RESTRICT FLOW CASE STUDY · PRE-COMMISSIONING DESIGN

How Restrict Flow Designed a Compact Anti-Cavitate Orifice Plate™ for the NAWS Snake Creek Pumping Plant Commissioning Loop

A pre-commissioning design case study for a 24-inch raw-water discharge line requiring 224 PSI pressure reduction within a constrained pipe envelope.

Project: NAWS Contract 6-1A — Intake and Snake Creek Pumping Plant Modifications · Owners: U.S. Bureau of Reclamation; ND State Water Commission · Engineer of record: Houston Engineering, Inc. · Contractor: PKG Contracting, Inc. · Referral partner: Stantec Corporation

STATUS — This case study documents the design selection, hydraulic review, and supplied Anti-Cavitate Orifice Plate™ prior to formal pump commissioning. Field validation results will be added after commissioning is complete.

At a glance

The Northwest Area Water Supply (NAWS) project is one of the largest raw-water supply systems in the upper Missouri basin. Its source-water pumping plant on the south shore of Lake Audubon — the Snake Creek Pumping Plant — is being modified to add new raw-water pumps that will move treated lake water toward Minot and the surrounding service area. Before any of those new pumps can be released to service, they have to run against a calibrated, sustained back-pressure for commissioning. The back-pressure has to be developed in a temporary discharge spool that fits between an existing dismantling joint and the concrete bulkhead at the head of the Lake Audubon discharge structure.

The design pressure drop is **224 PSI** at the design flow of 17,014 GPM, on a 24-inch line. The commissioning envelope spans flows from 2,083 GPM (one pump minimum) to over 20,000 GPM (full station) — a turndown of nearly 10:1 — and actual pressure drop across a fixed restriction varies with operating flow. Restrict Flow's project-specific analysis returned a cavitation number of **σ = 0.19** for the design service condition, which sits in the severe range of Restrict Flow's internal cavitation scale. A traditional multi staged restriction orifice configuration — the textbook approach for high-pressure-drop service when straight-pipe length is available — was estimated to require on the order of tens to more than one hundred feet of total straight run, depending on stage count and inter-plate recovery assumptions. The available run between the dismantling joint and the discharge bulkhead is approximately 19 feet. The available straight run was insufficient for a conventional staged layout.

Restrict Flow's Anti-Cavitate Orifice Plate™ (**P/N ACP24CS1375300**) is designed to manage the full 224 PSI pressure drop in a single plate, 1.38 inches thick between the flanges, installed between the existing AWWA Class F dismantling joint and a 300# B16.5 slip-on flange. The entire assembly requires 18 inches of flange separation for installation or a spool or assembly joint, but when tightened up it takes only the 1.375 inches between flanges. The single-plate configuration was selected as the compact arrangement that fits within the available flange-separation envelope on the commissioning spool.

The discharge test loop

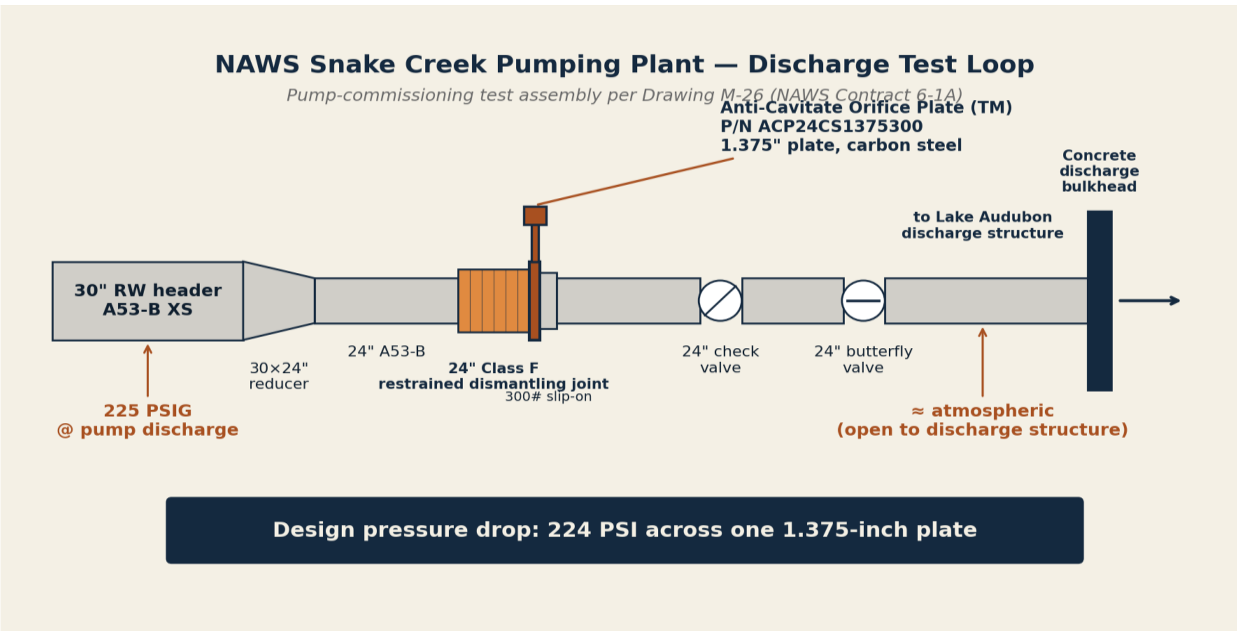

Figure 1. Snake Creek pump-commissioning discharge test loop, simplified from Drawing M-26 (NAWS Contract 6-1A). Raw lake water moves from the new pump discharge through a 30-inch header, a 30 × 24-inch reducer, the AWWA Class F restrained dismantling joint, the Anti-Cavitate Orifice Plate, a 24-inch check valve and butterfly valve, and out through the concrete discharge bulkhead into the Lake Audubon discharge structure. The orifice plate is the device specified to develop the line pressure drop from 225 PSIG to atmospheric during commissioning.

The application: pump commissioning at a federal raw-water intake

The Snake Creek Pumping Plant is the source-end pumping station for the NAWS supply system. It draws from Lake Audubon, the regulating reservoir below Lake Sakakawea on the Missouri River, and lifts that water into the NAWS distribution system serving Minot, ND and surrounding communities. NAWS is jointly developed by the U.S. Bureau of Reclamation and the North Dakota State Water Commission. Contract 6-1A is the intake-and-pumping-plant modifications scope. Houston Engineering, Inc. of Bismarck is the engineer of record (Drawing M-26 of 197, sealed by the project's PE of record, North Dakota PE registration). The general contractor on this package is PKG Contracting, Inc.

The orifice plate that is the subject of this case study is ***not*** a permanent piece of the NAWS process. It is a temporary pump-commissioning element. Sheet keynote A on Drawing M-26 reads, in part:

"Contractor shall provide pump testing assembly spool, inclusive of orifice plate(s), for commissioning of NAWS raw water pumps … Temporary assembly shall be installed in place of final fit-out configuration and shall be replaced with the pressure relief valve piping/discharge header piping once testing is completed."

In other words, the plate exists to put a calibrated hydraulic load on the new pumps so they can be tested at one-pump-running and full-station-running conditions before the rest of the NAWS distribution piping is brought into service. Once commissioning passes, the orifice plate and its temporary spool are pulled and the line is reconfigured to the permanent pressure-relief valve / discharge-header arrangement.

Drawing context

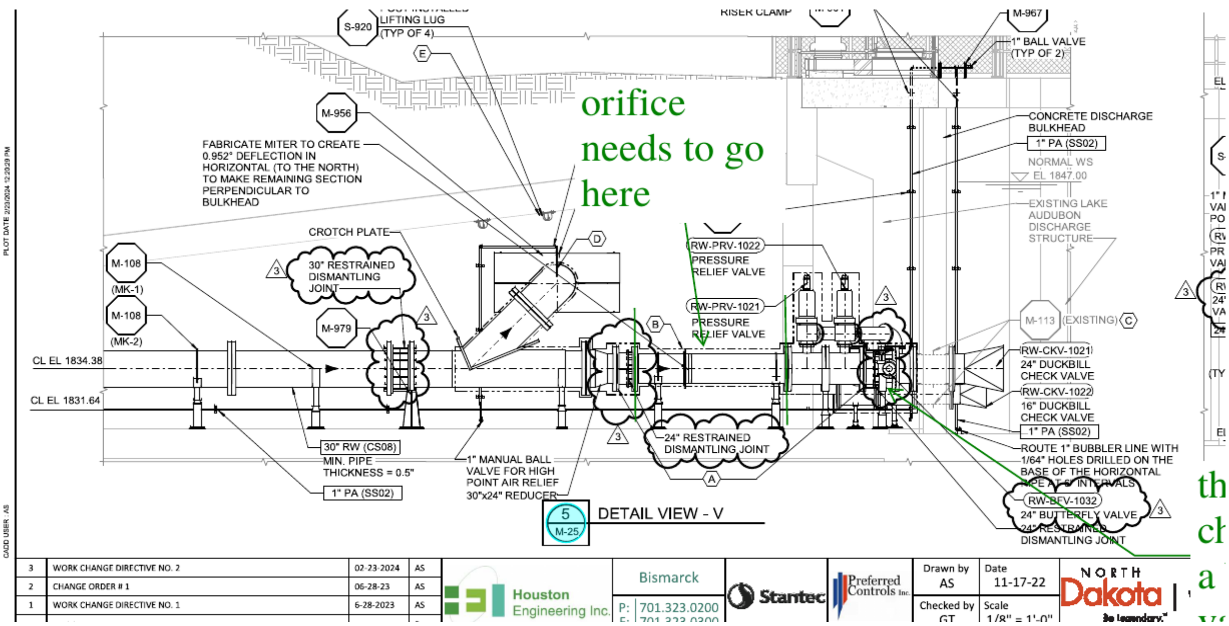

Figure 2. Excerpt from Drawing M-26 (NAWS Contract 6-1A, Houston Engineering, Bismarck), Detail View V — Discharge Pipeline Enlarged Plan and Sections, showing the 30-inch RW header, the 30 × 24-inch reducer, the 24-inch restrained dismantling joint, and the concrete discharge bulkhead. The hand-marked annotation "orifice needs to go here" is the contractor's call-out identifying the installation point for the Anti-Cavitate Orifice Plate. The constrained pipe-length envelope between the dismantling joint and the bulkhead is the geometric driver behind the design selection.

The hydraulic problem

Raw water leaves the Snake Creek pump discharge at 225 PSIG. The Lake Audubon discharge structure is effectively atmospheric, with any local static head at the outlet accounted for in the project calculation. The 224 PSI design pressure differential at design flow must be dissipated as turbulence and heat between those two points.

The classical pressure-drop relationship for an orifice plate, derived from the Bernoulli energy equation with a discharge-coefficient correction, is

$$\Delta P = (\rho / 2) \cdot (Q / (C_d \cdot A_o))^2$$

where ρ is fluid density, Q is volumetric flow rate, C_d is the discharge coefficient (a function of plate geometry and Reynolds number), and A_o is the orifice throat area. The relationship is *quadratic in flow* — pressure drop across a fixed restriction varies strongly with flow rate, so the commissioning envelope must be evaluated at both low-flow and high-flow operating conditions. The 224 PSI design pressure drop applies at the specified design flow of 17,014 GPM; pressure drop at one-pump minimum flow is substantially lower, and the plate has to behave correctly across the full envelope.

More importantly, ΔP is not the only consideration. It is the *pressure profile through the plate* that determines whether the service cavitates.

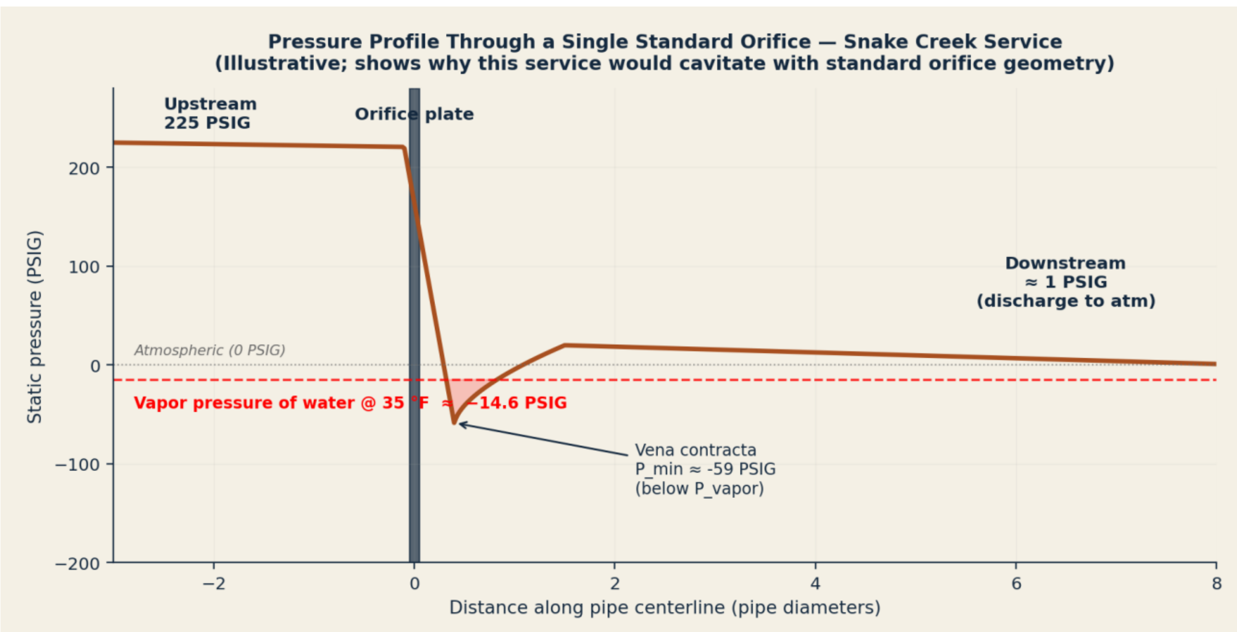

Figure 3. Illustrative pressure profile through a single standard orifice plate operating at Snake Creek discharge conditions. As the fluid accelerates through the orifice, static pressure dives at the vena contracta. At the design conditions modeled here, the predicted vena-contracta pressure falls well below the vapor pressure of water at 35 °F (P_{vapor} ≈ 0.1 PSIA, approximately −14.6 PSIG when expressed relative to sea-level atmospheric pressure). The shaded region under the vapor-pressure line is where bubble formation is expected. As pressure recovers downstream the bubbles collapse — and that collapse is the mechanism that damages plates, downstream pipe walls, gauges, and supports. A standard plate would be expected to experience severe cavitation-related damage in this service.

The cavitation number

Cavitation potential in an orifice plate is conventionally captured by a dimensionless cavitation number ***σ***, roughly of the form

$$\sigma = (P_d - P_{vapor}) / (P_u - P_d)$$

with site-specific corrections drawn from the *Flow Measurement Engineering Handbook* (R. W. Miller, McGraw-Hill) and from plate-geometry-aware vendor methodologies. Because cavitation-number calculations vary by methodology, pressure reference, and correction factors, the published σ value should be treated as the result of the project-specific design analysis rather than a direct substitution into the simplified equation shown above. Restrict Flow's project-specific analysis, performed against the customer-supplied design data, returned σ = 0.19 for the Snake Creek discharge service. On Restrict Flow's internal cavitation scale, that places the application in the **severe and damaging cavitation likely** zone (0 to 1). Cavitation-related noise and vibration are not expected to be significant for σ values above approximately 3.0; the Snake Creek service sits well below that threshold.

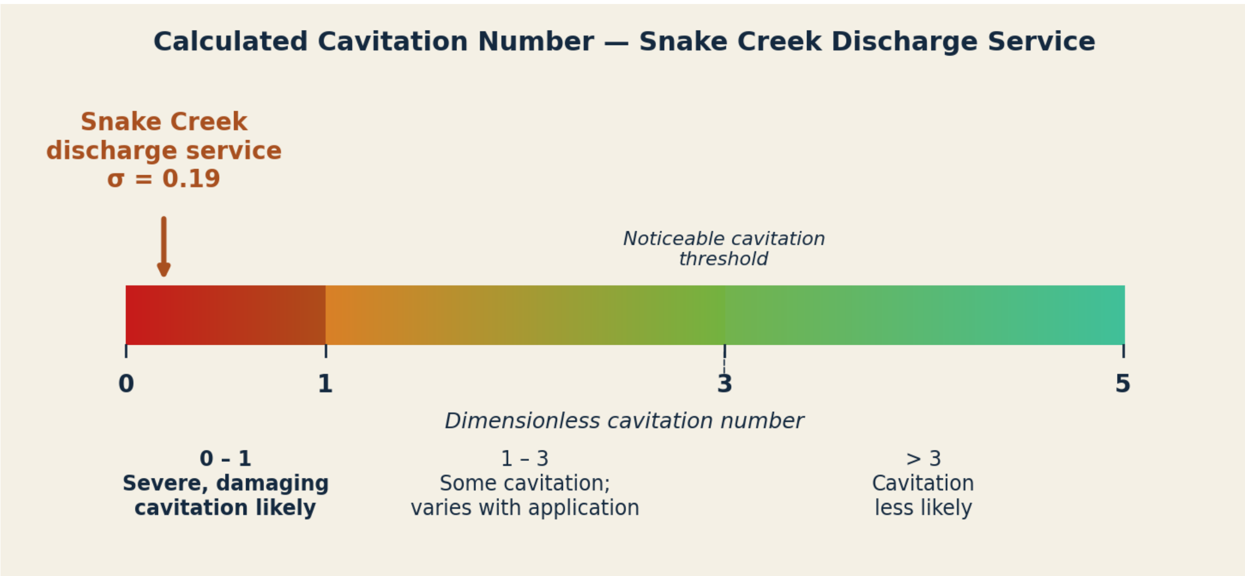

Figure 4. Calculated cavitation number for Snake Creek discharge service, plotted against the dimensionless cavitation scale used in Restrict Flow's design analyses. A standard restriction orifice plate operating in the σ < 1 zone would be expected to produce significant audible noise, vibration, and progressive material loss on plate edges and downstream pipe walls.

Why a staged orifice configuration was not workable here

The textbook engineering response to a service with a high pressure drop and a low cavitation number is to spread the drop across multiple plates so that no single plate generates a vena contracta low enough to flash the fluid. Multi-plate ("staged") configurations require inter-plate spacing on the order of 3 to 5 pipe diameters per the *Flow Measurement Engineering Handbook* (R. W. Miller, McGraw-Hill) so that the jet has reattached and the pressure has recovered before the next plate.

For the 224 PSI design pressure drop on this service, conventional staging methodology suggests three to seven plates depending on how aggressively each stage is loaded. With 24-inch pipe, 3D inter-plate spacing is 6 ft of pipe and 5D is 10 ft. Depending on stage count, inter-plate recovery assumptions, and upstream and downstream straight-run allowances, a conventional staged layout was estimated to require on the order of tens to more than one hundred feet of total straight run.

The available pipe-length real estate at Snake Creek, between the existing AWWA Class F restrained dismantling joint and the concrete discharge bulkhead, is approximately 19 feet. That envelope was insufficient for a conventional staged restriction layout.

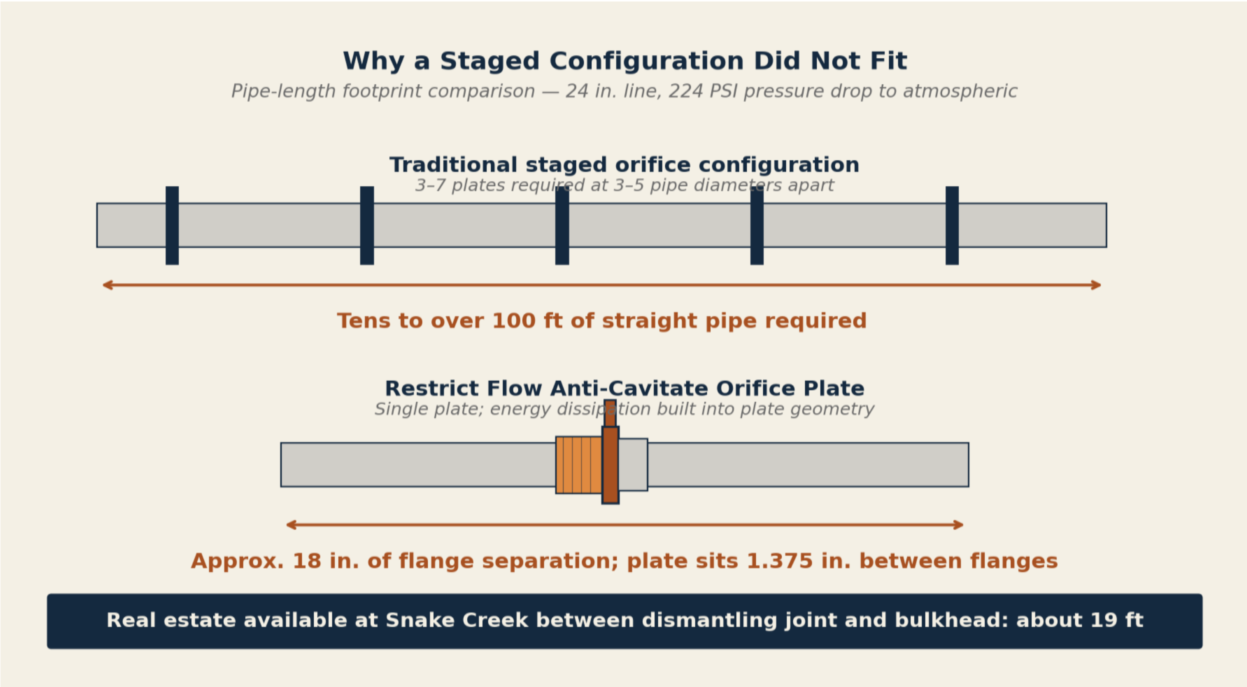

Figure 5. Pipe-length footprint comparison. A conventional staged orifice configuration developing the design pressure drop on this service was estimated to require on the order of tens to more than one hundred feet of total straight run, depending on stage count, inter-plate recovery assumptions, and upstream and downstream straight-run allowances. The Snake Creek discharge geometry offered approximately 19 feet of available run between the dismantling joint and the bulkhead. The Restrict Flow Anti-Cavitate Orifice Plate is designed to manage the design pressure drop in 1.375 inches of plate thickness, with 18 inches of total flange separation required for installation.

The compact Anti-Cavitate Orifice Plate design

Restrict Flow specified its **Anti-Cavitate Orifice Plate™ (P/N ACP24CS1375300)** for this service. The Anti-Cavitate Orifice Plate is a single-stage device that uses a proprietary plate geometry to dissipate the pressure-drop energy across the plate thickness rather than across multiple plates with intervening pipe length. The design draws on flow-element work originally developed for nuclear cooling-system flow elements and refined across a decade of marine, power, paper, and petrochemical service. The platform was first publicly demonstrated at the UAE Nuclear Power Program kickoff in 2010 and has since been deployed in industrial and federal-infrastructure piping systems across North America.

For Snake Creek the device was specified in carbon steel. The service is raw lake water at pH 6.0–8.5 and 32–90 °F, with no aggressive additives and only nominal grit/sediment loading. The plate is a temporary commissioning element with a defined service life: it sees flow only during the pump-commissioning window, then is pulled and replaced by the permanent pressure-relief valve piping. Carbon steel was selected as appropriate for the temporary commissioning duty cycle, based on the submitted water chemistry and project requirements. A specification calling for stainless or super-austenitic alloys would have added cost and lead time without providing meaningful service-life benefit for this particular use case.

The plate thickness — **1.375 inches** — is set by the geometry of the plate's internal energy-dissipating features, which are matched to the fluid, the pressure differential, and the pipe ID. Installation requires the upstream and downstream flanges to be separated by approximately 18 inches in order to insert the plate; once installed, the plate itself sits 1.375 inches between flanges. On this project, the AWWA Class F restrained dismantling joint upstream of the plate provides the necessary axial movement to make insertion possible without disturbing the rest of the spool. The downstream side is a standard ASME B16.5 Class 300 slip-on flange.

Project and equipment specifications

Project	NAWS Contract 6-1A — Intake and Snake Creek Pumping Plant Modifications
Project number	NDSWC Project No. 237-4 / Contract 6-1A
Location	Coleharbor, North Dakota — Snake Creek Pumping Plant
Contractor	PKG Contracting, Inc. (Fargo, ND)
Engineer of record	Houston Engineering, Inc. (Bismarck, ND)
Owners	U.S. Bureau of Reclamation; North Dakota State Water Commission
Service	Raw lake water (Lake Sakakawea), pump-commissioning test loop
Pipe	24 in. A53 Grade B ERW, 0.500 in. wall (XS)
Flange	ASME B16.5 Class 300 slip-on against 24 in. AWWA C207 Class F restrained dismantling joint
Upstream pressure	225 PSIG (one-pump and full-station discharge)
Downstream pressure	Atmospheric, ≈ 1 PSIG (1,834 ft elevation MSL)
Pressure drop	224 PSI at design flow

Flow envelope	2,083 GPM (one pump min) – 5,671 (one pump max) – up to 20,432 GPM (full station)
Design flow	17,014 GPM
Temperature	32 °F – 90 °F (lake-temperature seasonal range)
Cavitation number	σ = 0.19 (severe range; 0–1 zone)
Restrict Flow part	Anti-Cavitate Orifice Plate™, P/N ACP24CS1375300
Plate material	Carbon steel
Plate thickness	1.375 in. installed between flanges (18 in. of flange separation required for insertion)

How the project came to Restrict Flow

PKG Contracting reached out to Restrict Flow in April 2023 on a referral from **Stantec Corporation**, an engineering and design consultancy on the project. The original conversation centered on whether a dedicated restriction element would be needed at all on the Snake Creek discharge spool. Restrict Flow's analysis of the supplied design data returned σ = 0.19 and confirmed that the service would cavitate without a properly sized restriction. The project subsequently paused on funding while alternative approaches were explored. None of the alternatives delivered the required pressure drop within the available pipe envelope. PKG re-engaged Restrict Flow in November 2025; Restrict Flow issued the formal proposal and PKG placed the order. The Anti-Cavitate Orifice Plate (P/N ACP24CS1375300) shipped on schedule and was delivered to the project staging address in Coleharbor, North Dakota in January 2026, ahead of the customer's required commissioning window.

Status: supplied for commissioning; field validation pending

This case study is being published ahead of the formal commissioning run. As of the publication date, installation and pump commissioning are scheduled for the same week. Restrict Flow will issue a Phase 2 addendum to this document once commissioning has been completed and field data — pressure measurements, vibration and acoustic measurements, and post-commissioning visual inspection of the plate and downstream piping — are available. The addendum will be appended to the published version of this case study at restrictflow.com.

About Restrict Flow LLC

Restrict Flow LLC designs and manufactures custom restriction orifice plates and the Anti-Cavitate Orifice Plate™ for industrial, power, marine, nuclear, paper, pharmaceutical, and petrochemical piping systems. The company's Chief Engineer, Jeff Chappel, is a former NASA Johnson Space Center project manager and was the founding engineer behind a nuclear flow-element company whose flow elements were applied in nuclear cooling system applications and advanced reactor development programs. Restrict Flow operates from Friendswood, Texas, is a Service-Disabled Veteran-Owned Small Business (SDVOSB), and serves clients across federal, municipal, and private-sector piping infrastructure.

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