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Via WQWebPortal Electronic Filing April 15, 2024

WA State Department of Ecology
Central Regional Office
1250 West Alder Street
Union Gap, WA 98903-0009

Subject: **Wells Hydroelectric Project NPDES Waste Discharge Permit No. WA0991031; 2023 Environmentally Acceptable Lubricant (EAL) Annual Report**

Dear Ecology,

The Public Utility District No. 1 of Douglas County (Douglas PUD) respectfully submits to Washington State Department of Ecology (Ecology) the 2023 Environmentally Acceptable Lubricant (EAL) Annual Report, pursuant to requirements within Section S10.B of the National Pollutant Discharge Elimination System (NPDES) Wastewater Discharge Permit No. WA0991031 issued to the Wells Hydroelectric Project on March 7, 2022.

Various sections of the Permit require Douglas PUD to submit plans and/or reports for Ecology's review and approval. As such, please indicate your receipt of this document and provide comments and/or suggested revisions, should they exist, within 30 days of receipt. If Ecology has no comments, please indicate approval of the document attached herein toward meeting the terms and conditions of Section S10 of the permit. In the absence of receiving formal comment(s) from Ecology, Douglas PUD will assume the document to be final. If you have any questions, please contact me at 509-881-2323.

Respectfully,

Andrew Gingerich
Natural Resources Supervisor
andrewg@dcpud.org

Cc: Andrea Jedel – Ecology
Keith Primm – Ecology
Gary Ivory – Douglas PUD
Shane Bickford – Douglas PUD
Mariah Mayfield – Douglas PUD
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Attachment A. Environmentally Acceptable Lubricant (EAL) Annual Report dated April 2024 for the Wells Hydroelectric Project No. 2149

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) WASTE DISCHARGE PERMIT NO. WA0991031

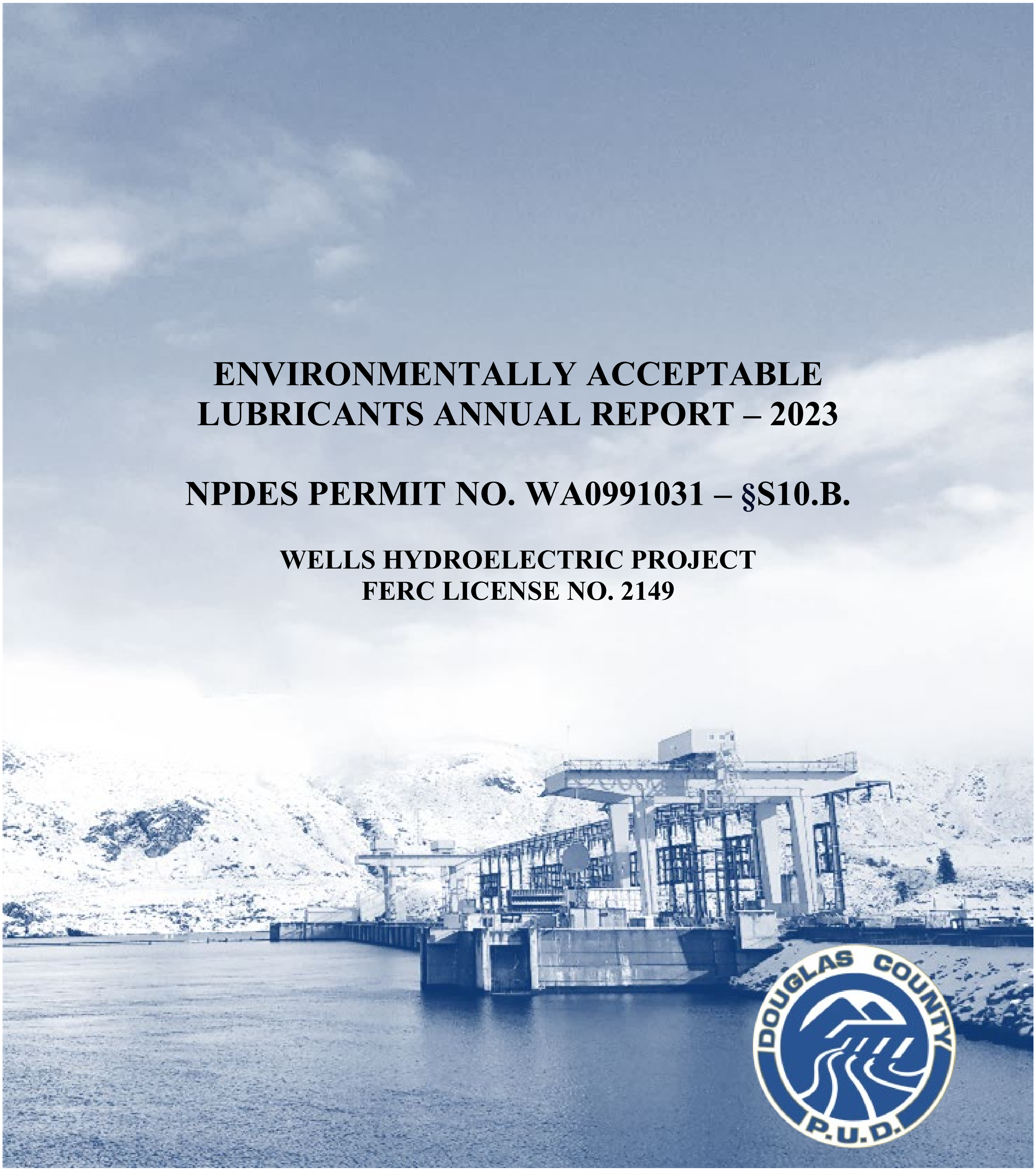
ATTACHMENT A

ENVIRONMENTALLY ACCEPTABLE LUBRICANT (EAL) ANNUAL REPORT DATED APRIL 2024 FOR THE WELLS HYDROELECTRIC PROJECT NO. 2149

ENVIRONMENTALLY ACCEPTABLE LUBRICANTS ANNUAL REPORT – 2023

NPDES PERMIT NO. WA0991031 – §S10.B.

WELLS HYDROELECTRIC PROJECT
FERC LICENSE NO. 2149



April 2024

Public Utility District No. 1 of Douglas County

1151 Valley Mall Pkwy, East Wenatchee, Washington 98802

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1.0 INTRODUCTION

The Wells Hydroelectric Project (Wells Project) is owned and operated by the Public Utility District No. 1 of Douglas County (the District) under the articles of the license issued for Project No. 2149 by the Federal Energy Regulatory Commission, and subsequent Amendments. Wells Project is the chief generating resource for the District and customer owners. The design of Wells Project features ten generating units with a nameplate rating of 832MW and a peaking capacity of approximately 840MW. The Wells Project impoundment structures (dam) include a centrally located concrete structure known as a Hydrocombine, with two earth dam embankments between the abutments. The reservoir created by the Wells Project (Lake Pateros) extends approximately 30 miles upstream to Chief Joseph Dam. The right (west) bank development at the dam is comprised of an earth and rockfill embankment approximately 40 feet in height and about 2,300 feet long. The left (east) bank development consists of an earth and rockfill embankment, approximately 160 feet in height at its maximum section approximately 1,000 feet long. Between the two embankment sections are the concrete structures, including two fish passage facility structures separated by a 1,000-foot Hydrocombine. The Hydrocombine is a series of eleven spillway bays uniquely integrated with ten generating units. Spillway bays are designed to pass water between the generator silos. The turbine unit intakes are deeper than the spillway between 75-135ft below reservoir elevation. Figure 1 below shows the Hydrocombine with the spillways, generating silos, fish passage facilities, and the west and east embankments:

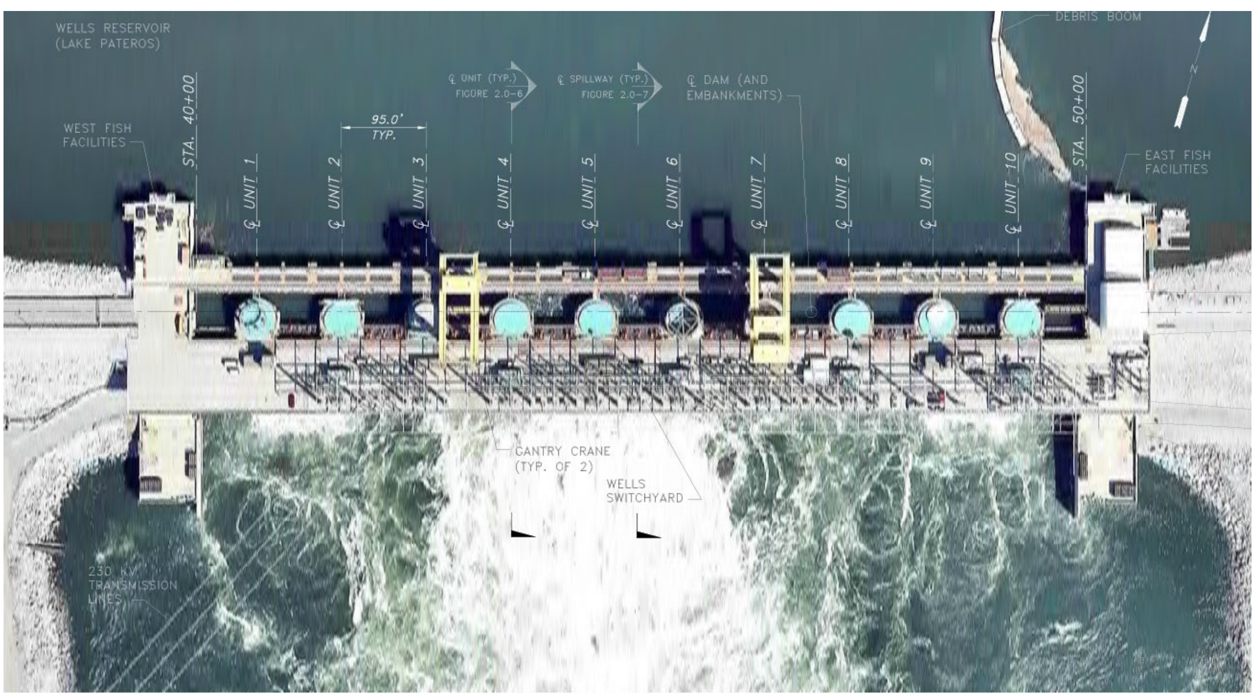


Figure 1. Wells Hydroelectric Project Overview

2.0 REPORT OBJECTIVES

The District was issued a National Pollutant Discharge Elimination System (NPDES) Waste Discharge Permit for Wells Project by the Washington State Department of Ecology (WDOE) on March 7, 2022 (WA0991031 i.e. "Permit"). This permit requires the District to prepare an annual Environmentally Acceptable Lubricant (EAL) report as discussed in §S10.B and found under the Oil, Grease, and Lubricant Management Section of the Permit:

> *The permittee must select Environmentally Acceptable Lubricants (EALs) for all oil to water interfaces including wicket gates, bearings, lubricated wire ropes, generators and other in-line equipment, unless technically infeasible.*
>
> *EPA defines technically infeasible as "no EAL products are approved for use in a given application that meet manufacturer specifications for that equipment; products which come pre-lubricated (e.g., wire ropes) and have no available alternatives manufactured with EALs; or products meeting a manufacturer's specifications are not available."*
>
> *EALs are lubricants demonstrated to meet standards for biodegradability, toxicity, and bioaccumulation potential that minimize their likely adverse consequences in the aquatic environment, compared to conventional lubricants.*
>
> *The permittee will utilize Environmentally Acceptable Lubricants (EAL) unless technically infeasible and submit an Annual EAL Report:*
>
> *1. Identify which equipment uses Conventional versus Environmentally Acceptable Lubricants.*
>
> *2. An evaluation of the technical feasibility for using EALs for each equipment;*
>
> *3. Develop a timeline for converting appropriate equipment to EAL usage.*

This report satisfies these requirements with a discussion on important conversion considerations for EAL use in hydropower equipment and what constitutes in-line or oil to water interface equipment at the Wells Project. It discusses what equipment meets this definition and the type of lubricant that equipment currently uses. Subsequently, the report provides technical feasibility evaluations for EAL conversions in the Wells Project in-line equipment. Finally, it provides conversion schedules and timeline for conversion as applicable.

3.0 OVERVIEW OF EALS AND HYDROPOWER

3.1 Definition of an EAL

The United States Environmental Protection Agency (USEPA) broadly defines EALs as lubricants that meet standards for biodegradability, toxicity, and bioaccumulation when introduced into the natural aquatic environment (USEPA 2011). This report refers to these properties as environmental release properties. However, when labeling EAL on products, lubricant manufacturers commonly use different standards or criteria for establishing environmental release properties. Given the lack of official convention, it is important to clearly define what is considered an EAL in this report.

In the United States, EAL usage is defined and regulated by USEPA specifically for the marine vessel industry through USEPA's 800-R-2-002 report, the Vessel General Permit (VGP) program, and the developing regulations subsequent to the Vessel Incidental Discharge Act (VIDA). In Europe, EALs are largely defined by a series of European Eco-labeling certification programs including Blue Angel, Nordic Swan, Swedish Standard, and European Eco-label programs (Kinectrics Inc. 2020). Some of these programs are also recognized as EAL defining standards by the USEPA (USEPA 2013). Although these programs are not specific to the Hydropower industry, it is consistent with other hydropower owner utilities, such as the United States Army Corps of Engineers (USACE), to define EALs as lubricants which have either

a) been classified as USEPA Vessel General Permit (VGP) compliant,
b) have acceptable test data specified in USEPA 800-R-2-002 or VGP Appendix A, or
c) have a European Ecolabel certification (USACE 2016a).

Though slight differences still exist between these programs, this definition establishes more consistent environmental release property criteria in order to achieve the label of an EAL. In addition, the USACE also further suggests categorizing EALs into two tiers. Tier 1 EALs fully meet the above requirements regarding environmental release properties and Tier 2 EALs only meet some portion of these requirements (Medina 2018). This report uses this USACE definition to define EALs as either Tier 1 or Tier 2 accordingly.

3.2 Considerations For EAL Conversions in Hydropower Equipment

3.2.1 Definition of Technical Feasibility

The definition of technical feasibility of EAL implementation provided in the Wells Project NPDES Permit and reiterated in Section 2.0 of this report emphasizes evaluating the ability of EAL products to meet equipment manufacturer lubrication specifications. Thus, the technical feasibility of EAL implementation is based on the ability of equipment to function as intended while using EALs. However, due to the intrinsic differences between conventional lubricants and EALs, achieving intended equipment functionality when using EALs in equipment that was designed for conventional lubricants is not a simple feat. The following considerations are necessary for any EAL to achieve intended equipment functionality in hydropower equipment that was not designed for EAL use.

3.2.2 Manufacturer Endorsement

Prior to performing an EAL conversion in equipment which was designed for conventional lubricants, the Wells Project should obtain specific EAL product endorsement and necessary conversion procedures from a candidate system equipment's manufacturer or designer. Proceeding with an EAL conversion without such endorsement or proper conversion procedures will increase the risk of equipment damage and malfunction. Doing so could also void a manufacturer's warranty. There are well documented hazards with performing conversions of mechanical equipment from conventional lubricants to EAL lubricants. These are discussed below in this report. Equipment manufacturer endorsement will in many cases be difficult or impossible to obtain. Much of the Wells Project in-line equipment was designed and built decades ago, and many manufacturers have since disappeared. In addition, many modern hydropower equipment manufacturers are unwilling to endorse EAL products in new or existing equipment due to liability and technical feasibility risks.

3.2.3 Dam Safety Implications

When considering EAL conversions, the District must consider the critical functionality of equipment that has implications for dam safety. Dam safety refers to the dam's safe and reliable regulation of the Columbia River and the protection of human life. If equipment is necessary for dam safety or affects the redundancy of any other equipment with dam safety implications, it should be considered *Critical*. If critical equipment is endangered from the hazards discussed below, it will be considered infeasible for conversion to an EAL.

3.2.4 System Compatibility

System compatibility is of great concern when considering EAL conversions of existing hydropower equipment. System compatibility refers to how the EAL will chemically react when introduced into existing equipment. There are at least five different commonly known areas of compatibility issues when performing conventional oil to EAL conversions in hydropower equipment:

First, internal coatings are often used inside hydropower hydraulics or lubricated equipment to provide surface protection and maintain useful service life of equipment. Coatings exposed to chemically incompatible EALs may break down or dissolve (Smith n.d.). This would leave contamination in the lubricant and lack of surface protection on internal surfaces.

Second, seals, including O-rings and gaskets, are a common method of joining or sealing piping and opposing faces of hydraulic hydropower components. Commonly used seal materials exposed to incompatible EALs are known to swell and rupture. Thus, a system that may be operating normally prior to an EAL conversion from conventional lubricants, may develop massive leaks shortly afterwards (Smith n.d.). Leaks especially in high pressure equipment may also endanger human life.

Third, to perform a conversion of an in-service piece of equipment, the existing conventional oil must be drained and flushed out and replaced with the new EAL. Even brand-new equipment will commonly be filled with conventional lubricants for testing purposes that also must be flushed before EALs can be used. Flushing will inevitably introduce the new EAL and conventional lubricant together. Improper chemical compatibility between these two lubricants can lead to foaming and the creation of varnish or sludge. Even small amounts of additives used in conventional oils can lead to incompatibilities with EALs. For example, zinc additives are commonly used for anti-wear properties and oxidation inhibition, but they can cause EALs to solidify (WSU 2013). Most manufactures consider their additives proprietary making it very difficult to compare EALs for compatibility with an existing conventional lubricant (Acres International Ltd. 2005). In addition, most EALs cannot be contaminated with more than 5% conventional lubricant products before their environmental release properties will be entirely voided. Some EAL lubricants can only be compromised by 2% conventional lubricant products (WSU 2013). Achieving this level of cleanliness from conventional lubricants during an EAL conversion may be unachievable in certain hydropower systems.

Fourth, conventional lubricants deposit solidified residuals and lubricant impregnation inside equipment or piping. Solidified residuals do not interfere with the operation of the equipment when using conventional lubricants. However, many EALs are known to cause these residuals to dissolve and enter a converted lubrication system. These residuals are known to react with EALs causing lubrication degradation, oxidation, gelling, or acidification (WSU 2013). Even if equipment is thoroughly cleaned and even sandblasted, impregnated lubricant will continue to weep out of the metal. Both dissolved residuals and impregnated lubricant can also void an EAL’s environmental release properties.

Fifth, plant interconnectivity is a compatibility concern for EAL use in lubricant distribution systems. Hydropower plants, including the Wells Project, are commonly designed with extensive lubrication distribution networks that are interconnected across the entire plant. Due to the existing design of the infrastructure and the compatibility issues described above in this section, it would be infeasible to perform a conversion of only singular components of an interconnected system. Thus, entire plant wide systems must be converted or replaced at once.

3.2.5 System Susceptibility to Contamination

A fundamental consideration for performing EAL conversions in hydropower equipment is determining a candidate system's susceptibility to contamination. EALs may meet all of the physical operating performance characteristics necessary for a candidate system in a clean, controlled laboratory environment for relatively short test durations. Nevertheless, since EALs are inherently formulated to degrade in the presence of the natural environment, equipment that is susceptible or actively exposed to water, bacteria, sunlight, air, sediment, or conventional oil residuals is at risk of unwanted EAL degradation. Degraded EALs will no longer meet the minimum physical characteristic requirements for any hydropower equipment. Degrading EALs can also become acidified leading to direct damage of seals and large system leaks (Smith n.d.). Degradation of EALs will ultimately lead to system damage, malfunction, and or failure, and systems that are exposed or have susceptibility to contaminants will be considered infeasible for conversion to EALs.

3.2.6 EAL Formulations Categories and Performance Properties

EAL's must possess the physical lubricant operational performance characteristics required for that equipment. For mechanical hydropower equipment, these characteristics may include lubricity, viscosity, moisture content, acidity, foaming resistance, air release, stability, water separation, corrosion inhibition, anti-wear, pour point, useful life, and oxidation stability. Further, while it is common for hydropower equipment manufacturers to not fully define all the necessary lubricant physical characteristic requirements for their equipment to the customer, generalized lubrication industry standards do exist for Hydropower equipment. The USACE's Lubricants and Hydraulic Fluids Engineer Manual 1110-2-1424 is an industry accepted resource for compiling test standards for lubricants like turbine oil, hydraulic fluid, gear oil, and grease for use in hydropower.

Manufacturers of EALs may advertise data showing successful completion of at least some of these laboratory tests. It is considered best practice to have potential EAL candidates tested by third party laboratories for physical characteristics validation. However, during evaluation of EALs, physical characteristic validation for the Wells Project's in-line equipment should only be performed if a candidate system was first found feasible through all other considerations described in this report.

EAL chemical formulations will affect the physical lubricant performance properties. Generally, EALs are categorized into four base solution chemical structures: 1) vegetable oils, 2) polyalkylene glycols or polyglycols, 3) synthetic esters, and 4) polyalphaolefins or isoparaffins. Some products contain various mixtures of different base stocks or have base stocks that do not fit in any of these categories such as water-based EALs (Acres International Ltd. 2005). EAL base stocks typically make up 96-99% of a lubricant and the remaining 1-4% consists of various additives used to meet necessary performance physical characteristic properties (Kinectrics Inc. 2020). Pure base substances tend to be composed of organic molecules that have the capability to biodegrade, but lubricant additives tend to be inorganic particles that will not biodegrade. Lubricant additives also often have high potential to bio-accumulate in aquatic organisms (Acres International Ltd. 2005). Thus, the addition of necessary physical performance enhancing additives to an EAL formulation is often in opposition to achieving the desired environmental release properties of an EAL. Using an EAL in the Wells Project's in-line equipment may require physical performance property concessions which an equipment manufacturer should endorse.

The following sections and Figure 2 discuss some of the different attributes of each EAL category that pertain to hydropower and dam equipment.

3.2.6.1 Vegetable Oil Lubricants (HETGs)

Vegetable oil-based fluids (Hydraulic Environmentally compatible Tri-Glycerides or HETGs) made from canola, sunflower, corn, soybeans, and other plants have excellent biodegradability, minimal toxicity, and provide good lubrication. The base oils are usually compatible with conventional oils, but additives have potential to be incompatible. As a lubricant category, they are highly prone to oxidation leading to the formation of sludge or solidified gel. HETGs tend to have 50% less service life than conventional oils and cost 2 to 3 times more. HETG's typical low end operating temperature ranges can also produce restrictions for outdoor operational use (Acres International Ltd. 2005) (WSU 2013). Finally, HETGs are known to cause petroleum sediments to dissolve leading to clogged systems (USACE 2016a). HETGs are the most susceptible to hydrolysis or water assisted degradation compared to other EALs (WSU 2013).

3.2.6.2 Polyglycol Lubricants (HEPGs)

Polyglycols (Hydraulic Environmentally compatible Polyalkylene Glycols or HEPGs) are polymers of ethylene or propylene oxides. HEPGs have been used in construction equipment for decades and exhibit good performance characteristics such as lubricity, viscosity, aging performance, and thermal stability. However, HEPGs are highly soluble in water and are incompatible with petroleum oils and certain types of seals, especially polyurethane seals. Extra special care must be taken when converting a conventional oil system to use HEPGs because HEPGs will remove deposits left by petroleum lubricants resulting in production of varnish. Finally, they are typically 2 to 3 times more expensive than conventional lubricants (Acres International Ltd. 2005) (WSU 2013).

3.2.6.3 Synthetic Ester Lubricants (HEESs)

Synthetic esters (Hydraulic Environmentally compatible Ester Synthetics or HEESs) are byproducts of animal fat or vegetable oil and alcohols. While not as good as vegetable oils with respect to biodegradability and toxicity performance, HEESs tend to have better environmental release properties compared to HEPGs or HEPRs. HEESs can be used in a wider operating range of temperatures than vegetable oils and generally have good viscosity, lubricity, anti-wear performance, and oxidative stability when not exposed to contamination (Acres International Ltd. 2005) (WSU 2013). HEESs can be either fully saturated or unsaturated. The latter is more prone to oxidation and low temperature gelling (WSU 2013). HEESs are known to have conversion incompatibilities with seals and coats. For initial cost, HEESs can be 3-6 times more expensive than petroleum lubricants (Acres International Ltd. 2002) (USEPA 2011). HEES base oils are usually compatible with petroleum oils but can cause residual petroleum sediments to dissolve and enter the lubricant. Finally, HEESs are susceptible to hydrolysis (WSU 2013).

3.2.6.4 Isoparaffin Lubricants (HEPRs)

Isoparaffins or Polyalphaolefins (Hydraulic Environmentally compatible Poly-Rs or HEPRs) are highly refined petroleum products that are commonly used in the automotive industry and have good viscosity, thermal operating range characteristics, oxidative stability, and are generally compatible with conventional oils. Disadvantages with HEPRs include possible incompatibilities with seals and gaskets leading to seal failure. HEPRs generally perform worse in environmental release property testing when compared to all other EAL products, even to the point of not meeting the definition of an EAL in this report (Acres International Ltd. 2005) (WSU 2013).

Parameter	Hydraulic Fluid Type			
	Vegetable Oil (HETG)	Synthetic Ester (HEES)	Polyglycol (HEPG)	PAO & Related HEPR
Viscosity Index ASTM D2270	100-250	120-200	100-200	140-160[1]
Water solubility	Low solubility	Low solubility	Soluble[2]	Low solubility
Miscibility (mixing) with Mineral Oil	Good	Good	Not Miscible[2]	Good[3]
Low temperature performance	Weak	Good	Good	Good
Oxidation resistance	Weak	Good	Good	Good
Hydrolytic stability	Low	Medium	Good	Good
Seal material compatibility	Limited/Good	Limited	Limited	Good
Paint compatibility	Good	Limited/Good	Limited	Good
Additive solubility	Good	Good	Moderate	Limited/Good
Lubricity of base fluid	Good	Good	Limited/Good	Limited/Good
Corrosion resistance	Poor	Limited/Good	Limited	Good
Renewability content	High	Variable	None	Variable
Biodegradability	Good	Good	Moderate/Good	Poor/Moderate/Good
Toxicity, LC50, (Rainbow) Trout, EPA 560/6-82-002	633 - > 5000	>5000	80 - > 5000	100 - >5000
[1]Bosch Rexroth AG Publication No. RE90221/05.10, "Environmentally Acceptable Hydraulic Fluids," p.9 [2]Solubility & miscibility ratings shown are for Polyethylene Glycol type PAGs. Polypropylene Glycol type PAG fluids are not addressed in the table. [3]Mortier, R.M., Fox, M.F., Orszulik, S.T., Chemistry and Technology of Lubricants, 3d e., Springer Science+ Business Media, p.268, 2010				

* ASTM D2270 defines methodology for determining a unitless viscosity index to compare the degree of change in viscosities due to temperature between petroleum products. Lower values indicate a lubricant is more susceptible to viscosity property changes due to temperature changes. The ASTM D2270 index value Shell T68, the current turbine oil used at Wells Project, is 105 (Shell 2013).

* LC50 is the concentration required for 50% mortality of test specimens within 96 hours of exposure as discussed above.

(USACE 2016a)

Figure 2. EAL Attributes by Base EAL Type

3.2.7 Alternatives

During determination of the feasibility of converting equipment from conventional lubricants to EALs, alternative strategies should be considered. Consideration of alternative strategies will both mitigate the risk of discharges into the aquatic environment and the risk of damage to equipment. These strategies may include installation of additional containment measures or relocation of equipment. Likewise, alternatives may also include increasing inspection frequency or maintenance activities.

3.2.8 Logistics

While this report focuses on evaluating technical aspects of EAL conversions, it should be noted that there are other logistical considerations for performing EAL conversions in the Wells Project's equipment including the production capabilities of EAL manufacturers, long-term sustainability of the EAL manufacturer businesses or product lines, and the increased costs to the District. Many EAL products are relatively new and have been created by smaller organizations or research teams, which may not have the necessary backing from corporations with the ability to manufacture the quantity of EAL's that are needed in equipment at the Wells Project. Small or new organizations pose an additional risk of not being able to provide a particular EAL product over the decades of particular equipment's useful life. If a manufacturer went out of business or discontinued a particular EAL product, it would force the District to perform another complicated and hazardous conversion process. Finally, EALs are significantly more expensive than conventional lubricants, both in terms of upfront costs and frequency of replacement. EAL products are also unlikely to be able to achieve the same useful life as conventional lubricants in the Wells Project's in-line equipment, meaning the District would need to purchase higher quantities of lubricant than it does currently. Thus, operational costs for in-line equipment may be substantially higher if EALs are used.

4.0 CONVENTIONAL VERSUS EAL USE IN THE WELLS PROJECT IN-LINE EQUIPMENT

The District understands that the WDOE considers in-line or oil-to-water interface equipment to be all equipment that by design will cause a lubricant discharge by bringing lubricant into direct contact with the waters of the Columbia River. Under §S10.B of the Wells Project NPDES Permit, in-line or oil-to-water equipment must be investigated by the District for the purposes of understanding the feasibility of conversion to EALs. Equipment that meets this definition is included in Table 1 as *Direct* discharge types.

In addition, the District has included additional evaluations for equipment subject to immersion or that is located over water and during normal operation could plausibly experience a malfunction of a singular wearing component leading to an indirect discharge into the waters of the Columbia River. This is considered an *Indirect* discharge type in Table 1. These additional evaluations exclude equipment which would require multiple successive failures, failures of non-wearing parts, or significantly abnormal or catastrophic events for a discharge to occur. Table 1 also includes the lubricants that both direct and indirect in-line equipment at the Wells Project currently uses.

Table 1. Wells Project In-line Equipment

	Equipment	Lubrication Product Used	Current Status
Direct Discharges	Wire Rope and Lifting Equipment - Gantry Cranes Wire Rope - Spillway Gate Hoists - Spillway Flap Gate Hoists - Draft-tube Gates and Hoists - Unit Intake Trash Rake - Spill gate Lifting Beams - Intake Gate Lifting Beams - Stoplog/Trashrack Lifting Beams	Rope Lubricant: Wirelife Monolec Penetrating Lubricant 2001 Rope Sealer: Wirelife Almasol Coating Lubricant 2002 Rope Sealer: Lloyds Laboratories Loobit Multi-Duty Grease: Shell Mallus GL 500	Conventional Conventional Conventional Conventional
Direct Discharges	Wicket Gate Bushings - Unit Turbines - Fish Collection Chamber Pump Turbines	Mobil SHC 101 Panolin Biogrease EP1	EAL Tier 2 EAL Tier 1
Indirect Discharges	Turbine Oil Systems	Shell T68 Turbine Oil	Conventional
Indirect Discharges	Thrust Bearing Systems	Shell T68 Turbine Oil	Conventional
Indirect Discharges	Gearbox Systems - Spillway Gate Hoists - Flap Gate Hoists - Draft Tube Gate Hoists - Gantry Cranes	Shell Omala HD 220 Shell Tellus Pre. 46 Shell T68 Turbine Oil Shell Spirax HD 80-90	Conventional Conventional Conventional Conventional
Indirect Discharges	Gate Wheels - Spillway Gates - Intake Gates - Spillway Bulkhead Gate	Shell Gadus V220C	Conventional

5.0 TECHNICAL FEASIBILITY OF EAL CONVERSION IN THE WELLS PROJECT IN-LINE EQUPMENT

5.1 Wire Rope and Lifting Equipment

Lubricant is an essential component of wire rope. Wire ropes are made by wrapping a series of small steel strands together helically to form larger strands. Then larger strands are helically wrapped around a core strand. While wire ropes are in use passing over sheaves or drums, individual strands of a rope bend and flex differently from the adjacent strands causing friction and abrasion (see Figure 3). Lubrication is applied to the core and on the outer strands to protect the rope from this friction and abrasion as strands adjust. Additionally, various rigging operations at hydropower facilities require that wire rope be splashed or submerged in water. Lubrication prevents water from penetrating the rope's core and keeps the rope free of corrosion damage. Improper long-term care of a wire rope's lubricant can lead to failure from corrosion or abrasion related fatigue. The Wells Project uses wire ropes on gantry cranes, spill gate hoists, spillway flap gates, draft tube gates, and the unit intake trash rake.

Figure 3. Wells Project Spillway Hoist Wire Rope with Strand Adjustment Visible

The Wells Project spillway hoists are a critical component for safely regulating the flow of water through 7 of the 11 spillways at the Wells Project. These hoists allow plant personnel to quickly raise or lower the vertical leaf spill gates in the spillways. The hoists are stationary and use an electric motor and gearbox to retract or extend wire rope that is connected to the spill gates with load blocks.

Other hydropower plant facilities typically have separate cranes to provide service for unit intake gates, maintenance and construction inside the powerhouse, draft tube gates, and spillways. However, the integrated Hydrocombine design at the Wells Project requires the gantry crane equipment to multitask. The Wells Project's large gantry cranes are uniquely responsible for supporting maintenance and construction throughout the plant as well as regulating the spillways and turbine unit intake hydraulic structures. In the event that river flows exceed the amount that can be passed by the 7 lower leaf spill gates equipped with automatic hoists, the gantry cranes are required to operate the other 4 lower leaf gates. In the extreme event that river flows exceed this spill capacity, the gantry cranes are required for complete removal of all of the lower leaf and upper leaf spill gates. The Wells Project also uses the gantry cranes to install and remove the turbine unit intake gates, spill gate flap gates, sectional intake stoplogs, fish flow and bypass barriers, and trash racks at submerged depths of up to 135 feet.

The design of the Hydrocombine spillways prevented the addition of a lower crane deck on the downstream side of the dam, necessitating a unique solution for operating the tailrace (downstream of the turbine) draft tube dewatering gates. The Wells Project was designed with a gallery inside the dam that stores the draft tube gates called the draft tube gallery. Several crane trolleys inside of this gallery allow the draft tube gates to be stored or installed in different unit's draft tubes so maintenance can be performed. The gallery is below the normal water elevation of the tailrace so it must be pressurized to prevent water from backfilling the gallery. The draft tube hoists use wire rope to raise and lower the gates in their slots.

The Wells Project uses a trash rake to clean the turbine unit intake trash racks when upstream vegetation and other debris build up on the trash racks. This system is first hoisted with a gantry crane, and then the rake deploys a steel grappling style scraper blade that cleans the upstream faces of the unit intake trash racks. The blade is operated vertically with wire rope.

Load blocks, sometimes called block and tackles, are devices used with the Wells Project's lifting equipment and wire rope to reduce the required force needed to perform lifts. The Wells Project's load blocks have brass bushings that must be lubricated periodically to maintain proper lubrication and corrosion prevention. As discussed with wire rope above, these load blocks are submerged frequently during normal operations of hoisting the various gate structures at the Wells Project.

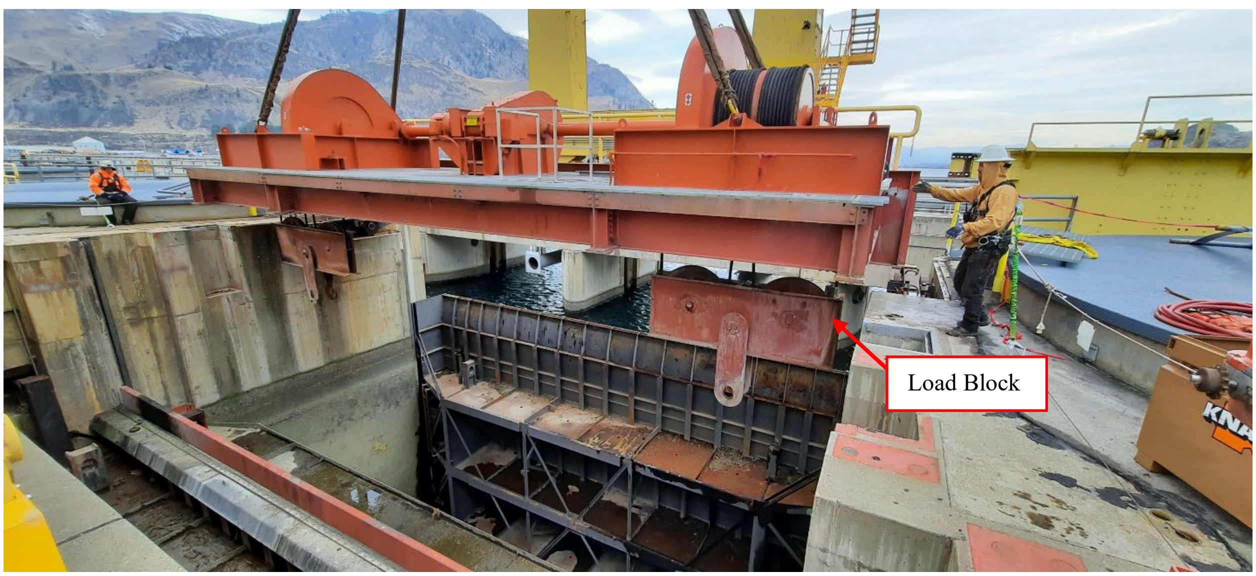


Figure 4 Wells Project Spillway Hoist Being Lifted Out of a Spillway

Figure 5 **Wells Project Lower Leaf Vertical Leaf Gate Connected to Gate Hoist with Wire Rope**

All of the Wells Project's hydraulic gate structures are hoisted with custom lifting beams. These devices allow crane hooks to interface with the picking points of different gates. These beams have large load bearing pins that serve as connection points between the lifting beam and crane. There are also other sliding mechanisms or rotating pivot points such as bronze bushings on these beams, which are lubricated by hand during periodic maintenance periods. Similarly, the Wells Project's draft tube gates have wheels that utilize bronze bushings that also require periodic lubrication maintenance.

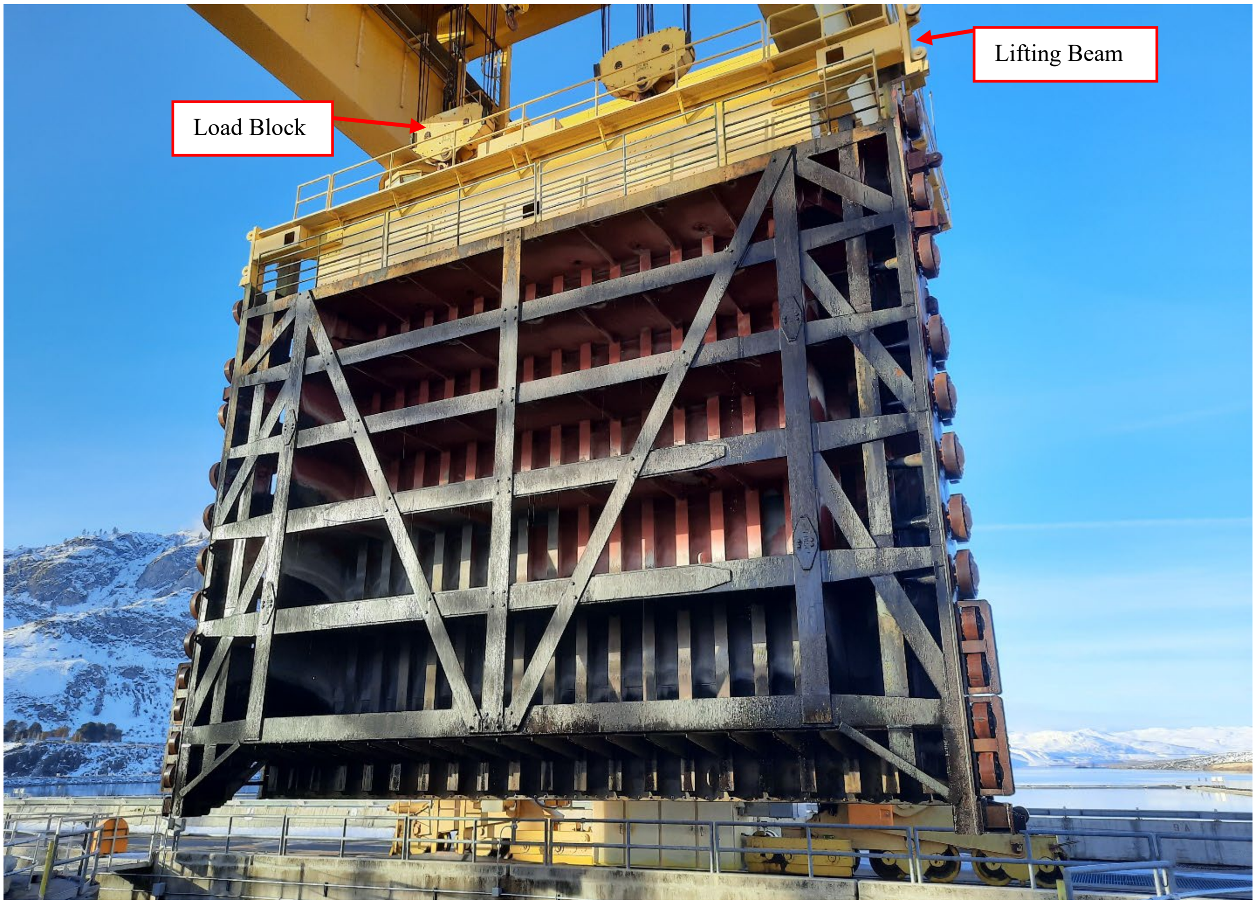


Figure 6. **Wells Project Gantry Crane Hoisting a Vertical Leaf Spill Gate using the Spill Gate Lifting Beam**

The Wells Project's Engineers evaluated the feasibility of using EALs on the wire rope and lifting equipment at the Wells Project and found conversions to be infeasible at this time for the following reasons:

Reason #1 – Contaminant Susceptibility

Research for this report found that the USACE recently initiated several one year long operational tests to determine the feasibility of using EALs on wire ropes, load blocks, and lifting beam equipment with in-service cranes at Bonneville and Ice Harbor Dams (USACE 2017). As a result of those tests, the USACE determined: "…EALs are not technically acceptable for application on wire ropes that are intended to be submerged water for extended periods of time. By design, EALs will biodegrade rapidly when exposed to an environment, such as the river, that contains organisms that will initiate biodegradation. The biodegradation is so efficient that the lubricant is not serviceable after 1 month of exposure" (USACE 2017). Similarly, the USACE stated that other lifting equipment including lifting beams and load blocks should not use EALs if it is subjected to frequent immersion service (USACE 2017). Due to this research and testing, the District believes that since the Wells Project has unique rigging service requirements that rely on significant water immersion during service, it is not feasible to convert wire ropes or other lifting equipment at the Wells Project to using EALs.

Reason #2 – Dam Safety Implications

Wire ropes and lifting beams and other lifting equipment are considered essential to the Wells Project dam and human health safety. Application of EALs on wire ropes and load blocks presents significant human safety and liability risk for the District. In the event that these equipment pieces become inoperable or have reduced functionality, dam safety requirement could no longer be met. Thus, wire ropes are considered critical and infeasible for conversion to EALs due to increased risk of operational malfunction or failure while using EALs.

Reason #3 – Lack of Manufacturer Endorsement

The District does not have original equipment manufacturer recommended EAL products for use in the Wells Project lifting equipment. While it is possible to decide to use EAL greases on wire ropes, many wire ropes are pre-lubricated from the manufacturer during manufacturing with conventional lubricants.

5.2 Wicket Gate Bushings

The Wells Project’s wicket gates control the flow of water through the Kaplan hydroelectric turbines and the Fish Collection Chamber Pumps. These gates are positioned radially inside the spiral case or scroll case around the inlet of the turbines. The wicket gates synchronously open or close increasing or restricting water passage through the turbine. Each gate has three bushings which support and align the upper and lower gate stems in place. These bushings require lubrication in order to prevent damage to the bushing materials from the wicket gate operation. This is accomplished with automatic greasing systems referred to as a Farval. The Farval systems pump grease into the upper bushings directly and down through the center of the wicket gate into the lower bushing. The lower and intermediate bushings are exposed to water washout so the greasing system must cyclically pump replacement grease.

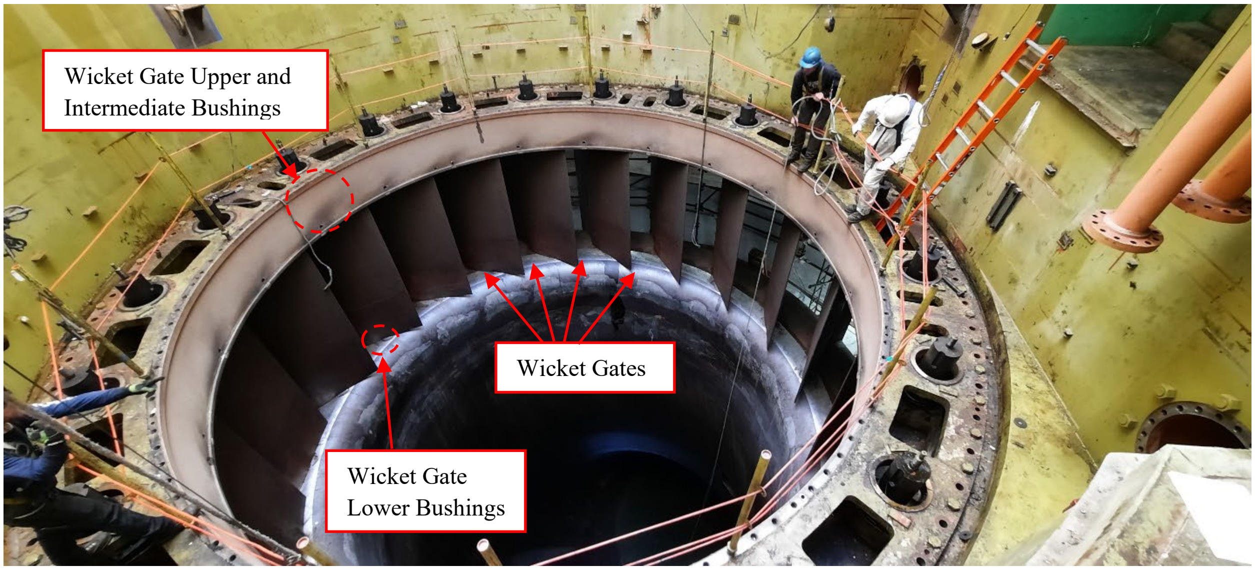


Figure 7. Wells Project Turbine Pit with Wicket Gates Shown During Construction without the Turbine Assembly

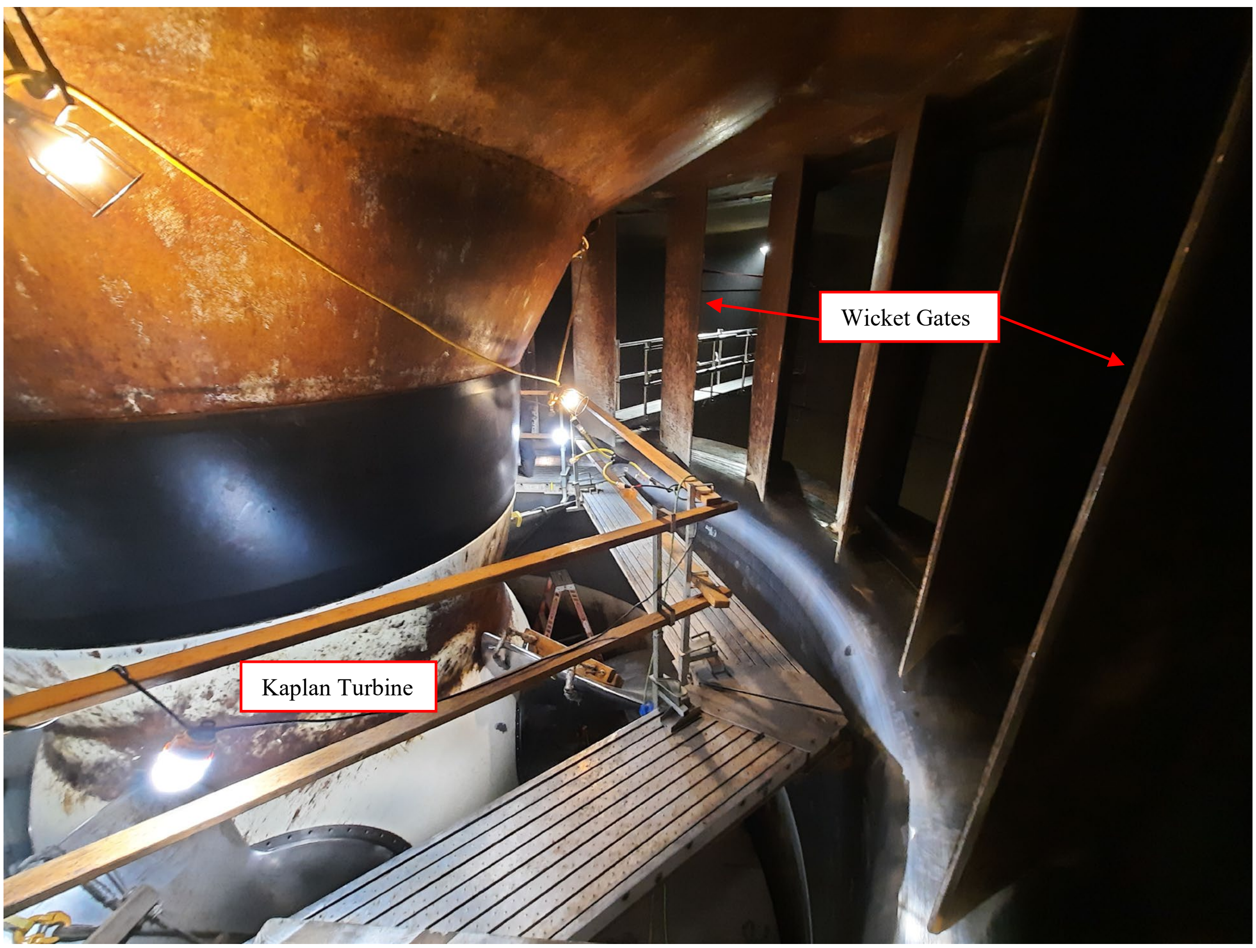


Figure 8. Wells Project Wicket Gates shown with Turbine Assembly Installed

In 2018, the USACE published their research of four different EAL greases that were tested in Farvals and wicket gate bushings at the Dalles Dam, Bonneville Dam, McNary Dam, and Lower Granite Dam. After the tests were finished, it was determined that the performance of the EALs were generally consistent with the conventional grease test control. Overall, there were no significant changes in the operational performance of the wicket gates during the test. The USACE concluded that Panolin Biogrease EP was the best performing grease for wicket gate bushings according to their testing (HDR 2018).

The Wells Project has previously converted its unit generator and fish pump wicket gate Farval systems to use a non-conventional “Environmentally Aware Lubricant” grease product which is defined by this report to be a Tier 2 EAL. In 2020, Wells Project performed a technical feasibility study for switching to a Tier 1 EAL product. Wells Project selected Panolin BioGrease EP grease as a feasible trial EAL candidate. During 2021 and 2022, Wells Project successfully tested this grease in one of the Wells Project generating units and is in the process of converting all wicket gate bushing Farval systems to use the Tier 1 EAL. An anticipated schedule for full plant implementation is included in Section 6.0.

5.3 Turbine Oil Systems

The Wells Project operates ten 84MW vertically mounted Kaplan turbine reaction units. Each Kaplan turbine is designed so that the angle of attack or pitch of the five blades adjusts synchronously via high pressure turbine oil. The unit governor regulates the flow of the turbine oil which travels through the oil head, down the inner pipes of the conjoined generator and turbine shafts, and into the turbine hub which is powered by the waters of the Columbia River. Inside the turbine there is an enclosed hydraulic cylinder with an internal stationary piston. Depending on the desired blade pitch, the governor allows high pressure oil to flow into a specific side of the hub piston which forces the surrounding cylinder to move up or down correspondingly. The top of the cylinder is connected to the turbine blades with rocking linkage arms which transmit the vertical motion of the cylinder into a rotating motion of the blades. Actuating the blades allows for power generation and water usage optimization at different desired power outputs and reservoir conditions.

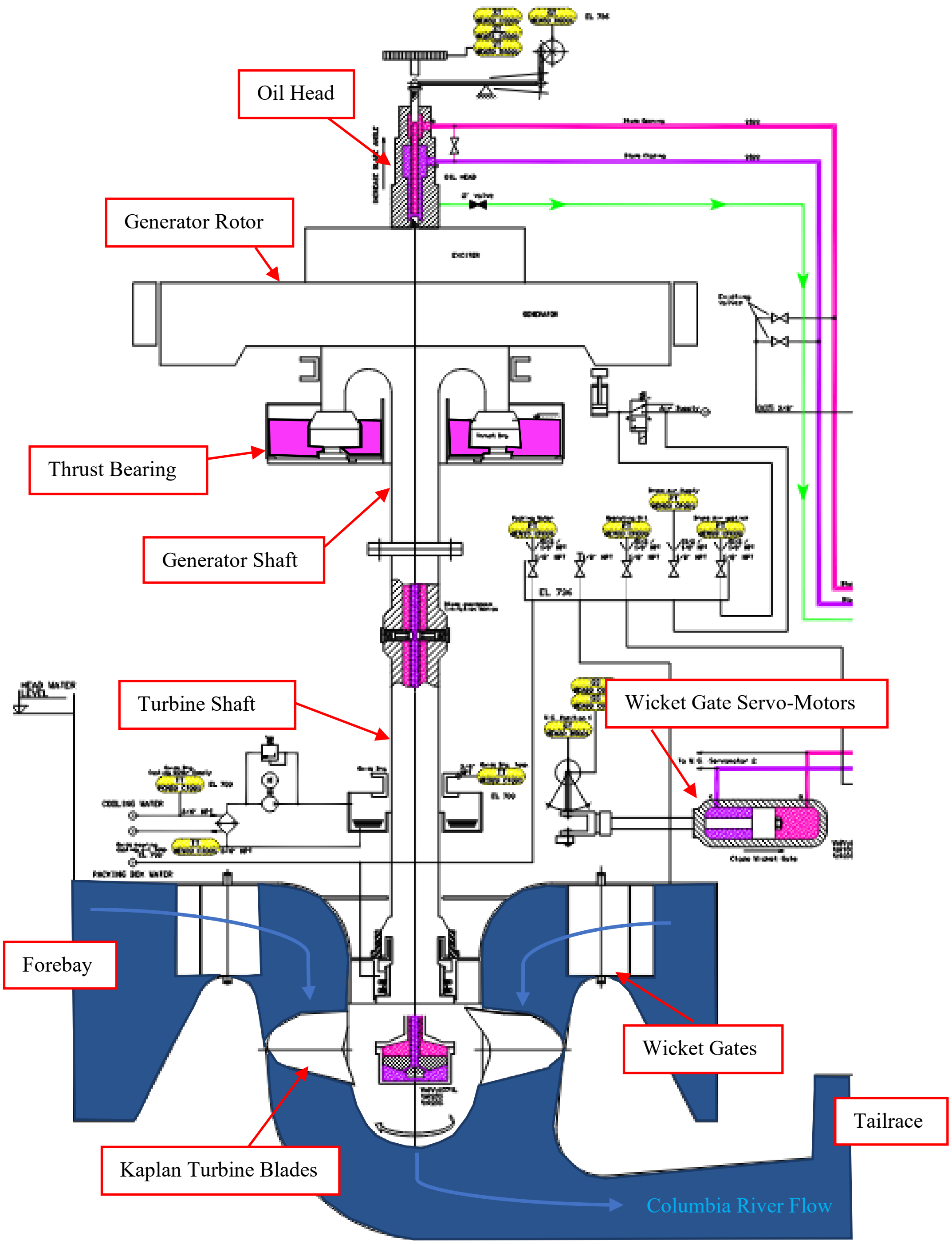
In addition to the turbine blade pitch, the governor controls oil flow into two linear motion servo-motors which rotate a circular beam called the operating ring. All of the wicket gates connect to this ring with linkage arms. One servo-motor will push and one motor will pull the operating ring horizontally thereby opening or closing every wicket gate synchronously to adjust the amount of water flowing past the turbine blades.

The governor makes automatic adjustments to the turbine blade angle and wicket gate position via feedback and control electronics. These electronic adjustments require small hydraulic valves and piping in the governor to allow for fine adjustment of oil pressure distribution. Each unit governor system can be supplied from the large oil storage tanks through the plant oil supply distribution plumbing. While the Kaplan turbine itself is the only in-line equipment element of this system, this entire system (Kaplan turbine, turbine shaft, generator shaft, oil head, governor, wicket gate actuating servo-motors, and supplemental systems) is hydraulically interconnected with turbine oil and is referred to as the Turbine Oil System for purposes of this report.

Figure 9. Wells Project Kaplan Turbine Assembly with Adjacent Headcovers ready for Installation

Turbine oil is retained inside the Kaplan turbine with special double blade trunnion seals around the outside of the turbine blades. These seals are a single piece and are installed with the blade at the time of turbine assembly. Over time, the turbine blade bushings can wear causing the blades to have a small amount of drooping or play. This typically leads to seal wear and ultimately seal leakage. However, during periodic maintenance periods, these seals are inspected to determine if they are functioning properly.

Figure 10. Kaplan Turbine Blade with Trunnion Seal during Assembly



(Turbine oil shown in purple and pink)

*Note: The thrust bearing is completely hydraulically isolated from the Turbine Oil System for the Kaplan turbine and the wicket gate servo-motors.

Figure 11. A Portion of Wells Project Turbine Oil System and Rotating Parts

The Wells Project Turbine Oil System has been evaluated for feasibility of EAL conversion. Below are the reasons why the system was found to be infeasible for an EAL conversion:

Reason #1 – Lack of Manufacturer Endorsement

There are no original equipment manufacturer recommended EAL products or conversion procedures for use in the Turbine Oil System. While the District is aware that EAL turbine oils exist that are advertised as meeting generally accepted laboratory performance standards for turbine oil, EAL's have additional intrinsic properties and limitations that necessitate equipment manufacturer design in order to maintain the essential turbine oil properties over the 40-year design life of the equipment. The original manufacturers of the Wells Project Turbine Oil System equipment (turbines - Fuji Electric Co., governors – Woodworth / American Governor, and remainder - Allis Chalmers / Voith Hydro) did not design the equipment with EAL properties and limitations in mind and thus cannot endorse EAL usage for the existing Wells Project equipment designs.

Reason #2 – System Incompatibilities

The Wells Project's Turbine Oil System is prone to chemical incompatibilities between new EALs and the Turbine Oil System's seals, internal coatings, and conventional lubricant residuals and lubricant impregnation. Consequences of adverse chemical reactions could lead to extensive damage to the Turbine Oil System including massive lubricant leaks and long, expensive outages for complete system teardown for cleaning and or repairs. The safety of plant maintenance and operational personnel could also be in jeopardy due to seal failures. In addition, Voith Hydro, the supplier of much of the Wells Project's Turbine Oil System by corporate acquisition, states that it is likely not possible to adequately clean existing Kaplan turbines from conventional oil (Smith n.d.). Voith Hydro has also told other hydropower utilities that they have no intention to stop testing new Kaplan turbines with conventional turbine oil during manufacturing (Bell 2022). Without the ability to clean out the conventional oil, an EAL's environmental release properties are likely to be voided after EAL conversion of the Turbine Oil System making a conversion of little environmental value.

Storage and distribution of EAL turbine oil is infeasible at the Wells Project. The Wells Project has large storage tanks, fire suppression systems, containments, and cleaning systems established for the conventional oil system which supplies the Turbine Oil Systems. The Wells Project could not utilize these existing systems for an EAL unless the entire plant was converted at one time. Such a large conversion represents an enormous risk to plant equipment. Instead, it would be more feasible for the Wells Project to prototype an EAL in a single unit Turbine Oil System for some period before converting other units. Additional storage tanks, piping, fire suppression, and filtering would need to be designed and constructed to supply this prototype system. This creates another feasibility issue as space and floor loading capacity is limited inside of the Wells Project plant.

Reason #3 – Contamination Susceptibility

Operating the Turbine Oil System with EAL turbine oil with inherent sensitivity to contamination would be a significant risk to the Wells Project's equipment. Contaminants that lead to EAL degradation inevitably ingress and collect in the Wells Project Kaplan turbines. The design of turbines does not allow for proper turbine oil filtering. With the exception of a small amount of oil which is pushed back to the oil head, the majority of oil in the Wells Project' turbine and shafts only shifts back and forth or remains static. Thus, prolonged exposure to contaminants is inevitable. If a small amount of water ingresses into the existing conventional oil in the turbine, it does not mix and will eventually return to the oil head and the rest of the system where it can evaporate. EALs that are exposed to water, will by design initiate degradation. According to the definition of an EAL discussed in this report, many accepted biodegradability standards stipulate that a majority of an EAL must be biodegraded within 28 days of exposure to the natural environment (Acres International Ltd. 2005). While the amount of contamination expected would be unlikely to cause an EAL filled turbine to degrade within 28 days, the District is concerned that the current turbine oil and equipment design life of 40 years would be severely limited if using EAL turbine oil due to contamination.

EAL degradation inside of the Turbine Oil System could cause a range of equipment damage and malfunction. Degrading EAL decomposes into byproducts including non-lubricating fluids and gases (e.g. carbon dioxide) that would be trapped in the turbine and would cause accelerated mechanical wear and improper corrosion prevention on internal turbine components. Corrosion increases the friction in the turbine operating components and increases the force that must be overcome by the governor system during blade pitch adjustment (Smith n.d.). Even minor degradation can cause consequential changes in acidity of the EAL. Acidified EAL could lead to complete failure of the blade's trunnion seals and massive leaking into the Columbia River. Also, Voith Hydro states that contaminant induced acidified EAL can lead to accelerated internal corrosion in Kaplan turbines (Smith n.d.). Degrading EALs can cause lubricant clumping or highly viscous residual gel formation (WSU 2013). If largescale clogging or gelling occurred inside of a turbine, it may require long and expensive outages for component disassembly needed to facilitate proper cleaning. The unit governor is even more susceptible to clogging and gelling as it uses much smaller piping and hydraulic valves. Clogged plumbing in a governor could lead to an inability to operate the governor properly. This is a plant safety hazard since the governor is the main mechanism for maintaining the proper velocity of the rotating equipment. Ultimately, since contamination is inevitable in the Wells Project's Turbine Oil System, using EAL lubricants that intentionally degrade in the presence of contamination is infeasible because of the significant risk of equipment damage.

Reason #4 – Design Alternatives Underway

The District is underway replacing the Kaplan turbine blade bushings used inside the turbine with specially coated self-lubricating Karon Bushings that are designed to reduce the friction between the rotating turbine blades inside their bushings and maintain proper lubrication over the spectrum of operating conditions. With decreased friction, Kaplan blade bushings wear more slowly thereby mitigating the risk of trunnion seal failure. Trunnion seal failure is the most likely cause of lubricant discharge to surface waters due to bushing wear (Pereira 2009). Given the emphasis on preventing oil discharge, and the new Karon Busing design, the risk of oil discharge is significantly reduced and, perhaps, addresses the challenges of using EALs in Wells Dam turbine unit. Moreover, these new designs are more protective and prevent oil discharges regardless of EAL status. A schedule for the new bushing implementation has been included in Section 6.0.

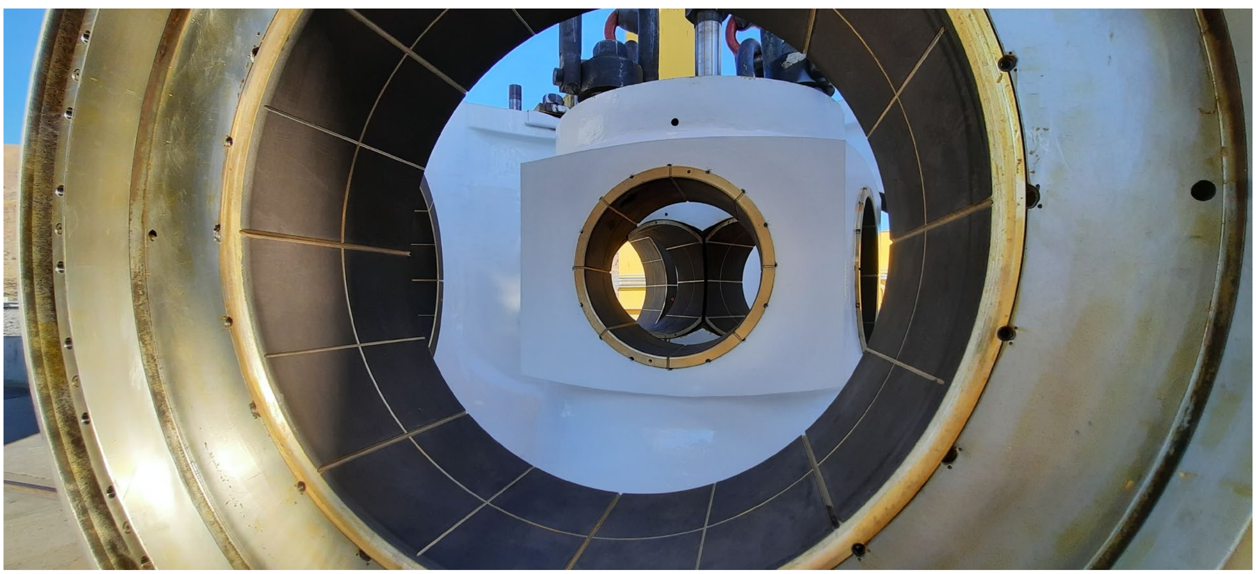


Figure 12. Wells Project New Karon Coated Kaplan Turbine Blade Bushings during Assembly

5.4 Thrust Bearing System

Each Kaplan turbine's rotating generator shaft is supported by the lower bracket assembly which forms an enclosure for the thrust bearing and generator guide bearing assemblies. The thrust bearing assembly consists of segmented shoes that support the vertical weight and down pull forces of the turbine. At the Wells Project, these vertical forces can exceed 3,000,000 pounds. Therefore, the design elements and assembly of these components is very sensitive. The generator guide bearing consists of radially spaced shoes around the perimeter of the generator shaft to provide horizontal stability to the rotating equipment. The Lower Bracket contains a turbine oil bath that provides necessary lubrication and heat dissipation for these bearings (See Figure 11 and 14). To remove heat from the oil, river water is piped to the water-cooled heat exchangers (coolers), which sit inside of the oil bath. There is no designed contact between the river water and the oil. These systems are collectively referred to in this report as the Thrust Bearing System.

The Wells Project's original Thrust Bearing Systems were built with copper cooling water plumbing and were susceptible over long periods of time to small pin hole leaks in the piping due to corrosion and internal erosion. During normal operation these leaks become quickly apparent because water in the cooling system, which is at a higher pressure than the oil during normal operation, fills the oil bath triggering both an alarm and an automatic unit shut down. Maintenance personnel can subsequently take the equipment out of service to fix the leak. Once the unit is shut down and the cooling water supply valve is closed, it is possible for a leak in the piping to allow relatively small amounts of turbine oil into the water filled piping. In conjunction to piping repairs, the District can then drain and flush this water out of the pipes to attempt to recapture as much oil as possible before the system is restored to operation.

Figure 13. Wells Project Thrust Bearing Housing and Shoe Components after 55 Years of Service

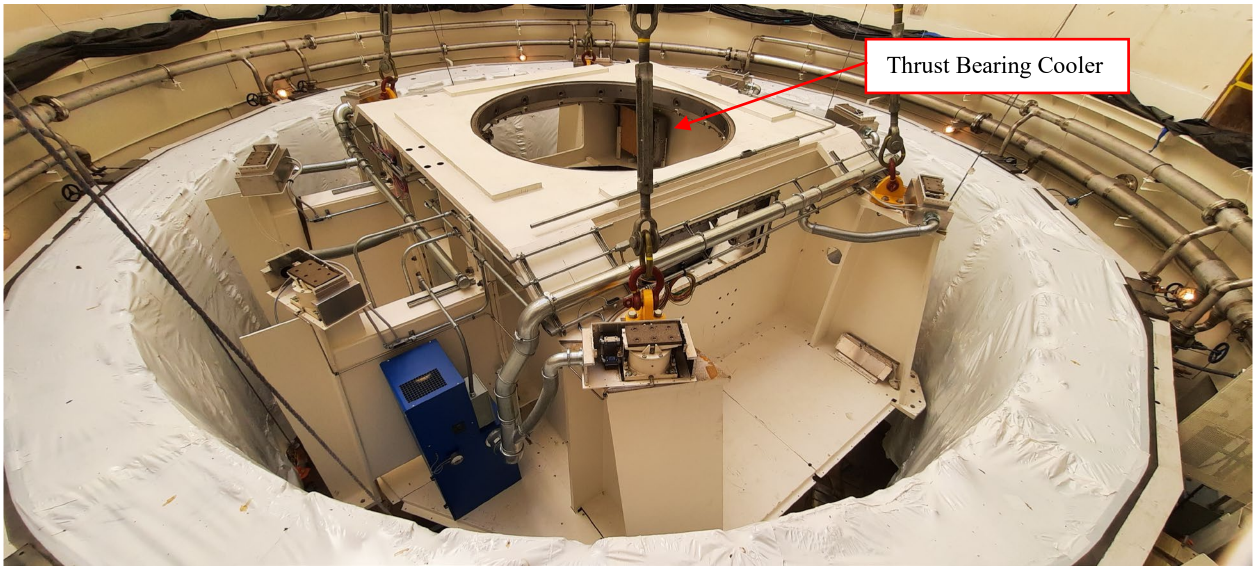


Figure 14. Installation of Wells Project Lower Bracket that Houses the Thrust and Generator Guide Bearings

The Wells Project Thrust Bearing System has been evaluated for feasibility of EAL conversion. Below are the reasons why the system was found infeasible for an EAL conversion:

Reason #1 – Lack of Manufacturer Endorsement

There are no original equipment manufacturer recommended EAL products for use in the Turbine Bearing System. The design of the Wells Project's thrust bearing uses complicated lubrication principles called hydrodynamic lubrication. While under rotation, the thrust bearing shoes pivot and balance allowing the turbine oil to create wedge shaped pressure distributions in-between the thrust bearing shoes and the generator shaft (See Figure 15). Metaphorically one might compare this process to a water ski boat's bow being pushed upwards as it moves through water (USBR 2004). The generator shaft thrust runner glides over these oil pressure wedges without making contact with bearing surfaces themselves. The District is concerned that different lubricants with slightly different physical properties could adversely affect this sensitive lubrication design, which is tailored specifically for the Wells Project. Adverse effects could include increases in operating temperatures, decreased useful life of components, and/or catastrophic damage to the bearings and generator shafts resulting in long and expensive repair outages. Further, the District is not aware that any turbine EALs have been tested or shown to be used successfully in similar hydrodynamic bearing applications.

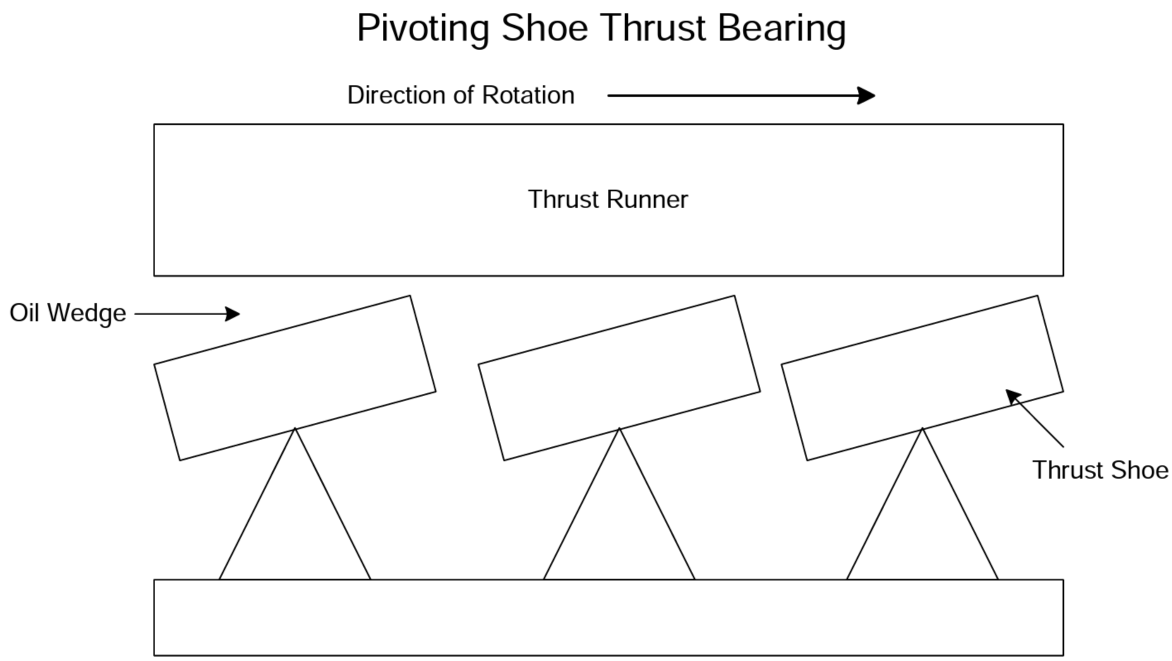


Figure 15. Diagram showing Thrust Bearing Shoes Pivoting to Create Hydrodynamic Lubrication

(USBR 2004)

Reason #2 – System Incompatibilities

Similar to the Turbine Oil System, the Wells Project's Thrust Bearing Systems are prone to chemical incompatibilities between new EALs and the internal coatings, seals, and conventional lubricant residuals. Consequences of adverse chemical reactions could lead to extensive damage to the thrust bearing system and cause long expensive repair outages.

Reason #3 – Contamination Susceptibility

Since cooler system leaks generally cause water to leak into the turbine oil bearing system during most operating conditions, the thrust bearing system would be at risk of damage if it used lubricants such as EALs that were highly susceptible to contamination induced degradation. Degraded EALs could quickly affect bearing performance and cause damage to the Trust Bearing System.

Reason #4 – Design Alternatives Underway

The Wells Project is already in the process of replacing the copper materials used in the cooling system piping with stainless steel materials, which are corrosion and wear resistant. Stainless steel piping will largely reduce the likelihood of pinhole leaks and keep the cooling systems "non-contact" with oil systems. Further, the plumbing receives non-destructive testing during maintenance inspections. The District believes these solutions will adequately address the possibility of oil discharges into the Columbia River from these systems. A schedule for these replacements has been included in Section 6.0.

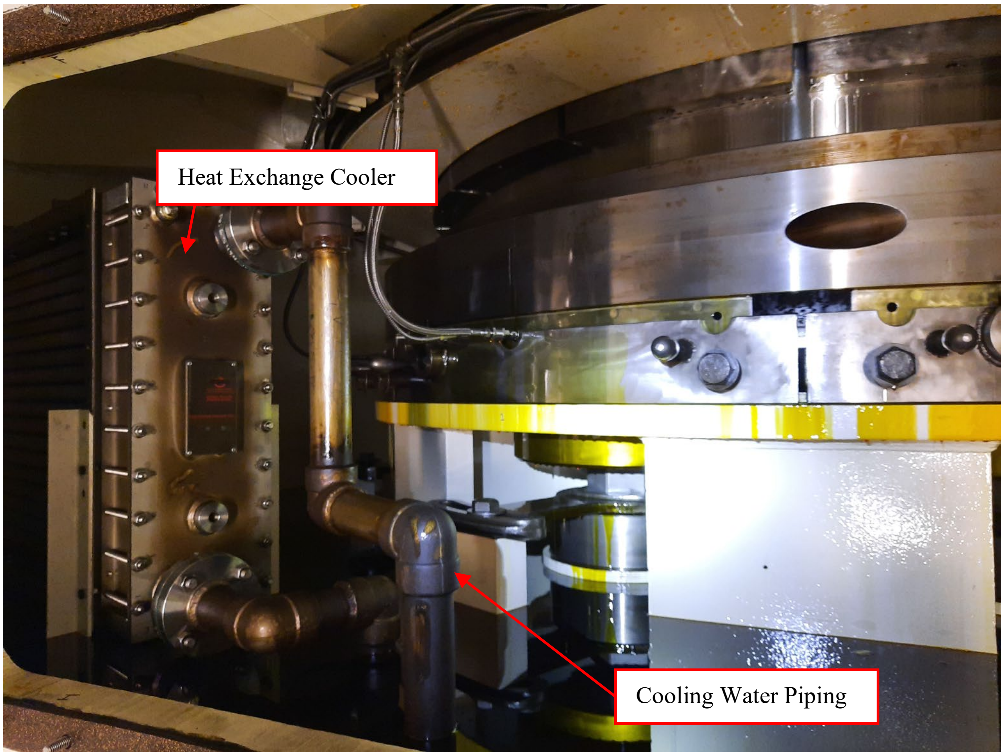


Figure 16. Wells Project Thrust Bearing Drained for Inspection with Stainless Steel Plumbing Upgrades

5.5 Gearbox Systems

The Wells Project uses electric motor driven gear reducing gear boxes on several pieces of equipment adjacent to or above the Columbia River including the spillway hoists, flap gate hoists, draft tube gate hoists, and gantry cranes. These systems share similar general designs of gears mounted on bearings inside of an enclosure that contains a bath of gear oil. Gear oil is designed to adhere to moving parts. As the gears rotate, the lubricant is caught and dragged up and over the gears providing necessary lubrication and protection. The output of the gearboxes is transmitted into rotating shafts or wheels. Rubber seals placed around the output shafts or wheel shafts retain any oil from splashing out of the gearbox when the gears are turning. In the event of a partial seal component failure, gear oil could potentially leak and reach the waters of the Columbia River.

Figure 17. **Wells Project Spillway Hoists Gear Reducing Gearbox**

Figure 18. **Wells Project Gantry Crane Driveline Gearbox**

These gearbox systems have been evaluated for feasibility of EAL conversion. Below are the reasons why they were found not be feasible for an EAL conversion:

Reason #1 – Lack of Manufacturer Endorsement

The District does not have original equipment manufacturer recommended EAL products for use or conversion procedures for these gearboxes.

Reason #2 – System Incompatibilities

Gearboxes at the Wells Project are prone to chemical incompatibilities between new EALs and the internal coatings, seals, and conventional lubricant residuals. Consequences of adverse chemical reactions could lead to equipment damage and leaks.

Reason #3 – Dam Safety Implications

Gearbox equipment is considered critical to the Wells Project's dam safety. Because of this and the hazards associated with converting existing equipment, the District believes this equipment is infeasible for conversion.

5.6 Gate Wheels

The Wells Project's gate structures include spill gates, spillway flap gates, intake gates, and spillway bulkhead use wheels with spherical roller bearings in order to allow the wheels to both rotate and pivot. This allows wheels to adjust according to any misalignment that may be present from manufacturing of the gate or from changes in the wheel tracks in the dam structure. These wheels are filled with grease and are sealed with front and back covers and seals.

Figure 19. Spill Gate Wheels

The Wells Project gate wheels have been evaluated for feasibility of EAL conversion. Below are the predominant reasons why they were found infeasible for an EAL conversion:

Reason #1 – Contaminant Susceptibility

The risks of water contamination and seal compatibility concerns described above are also relevant to gate wheel bearings. Even small seal leaks in EAL filled bearings would lead to EAL degradation allowing for corrosion and improper lubrication of the bearing components.

This would likely lead to seized bearings and increased friction while lowering or raising gates. Without the presence of grease, bearing surfaces can also be contaminated with particulates that will damage the components through abrasion.

Reason #2 – Dam Safety Implications

Gate wheels are considered critical to the Wells Project's dam safety. Because of this and the hazards associated with long term contamination exposure potential, the District believes this equipment is infeasible for conversion.

Reason #3 – System Incompatibilities

The Wells Project's gate wheels are prone to chemical incompatibilities between new EALs and the internal coatings, seals, and conventional lubricant residuals or impregnation. Consequences of adverse chemical reactions could lead to equipment damage and leaks.

Reason #4 – Manufacturer Endorsement

Manufacturer endorsement cannot be achieved for the Wells Project's gate wheels.

6.0 CONVERSION TO EAL SCHEDULE

Tables 2 and 3 below outline the schedules for implementing EAL grease in the Wells Project's Wicket Gate Bushings and replacing Thrust Bearing Cooling Piping Systems.

Table 2. Expected Schedule for Tier 1 EAL Wicket Gate Bushing Grease Implementation

UNIT	*CURRENT STATUS*	*CONVERSION BY*
TURBINE UNIT #01	Tier 1 EAL	Completed
TURBINE UNIT #02	Tier 2 EAL	12/2024
TURBINE UNIT #03	Tier 1 EAL	Completed
TURBINE UNIT #04	Tier 2 EAL	12/2024
TURBINE UNIT #05	Tier 2 EAL	12/2024
TURBINE UNIT #06	Tier 2 EAL	12/2024
TURBINE UNIT #07	Tier 2 EAL	12/2024
TURBINE UNIT #08	Tier 1 EAL	Completed
TURBINE UNIT #09	Tier 1 EAL	Completed
TURBINE UNIT #10	Tier 2 EAL	12/2024
FISH PUMP E. UNIT #1	Tier 2 EAL	12/2024
FISH PUMP E. UNIT #2	Tier 2 EAL	12/2024
FISH PUMP W. UNIT #1	Tier 2 EAL	12/2024
FISH PUMP W. UNIT #2	Tier 2 EAL	12/2024

Table 3. Expected Replacement Schedule of Thrust Bearing Cooling Piping and Kaplan Turbine Bushings

UNIT	CURRENT STATUS	REPLACEMENT BY
TURBINE UNIT #01	Original	12/2028
TURBINEUNIT #02	New	Completed
TURBINE UNIT #03	New	Completed
TURBINE UNIT #04	New	Completed
TURBINE UNIT #05	New	Completed
TURBINE UNIT #06	New	Completed
TURBINE UNIT #07	New	Completed
TURBINE UNIT #08	Original	12/2025
TURBINE UNIT #09	Original	06/2027
TURBINE UNIT #10	New	Completed

7.0 CONCLUSSION

The District is committed to operating the Wells Project safely, reliably, and in an environmentally responsible manner. The District has carefully considered EAL conversions in the Wells Project's in-line equipment and several additional systems. The District has summarized its conclusions for systems that are compatible with EALs in Table 4:

Table 4. Feasibility Matrix of EAL Conversion for Wells Project In-line Equipment

Technical Feasibility of EAL Conversion for Wells In-line Equipment ✓ = Pass; X = Fail		Manufacturer Endorsement	Dam Safety Implications	Incompatibility Hazards	Contaminant Susceptibility Hazards	EAL Physical Property Validation (only done if previous columns pass)	Feasible for EAL Conversion
Direct Discharges	Wire Rope and Lifting Equipment	X	X	✓	X		X
Direct Discharges	Wicket Gate Bushings	✓	✓	✓	✓	✓	✓
Indirect Discharges	Turbine Oil System	X	✓	X	X		X
Indirect Discharges	Thrust Bearing Systems	X	✓	X	X		X
Indirect Discharges	Gearbox Systems	X	X	X	✓		X
Indirect Discharges	Gate Wheel Bearings	X	X	X	X		X

While it is infeasible to perform EAL conversions for the Wells Project's wire rope and lifting equipment, Turbine Oil Systems, Thrust Bearing Systems, gearbox equipment, or gate wheels at this time, the District will continue to evaluate feasibility of converting in-line equipment at the Wells Project as EAL research and technology advance. The District is participating in and sponsoring ongoing EAL research through the Center for Energy Advancement for Technological Innovation (CEATI), which is currently conducting laboratory testing on physical properties of EAL turbine and transformer oils. CEATI is a hydropower utility users' group that performs technical research and development for its members.

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