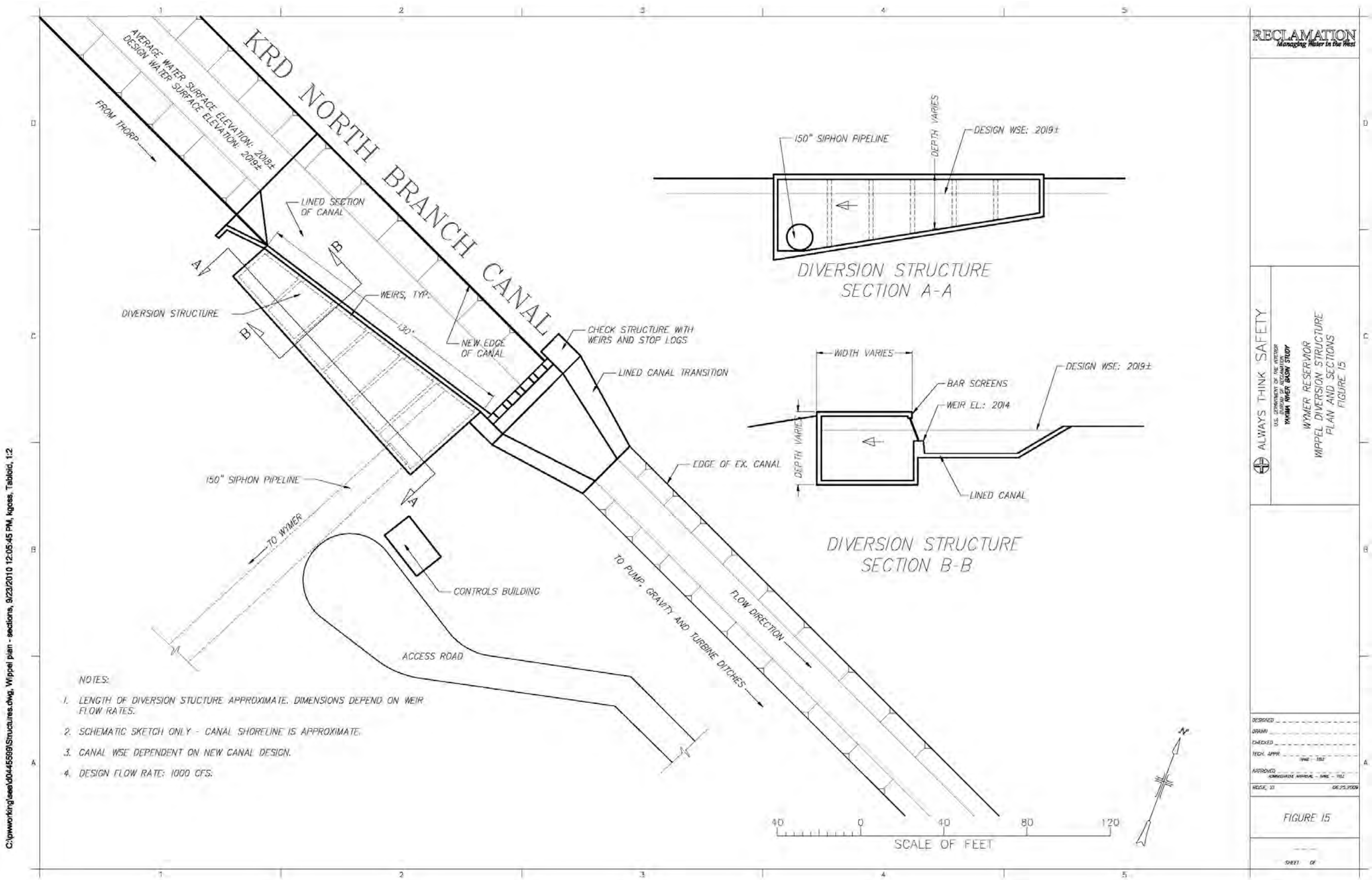
Wymer Reservoir, Tunnel and Siphon - Aerial
FIGURE 13

Yakima Basin Study



Wymer Reservoir, Tunnel and Siphon - Aerial
FIGURE 14

Yakima Basin Study


KRD NORTH BRANCH CANAL
AVERAGE WATER SURFACE ELEVATION: 2018±
DESIGN WATER SURFACE ELEVATION: 2019±
FROM THORP
LINED SECTION OF CANAL
DIVERSION STRUCTURE
WEIRS, TYP.
130'
NEW EDGE OF CANAL
CHECK STRUCTURE WITH WEIRS AND STOP LOGS
LINED CANAL TRANSITION
EDGE OF EX. CANAL
150" SIPHON PIPELINE
TO WYMER
CONTROLS BUILDING
ACCESS ROAD
TO PUMP, GRAVITY AND TURBINE DITCHES
FLOW DIRECTION
150" SIPHON PIPELINE
DEPTH VARIES
DESIGN WSE: 2019±
DIVERSION STRUCTURE
SECTION A-A
WIDTH VARIES
BAR SCREENS
WEIR EL.: 2014
DESIGN WSE: 2019±
DEPTH VARIES
LINED CANAL
DIVERSION STRUCTURE
SECTION B-B
NOTES:
1. LENGTH OF DIVERSION STUCTURE APPROXIMATE. DIMENSIONS DEPEND ON WEIR FLOW RATES.
2. SCHEMATIC SKETCH ONLY - CANAL SHORELINE IS APPROXIMATE.
3. CANAL WSE DEPENDENT ON NEW CANAL DESIGN.
4. DESIGN FLOW RATE: 1000 CFS.
40 0 40 80 120
SCALE OF FEET
N
RECLAMATION
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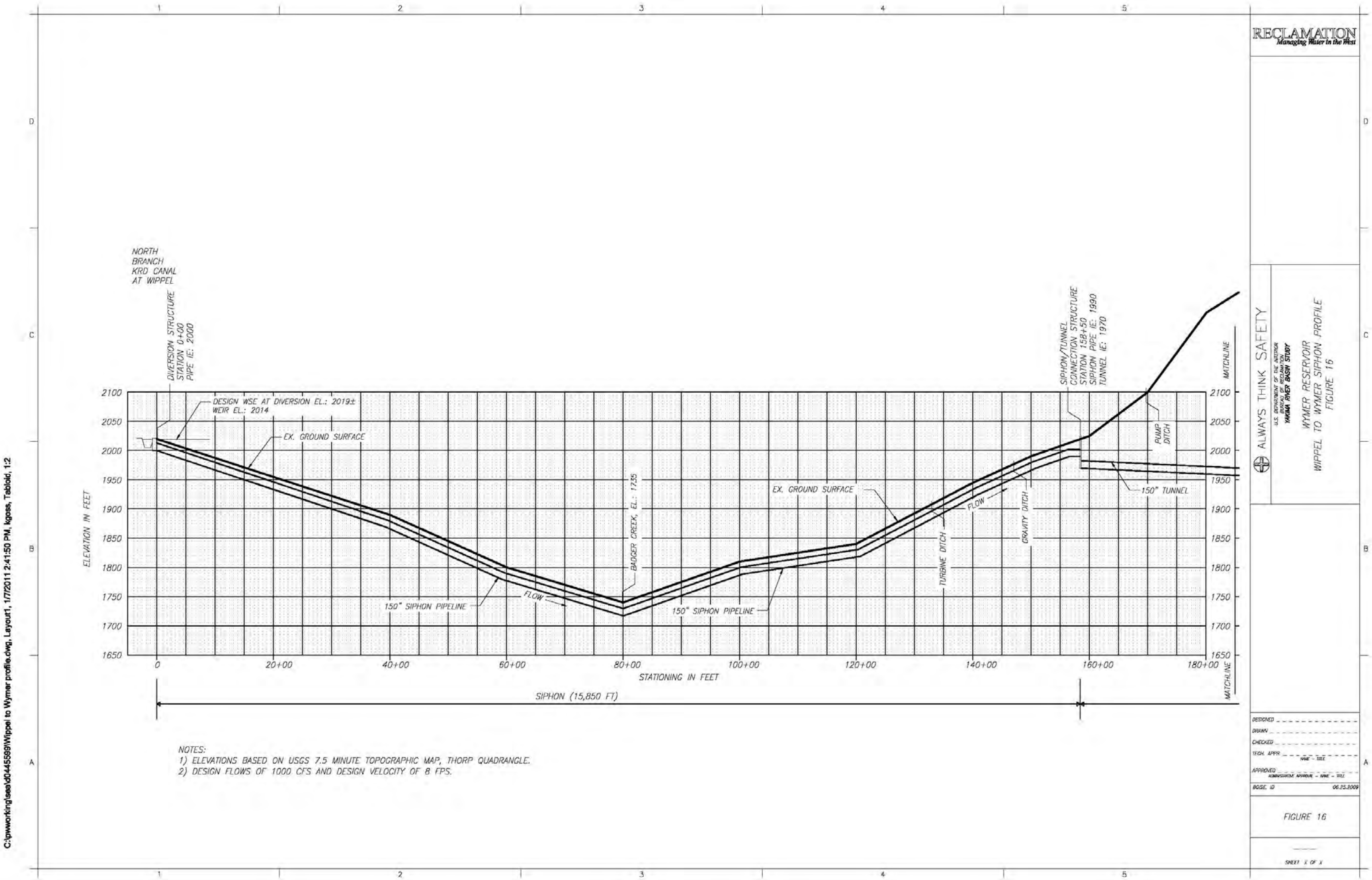
YAKIMA RIVER BASIN STUDY
WYMER RESERVIOR
WIPPEL DIVERSION STRUCTURE
PLAN AND SECTIONS
FIGURE 15
FIGURE 15
C:\pwworking\sea\d0445591\Structures.dwg, Wippel plan - sections, 9/23/2010 12:05:45 PM, kgoss, Tabloid, 1:2


RECLAMATION
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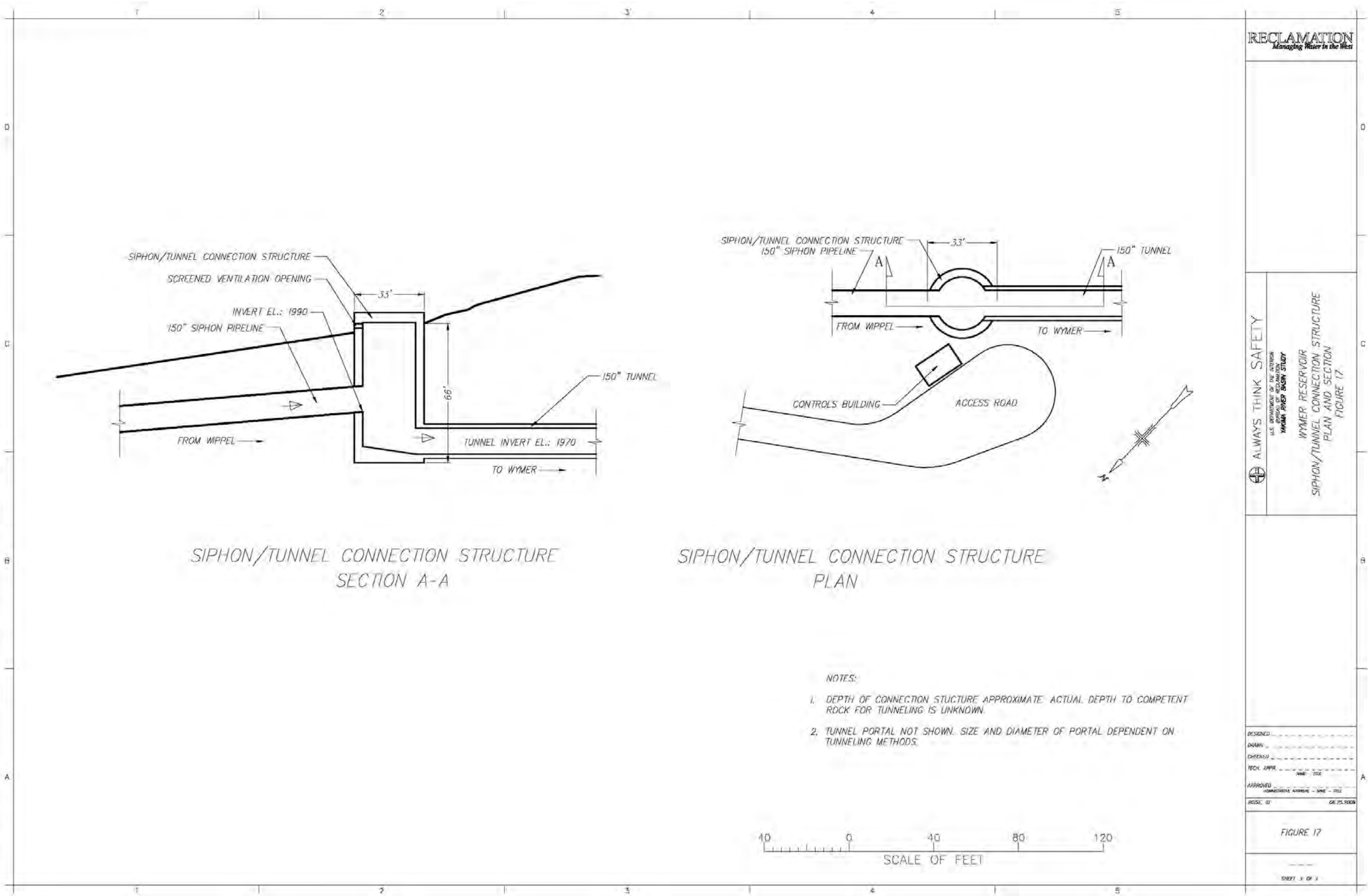
YAKIMA RIVER BASIN STUDY
WYMER RESERVOIR
WIPPEL TO WYMER SIPHON PROFILE
FIGURE 16
NORTH BRANCH KRD CANAL AT WIPPEL
DIVERSION STRUCTURE
STATION 0+00
PIPE IE: 2000
DESIGN WSE AT DIVERSION EL.: 2019±
WEIR EL.: 2014
EX. GROUND SURFACE
150" SIPHON PIPELINE
FLOW
BADGER CREEK, EL.: 1735
TURBINE DITCH
GRAVITY DITCH
SIPHON/TUNNEL CONNECTION STRUCTURE
STATION 158+50
SIPHON PIPE IE: 1990
TUNNEL IE: 1970
PUMP DITCH
150" TUNNEL
MATCHLINE
ELEVATION IN FEET
STATIONING IN FEET
SIPHON (15,850 FT)
NOTES:
1) ELEVATIONS BASED ON USGS 7.5 MINUTE TOPOGRAPHIC MAP, THORP QUADRANGLE.
2) DESIGN FLOWS OF 1000 CFS AND DESIGN VELOCITY OF 8 FPS.
DESIGNED
DRAWN
CHECKED
TECH. APPR.
APPROVED
BOISE, ID
FIGURE 16



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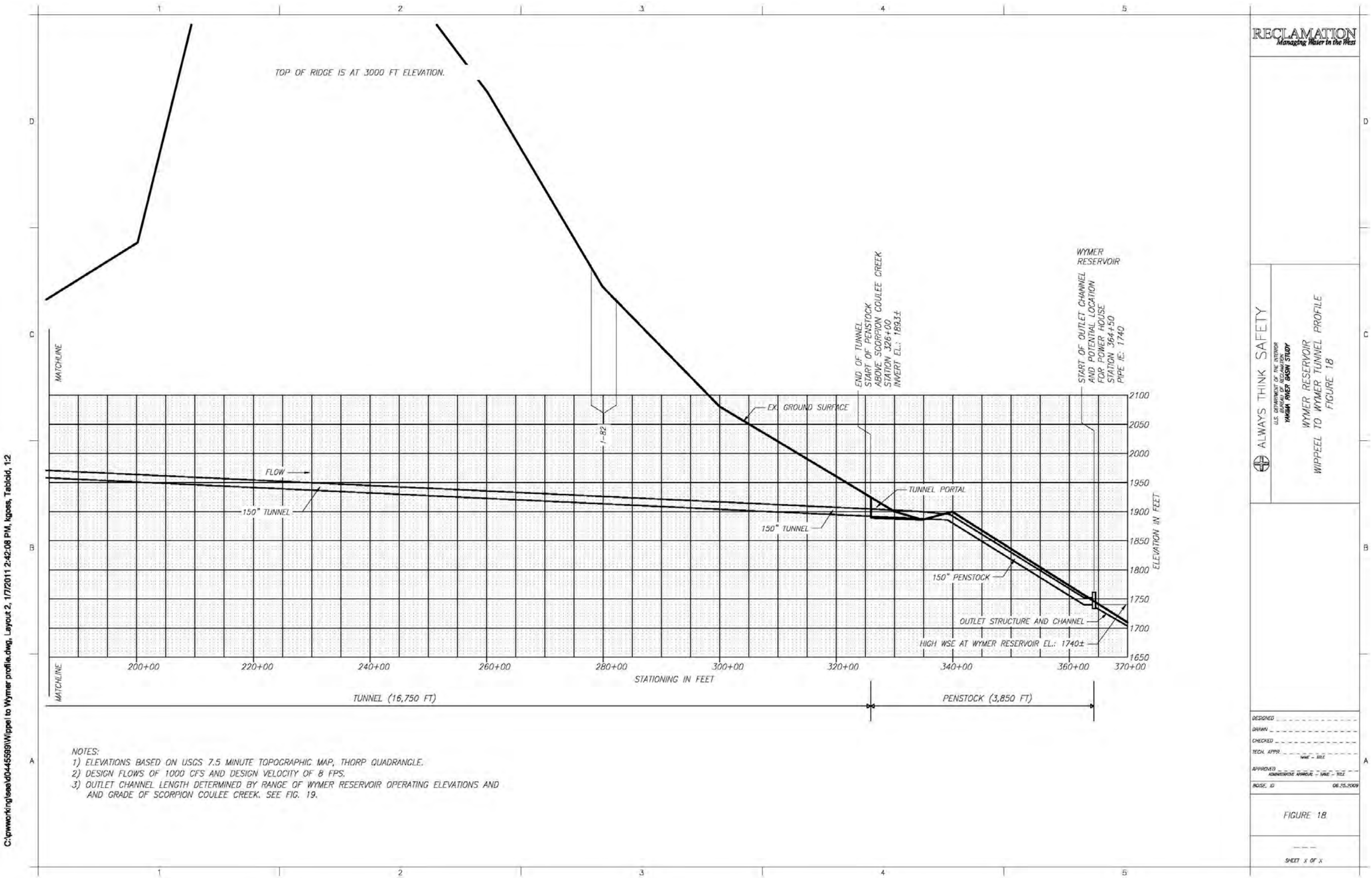
RECLAMATION
Managing Water in the West
TOP OF RIDGE IS AT 3000 FT ELEVATION.
MATCHLINE
I-82
EX. GROUND SURFACE
END OF TUNNEL
START OF PENSTOCK
ABOVE SCORPION COULEE CREEK
STATION 326+00
INVERT EL.: 1893±
WYMER
RESERVOIR
START OF OUTLET CHANNEL
AND POTENTIAL LOCATION
FOR POWER HOUSE
STATION 364+50
PIPE IE: 1740
FLOW
150" TUNNEL
TUNNEL PORTAL
150" TUNNEL
150" PENSTOCK
OUTLET STRUCTURE AND CHANNEL
HIGH WSE AT WYMER RESERVOIR EL.: 1740±
2100
2050
2000
1950
1900
1850
1800
1750
1700
1650
ELEVATION IN FEET
200+00
220+00
240+00
260+00
280+00
300+00
320+00
340+00
360+00
370+00
STATIONING IN FEET
TUNNEL (16,750 FT)
PENSTOCK (3,850 FT)
NOTES:
1) ELEVATIONS BASED ON USGS 7.5 MINUTE TOPOGRAPHIC MAP, THORP QUADRANGLE.
2) DESIGN FLOWS OF 1000 CFS AND DESIGN VELOCITY OF 8 FPS.
3) OUTLET CHANNEL LENGTH DETERMINED BY RANGE OF WYMER RESERVOIR OPERATING ELEVATIONS AND AND GRADE OF SCORPION COULEE CREEK. SEE FIG. 19.
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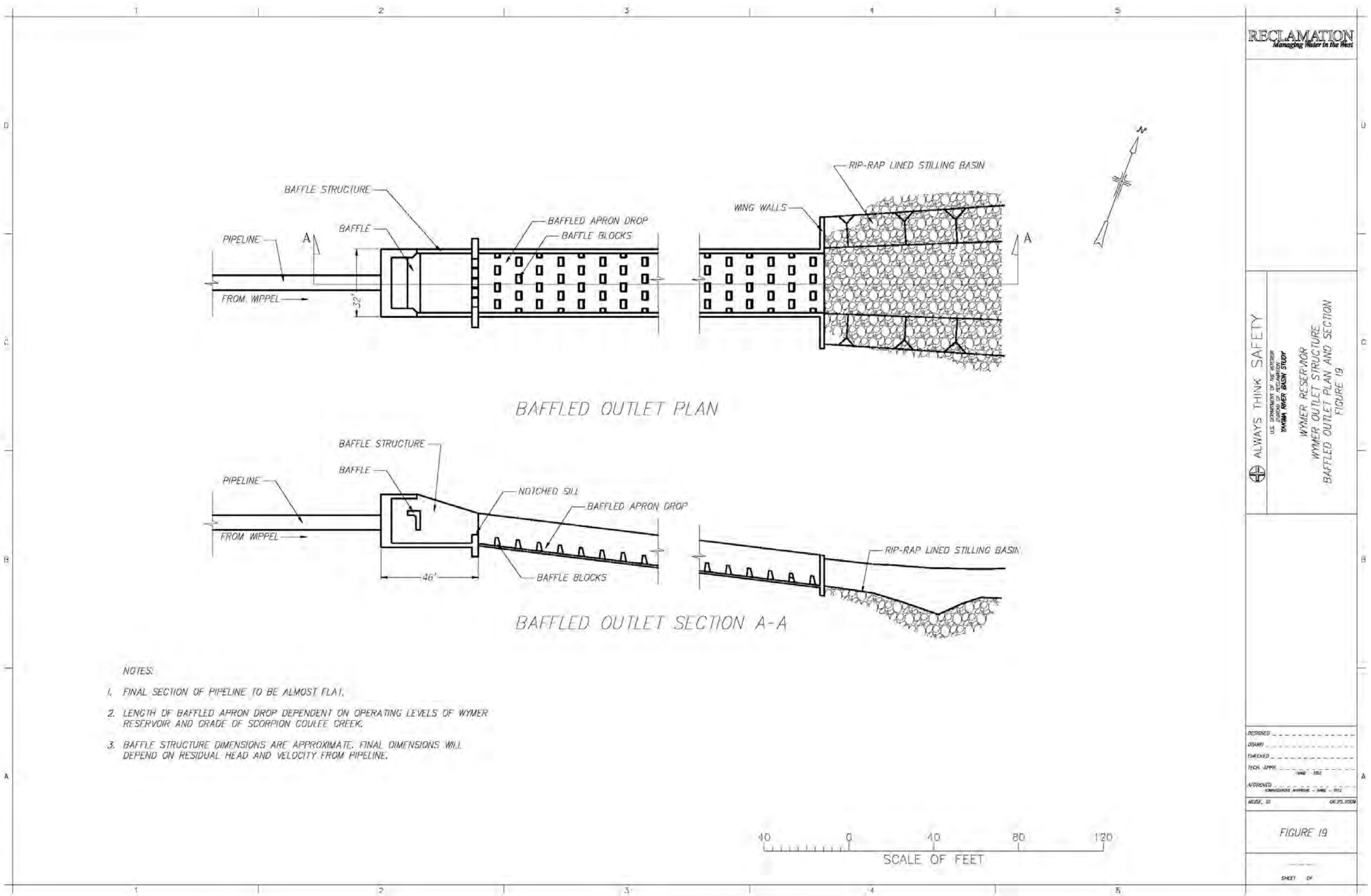
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN STUDY
WYMER RESERVOIR
WIPPEEL TO WYMER TUNNEL PROFILE
FIGURE 18
DESIGNED
DRAWN
CHECKED
TECH. APPR.
APPROVED
BOISE, ID
FIGURE 18
SHEET X OF X
C:\pwworking\sea\d0445599\Wippel to Wymer profile.dwg, Layout 2, 1/7/2011 2:42:08 PM, kgoss, Tabloid, 1:2

C:\pwworking\sea\d0445599\Structures.dwg, Outlet channel, 9/23/2010 10:52:59 AM, kgoss, Tabloid, 1:2



Appendix B

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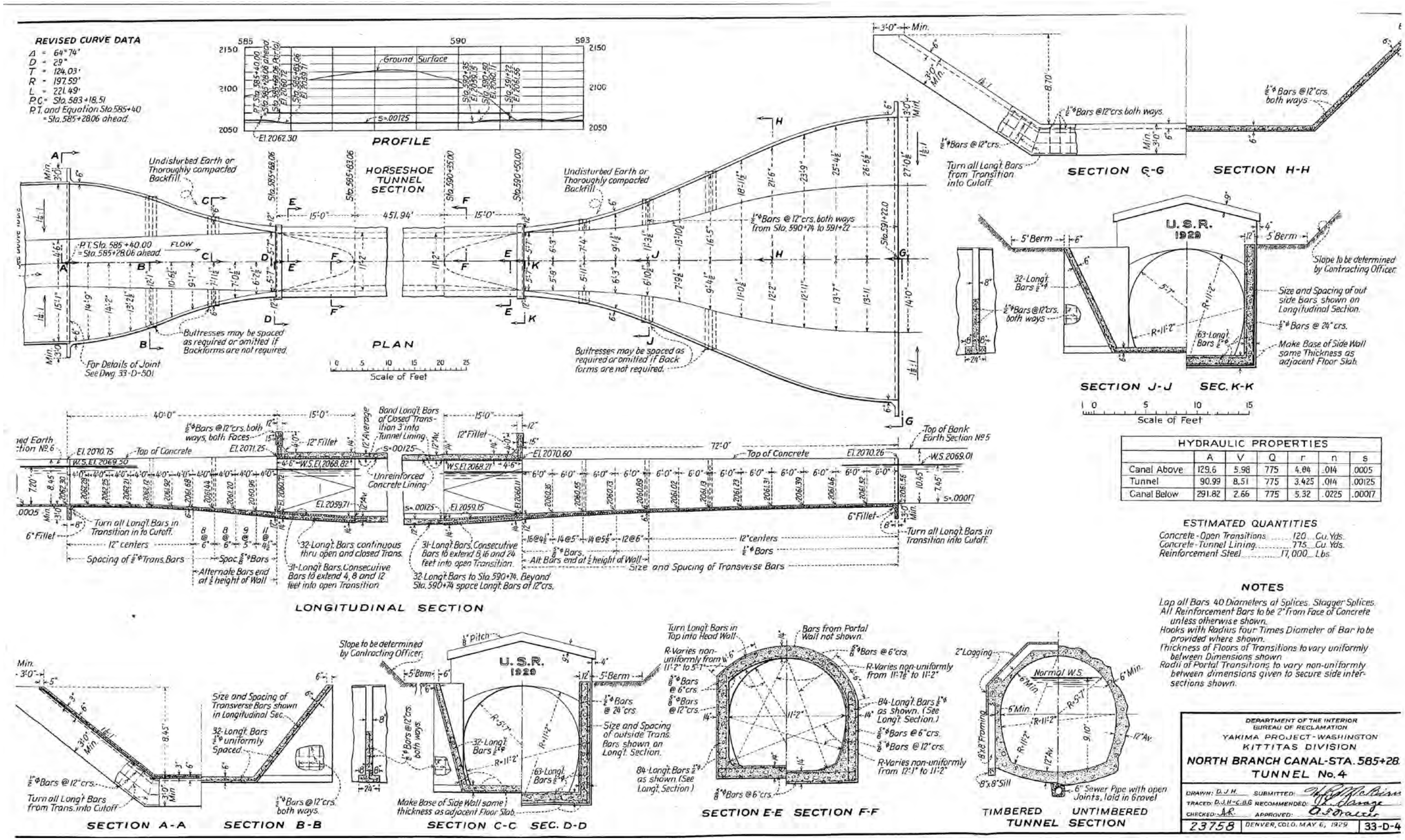
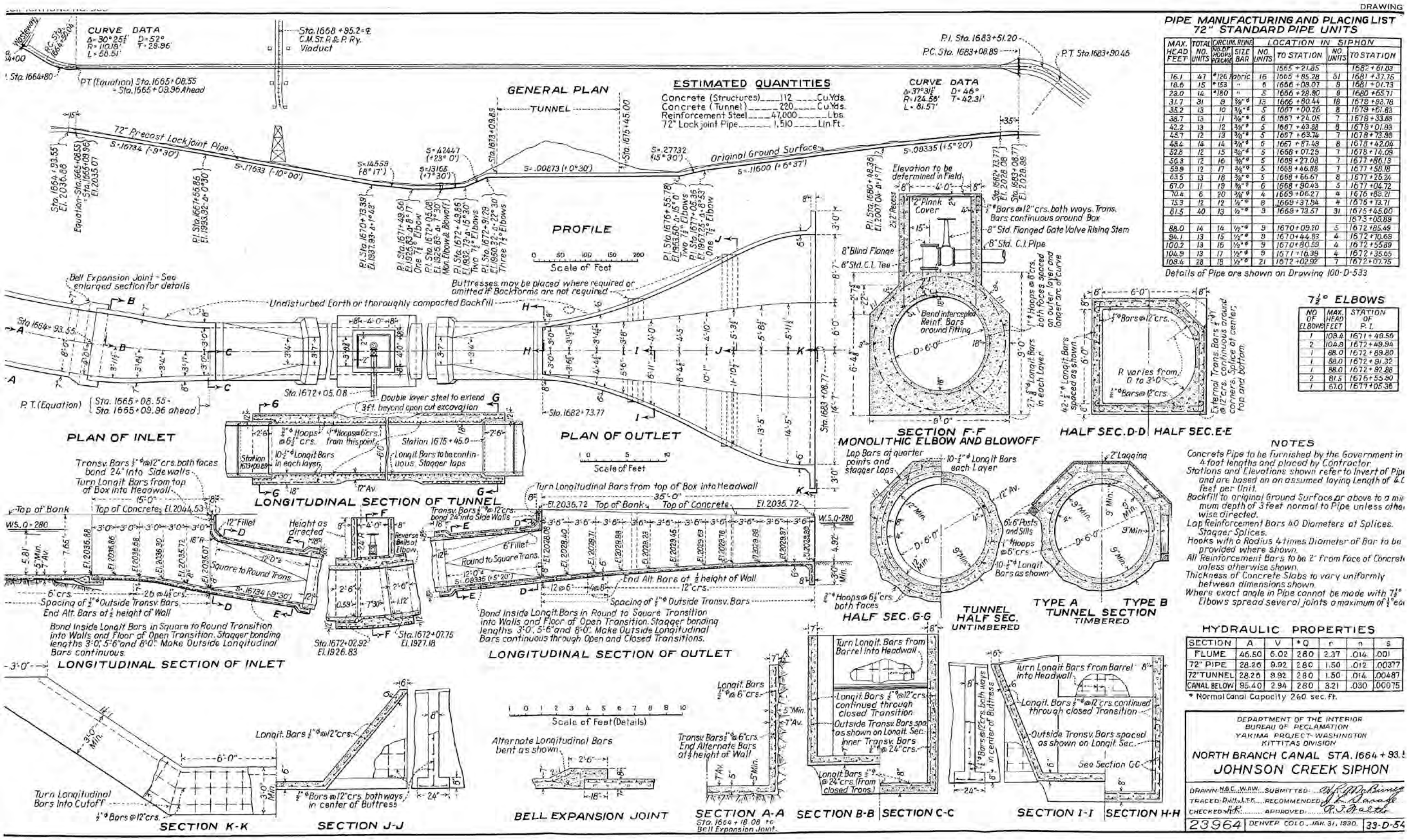


REVISED CURVE DATA
Δ = 64° 74'
D = 29°
T = 124.03'
R = 197.59'
L = 221.49'
P.C = Sta. 583+18.51
P.T. and Equation Sta. 585+40 = Sta. 585+28.06 ahead.
PROFILE
Ground Surface
HORSESHOE TUNNEL SECTION
PLAN
Scale of Feet
LONGITUDINAL SECTION
SECTION G-G
SECTION H-H
SECTION J-J
SEC. K-K
U.S.R. 1929
HYDRAULIC PROPERTIES
	A	V	Q	r	n	s
Canal Above	129.6	5.98	775	4.84	.014	.0005
Tunnel	90.99	8.51	775	3.425	.014	.00125
Canal Below	291.82	2.66	775	5.32	.0225	.00017
ESTIMATED QUANTITIES
Concrete - Open Transitions ...... 120 Cu. Yds.
Concrete - Tunnel Lining .... 775 Cu. Yds.
Reinforcement Steel .... 17,000 Lbs.
NOTES
Lap all Bars 40 Diameters at Splices. Stagger Splices.
All Reinforcement Bars to be 2" from Face of Concrete unless otherwise shown.
Hooks with Radius four Times Diameter of Bar to be provided where shown.
Thickness of Floors of Transitions to vary uniformly between Dimensions shown
Radii of Portal Transitions to vary non-uniformly between dimensions given to secure side intersections shown.
SECTION A-A
SECTION B-B
SECTION C-C
SEC. D-D
SECTION E-E
SECTION F-F
TIMBERED TUNNEL SECTION
UNTIMBERED TUNNEL SECTION
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT - WASHINGTON
KITTITAS DIVISION
NORTH BRANCH CANAL-STA. 585+28.
TUNNEL No. 4
DRAWN: D.J.H.
SUBMITTED:
TRACED: D.J.H.-C.B.G.
RECOMMENDED:
CHECKED: A.R.
APPROVED:
23758
DENVER, COLO. MAY 6, 1929
33-D-4



PIPE MANUFACTURING AND PLACING LIST
72" STANDARD PIPE UNITS

MAX. HEAD FEET	TOTAL NO. UNITS	CIRCUM. REINF. NO. OF HOOPS PER CAGE	CIRCUM. REINF. SIZE BAR	LOCATION IN SIPHON NO. UNITS	TO STATION	NO. UNITS	TO STATION
					1665 + 21.85		1682 + 61.83
16.1	47	*126	Fabric	16	1665 + 85.28	31	1681 + 37.75
18.6	15	*153	"	6	1666 + 09.07	8	1681 + 01.73
23.0	14	*180	"	5	1666 + 28.90	9	1680 + 65.71
31.7	31	9	3/8"φ	13	1666 + 80.44	18	1679 + 93.78
35.2	13	10	3/8"φ	5	1667 + 00.26	8	1679 + 61.83
38.7	13	11	3/8"φ	6	1667 + 24.05	7	1679 + 33.89
42.2	13	12	3/8"φ	5	1667 + 43.88	8	1679 + 01.83
45.7	12	13	3/8"φ	5	1667 + 63.74	7	1678 + 73.99
49.4	14	14	3/8"φ	6	1667 + 87.49	8	1678 + 42.04
52.8	12	15	3/8"φ	5	1668 + 07.29	7	1678 + 14.09
56.3	12	16	3/8"φ	5	1668 + 27.08	7	1677 + 86.13
59.9	12	17	3/8"φ	5	1668 + 46.88	7	1677 + 58.18
63.5	13	18	3/8"φ	5	1668 + 66.67	8	1677 + 26.24
67.0	11	19	3/8"φ	6	1668 + 90.43	5	1677 + 04.72
70.4	8	20	3/8"φ	4	1669 + 06.27	4	1676 + 89.21
75.3	12	12	1/2"φ	8	1669 + 37.94	4	1676 + 73.71
81.5	40	13	1/2"φ	9	1669 + 73.57	31	1675 + 45.00
							1673 + 03.89
88.0	14	14	1/2"φ	9	1670 + 09.20	5	1672 + 85.49
94.1	13	15	1/2"φ	9	1670 + 44.83	4	1672 + 70.69
100.2	13	16	1/2"φ	9	1670 + 80.59	4	1672 + 55.89
104.9	13	17	1/2"φ	9	1671 + 16.39	4	1672 + 35.65
109.4	28	18	1/2"φ	21	1672 + 02.92	7	1672 + 07.75

Details of Pipe are shown on Drawing 100-D-533

7½° ELBOWS

NO. OF ELBOWS	MAX. HEAD FEET	STATION OF P.I.
1	109.4	1671 + 49.56
2	104.9	1672 + 49.94
1	88.0	1672 + 89.80
1	88.0	1672 + 91.32
1	88.0	1672 + 92.88
2	81.5	1676 + 55.90
1	67.0	1677 + 05.36

HYDRAULIC PROPERTIES

SECTION	A	V	*Q	r	n	s
FLUME	46.50	6.02	280	2.37	.014	.001
72" PIPE	28.26	9.92	280	1.50	.012	.00377
72" TUNNEL	28.26	9.92	280	1.50	.014	.00487
CANAL BELOW	95.40	2.94	280	3.21	.030	.00075

* Normal Canal Capacity 260 sec. ft.

KRD North Branch Canal - Selected Data fror Existing Canal, Tunnels, and Siphons between Thorp and Wippel

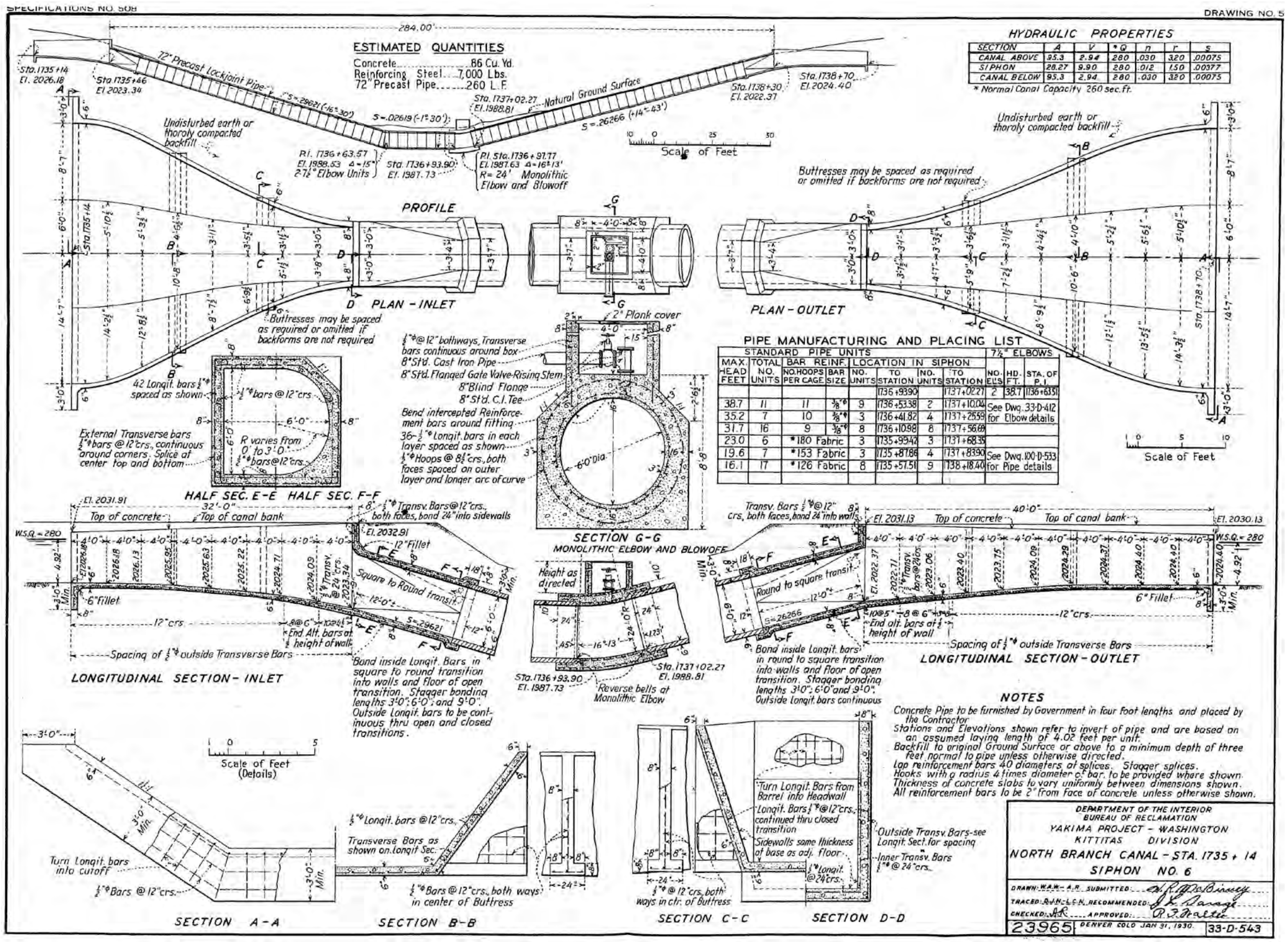
CANAL ID	LENGTH meters	LENGTH ft	Q cfs	AREA sf	BOTTOM WIDTH ft	DEPTH ft	SIDE SLOPE	ROUGHNESS	CANAL SLOPE ft/ft	VELOCITY fps	HYDRAULIC RADIUS
1	173.2	568.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	756.5	2482.0	926	346.86	30	8.2	1.5	0.0225	0.00015	2.67	5.82
3 Dry Creek Siphon	464.6	1524.4	925	97.93	---	---	---	0.0140	0.0020	9.47	---
4	85.5	280.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5 Little Dry Creek Siphon	101.6	333.2	925	97.93	---	---	---	0.0140	0.0020	9.47	---
6	1259.5	4132.3	926	346.86	30	8.2	1.5	0.0225	0.00015	2.67	5.82
7	1055.3	3462.4	926	346.86	30	8.2	1.5	0.0225	0.00015	2.67	5.82
8	1100.5	3610.5	926	346.86	30	8.2	1.5	0.0225	0.00015	2.67	5.82
9	479.5	1573.3	926	346.86	30	8.2	1.5	0.0225	0.00015	2.67	5.82
10	551.0	1807.9	926	346.86	30	8.2	1.5	0.0225	0.00015	2.67	5.82
11	735.9	2414.3	926	346.86	30	8.2	1.5	0.0225	0.00015	2.67	5.82
12	142.0	466.0	1320	236	12	9.75	1.25	0.014	.0003	5.6	5.46
13	2502.6	8210.6	775	291.82	28	7.45	1.5	0.0225	0.00017	2.66	5.32
14	1578.4	5178.5	775	291.82	28	7.45	1.5	0.0225	0.00017	2.66	5.32
15	457.8	1501.9	775	291.82	28	7.45	1.5	0.0225	0.00017	2.66	5.32
15.1 Badlands Tunnel #4	171.9	593.94	775	90.99	N/A	11.17	N/A	0.01400	0.000825	8.51	
16	182.5	598.8	775	291.82	28	7.45	1.5	0.0225	0.00017	2.66	5.32
17	288.1	945.1	775	291.82	28	7.45	1.5	0.0225	0.00017	2.66	5.32
18	315.2	1034.2	775	129.6	9	7.2	1.25	0.014	0.00050	5.98	4.040
19	4427.8	14527.0	775	291.82	28	7.45	1.5	0.0225	0.00017	2.66	5.32
20	354.8	1164.1	775	195	15	7.45	1.5	0.025	0.00057	3.98	4.66
21	808.0	2651.0	775	291.82	28	7.45	1.5	0.0225	0.00017	2.66	5.32
22	534.3	1752.9	690	279.36	28	7.2	1.5	0.0225	0.00015	2.47	5.18
23	666.0	2185.0	690	279.36	28	7.2	1.5	0.0225	0.00015	2.47	5.18
24	937.5	3075.8	650	255.5	26	7.0	1.5	0.0225	0.00017	2.54	4.99
25	807.8	2650.1	605	243.84	26	6.75	1.5	0.0225	0.00017	2.48	4.84
26	5016.9	16459.5	550	227.84	26	6.4	1.5	0.0225	0.00017	2.42	4.64
27	1075.4	3528.1	515	215.04	24	6.4	1.5	0.0225	0.00017	2.4	4.57
28	1037.3	3403.3	455	205.61	24	6.18	1.5	0.0225	0.00015	2.21	4.44
29	864.5	2836.4	455	205.61	24	6.18	1.5	0.0225	0.00015	2.21	4.44
30	1226.4	4023.6	400	168.28	22	5.55	1.5	0.0225	0.0002	2.37	4.00
31	293.3	962.1	400	168.28	22	5.55	1.5	0.0225	0.0002	2.37	4.00
32	1118.1	3668.4	400	168.28	22	5.55	1.5	0.0225	0.0002	2.37	4.00
33	727.3	2386.0	400	168.28	22	5.55	1.5	0.0225	0.0002	2.37	4.00
34	3225.8	10583.2	375	160.63	22	5.35	1.5	0.0225	0.0002	2.33	3.89
34.1	166.9	547.6	325	144.56	20	5.2	1.5	0.0225	0.0002	2.26	3.73
35	873.5	2865.7	325	144.56	20	5.2	1.5	0.0225	0.0002	2.26	3.73
36	1276.7	4188.5	325	144.56	20	5.2	1.5	0.0225	0.0002	2.26	3.73

KRD North Branch Canal - Selected Data fror Existing Canal, Tunnels, and Siphons between Thorp and Wippel

CANAL ID	LENGTH meters	LENGTH ft	Q cfs	AREA sf	BOTTOM WIDTH ft	DEPTH ft	SIDE SLOPE	ROUGHNESS	CANAL SLOPE ft/ft	VELOCITY fps	HYDRAULIC RADIUS
37	886.9	2909.9	290	127.13	20	4.7	1.5	0.0225	0.00023	2.29	3.44
38	1831.3	6008.2	280	117.74	18	4.7	1.5	0.0225	0.00025	2.36	3.37
39	1443.0	4734.1	280	117.74	18	4.7	1.5	0.0225	0.00025	2.36	3.37
40	290.2	952.2	260	77.78	14	4.75	0.5	0.03	0.001	3.37	3.16
40.1	126.6	415.2	260	112.95	18	4.55	1.5	0.0225	0.00025	2.31	3.28
41	423.2	1388.3	260	112.95	18	4.55	1.5	0.0225	0.00025	2.31	3.28
42	972.9	3191.8	260	81.84	12	4.4	1.5	0.03	0.001	3.2	2.94
43	476.3	1562.8	260	44.00	6	4.0	1.25	0.014	0.001	5.97	2.34
44 Big Johnson Siphon - channel		262.3	280	46.50	N/A					6.02	
44 Big Johnson Siphon - pipe		554.0	280	28.27	N/A	6				9.92	
44 Big Johnson Siphon - tunnel		235.1	280	28.27	N/A	6	N/A	0.01400	0.00380	9.92	
44 Big Johnson Siphon - pipe		503.4	280	28.27	N/A	6				9.92	
44 Big Johnson Siphon - channel		260.4	280	28.27	N/A					9.92	
45	1568.7	5146.8	260	90.32	12	4.73	1.5	0.03	0.00075	2.88	3.11
46 Little Johnson Siphon		284.0	280	28.27	N/A	6	N/A	0.01200	0.00342	9.90	
47	167.4	549.4	260	90.32	12	4.73	1.5	0.03	0.00075	2.88	3.11
48	512.7	1682.1	260	112.95	18	4.55	1.5	0.0225	0.00025	2.31	3.28
49 Tunnel #5	1074.2	3562.0	280	33.08	N/A	7	N/A	0.01400	0.00244	8.47	
50	1236.6	4057.0	210	83.94	14	4.15	1.5	0.025	0.000434	2.5	2.89
51	232.8	763.8	200	83.94	15	4.2	1.5	0.0225	0.00027	2.23	2.96
52	1476.7	4844.8	200	83.94	15	4.2	1.5	0.0225	0.00027	2.23	2.96

Notes:

1) Canal IDs 1-5 are upstream of Thorp Pump Station discharge location.
2) Information on tunnels and siphons was from spreadsheet and drawings provided by KRD.
3) Cell colors highlight canal sections grouped together in Table 2.



ESTIMATED QUANTITIES

Concrete .... 86 Cu. Yd.
Reinforcing Steel ... 7,000 Lbs.
72" Precast Pipe .... 260 L.F.

HYDRAULIC PROPERTIES

SECTION	A	V	*Q	n	r	s
CANAL ABOVE	95.3	2.94	280	.030	3.20	.00075
SIPHON	28.27	9.90	280	.012	1.50	.00377
CANAL BELOW	95.3	2.94	280	.030	3.20	.00075

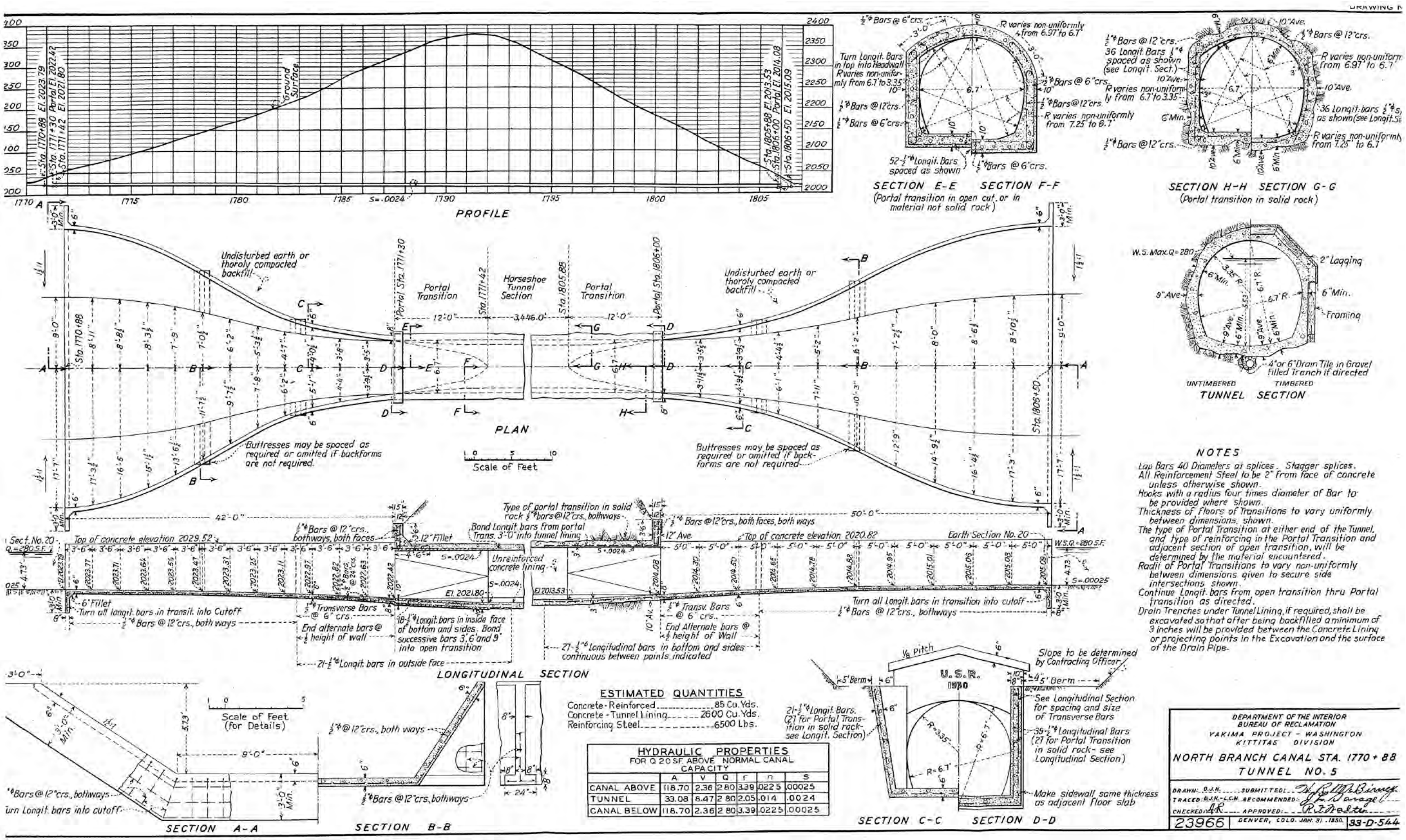
* Normal Canal Capacity 260 sec. ft.

PIPE MANUFACTURING AND PLACING LIST

STANDARD PIPE UNITS								7½° ELBOWS		
MAX. HEAD FEET	TOTAL NO. UNITS	BAR REINF. NO. HOOPS PER CAGE	BAR REINF. BAR SIZE	LOCATION IN SIPHON NO. UNITS	TO STATION	NO. UNITS	TO STATION	NO. EL'S	HD. FT.	STA. OF P.I.
					1736+93.90		1737+02.27	2	38.7	1736+63.51
38.7	11	11	⅜"φ	9	1736+53.38	2	1737+10.04	See Dwg. 33-D-412 for Elbow details		
35.2	7	10	⅜"φ	3	1736+41.82	4	1737+25.59			
31.7	16	9	⅜"φ	8	1736+10.98	8	1737+56.68			
23.0	6	*180 Fabric		3	1735+99.42	3	1737+68.35			
19.6	7	*153 Fabric		3	1735+87.86	4	1737+83.90	See Dwg. 100-D-533 for Pipe details		
16.1	17	*126 Fabric		8	1735+57.51	9	1738+18.40			

NOTES

Concrete Pipe to be furnished by Government in four foot lengths and placed by the Contractor.
Stations and Elevations shown refer to invert of pipe and are based on an assumed laying length of 4.02 feet per unit.
Backfill to original Ground Surface or above to a minimum depth of three feet normal to pipe unless otherwise directed.
Lap reinforcement bars 40 diameters at splices. Stagger splices.
Hooks with a radius 4 times diameter of bar, to be provided where shown.
Thickness of concrete slabs to vary uniformly between dimensions shown.
All reinforcement bars to be 2" from face of concrete unless otherwise shown.



HYDRAULIC PROPERTIES
FOR Q 20 SF. ABOVE NORMAL CANAL CAPACITY

	A	V	Q	r	n	S
CANAL ABOVE	118.70	2.36	280	3.39	.0225	.00025
TUNNEL	33.08	8.47	280	2.05	.014	.0024
CANAL BELOW	118.70	2.36	280	3.39	.0225	.00025