A STUDY OF EMISSIONS AND DREDGING EFFICIENCIES AT VANCOUVER FRASER PORT AUTHORITY

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ABSTRACT

Vancouver Fraser Port Authority (VFPA) has undertaken an assessment of current dredging operations in the Fraser River and a forward-looking study of dredging efficiencies, emerging technologies, and alternative fuels to position upcoming dredging contracts in support of the vision for the Port of Vancouver to be the world's most sustainable port. To accomplish this goal, the study Moffatt & Nichol (M&N) is conducting for VFPA has been segmented into six areas of interest: establishment of an emissions baseline, study of California emissions regulations to provide emissions thresholds for dredging activities, recommendations for emissions reductions, modification of dredging and disposal equipment and methods, discussion of alternative fuel sources, and assessment of emerging technologies.

INTRODUCTION

M&N has partnered with Synergy Enterprises, an environmental sustainability firm based in British Columbia, to perform an analysis of current emissions, specifications, historic performance, and new or developmental technologies in the dredging market and form recommendations to provide uplifts in efficiency, performance, and environmental sustainability. Synergy's initial scope of work included comparison of emissions trends of existing dredge equipment to California emissions standards with the goal of recognizing areas of improvement for air and noise emissions. Noise emissions shall be considered, and recommendations will be made to align upcoming dredging activities with VFPA's Underwater Noise Mitigation Plan, established in December 2020. Discussion of emissions standards and recommendations to address areas of exceedance are ongoing and while emissions regulations will be briefly discussed, recommendations for future application will not be addressed in this technical discussion.

M&N has analysed historical dredging production rates and the number of working days during each dredging period to inform a recommendation to VFPA on the minimum and optimal size of hopper dredge unit required. Assessment of the existing specifications, consideration of current and alternative disposal sites, and operational practices forms the basis of recommendations to be made to improve dredge performance efficiency while reducing emissions. To avoid limiting competition, determination of the appropriate size of the dredge to be used on upcoming VFPA contracts will include a survey of existing hopper dredges as well as those that may be newly constructed. Further, the consideration and recommendations for implementation of emerging technologies will also be limited to those that can be installed on existing dredging platforms or integrated into the construction of new hopper dredges. Such recommendations include environmental components to limit turbidity stemming from overflow, draghead selection, and green valves, choices that are supported by their implementation in the European dredging market by industry leaders. Upgrades to existing components may have a significant positive effect on the environmental impact of dredging activities in the Fraser River and neighboring disposal sites. Recommendations have also been included to encourage future VFPA contract winners to take advantage of the innovative automation and visualization tools currently on the market. Operational automation for dredging is an area that may provide some of the greatest gains in improvement of overall efficiency as the

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partnership between hardware sensors and software monitoring allows for adjustments in real time that optimize dredge performance. Similarly, VFPA has indicated an interest in visualization that may be achieved through use of hydrographic survey data collection in real time that informs a model available to the leverman, who can then make adjustments based on available material. Finally, one of the greatest areas of emphasis for upcoming VFPA contracts concerns the use of alternative fuels in support of a global trend away from traditional marine diesel. Research and industry input has led to both short term and possible long-term alternatives for use of LNG, hydrogen, ammonia, and molten carbonates as innovation in the fuel and propulsion spaces continues for the coming decades.

It is M&N's intent to provide VFPA with a comprehensive and strongly supported set of recommendations to achieve efficient, effective, and environmentally conscious dredging programs in service of the Port Authority's goal to become a leading Green Port. All recommendations to be discussed will protect the proprietary information provided by VFPA and its industry partners. Final recommendations to be provided to VFPA will not be included in this discussion in order to avoid limitation of future competition for Port Authority contracts or provide an advantage to contractors seeking work under the Port Authority. Inclusion of systems and components sourced from manufacturers discussed below in proposed dredges will not be considered an advantage for contract award.

ENVIRONMENTAL OBJECTIVES

The VFPA envisions becoming the world's most sustainable port, one that "*delivers economic prosperity through trade, maintains a healthy environment, and enables thriving communities through meaningful dialogue, shared aspirations and collective accountability*" (Port of Vancouver, 2020). The VFPA defines sustainability as "a holistic approach that considers ecological, social, and economical dimensions, recognizing that all must be considered together to find lasting prosperity" (University of Alberta, n.d.). As concerns about climate change and the carbon footprint reduction increase and continue to play an integral role in shaping our world, VFPA has committed to incorporate sustainable practices into strategic plans, to make a positive impact on communities, and to manage resources more efficiently for enhanced energy consumption. The VFPA continues to lead environmental programs and initiatives to protect the nearby environment and ecosystems, and further climate action and responsible practices. Successful existing programs have already been implemented to encourage quieter vessels and manage underwater noise generated from port operations, including in-water construction. For example, the EcoAction Program recognizes and celebrates shipping lines that invest in ship technologies, fuel, and environmental management to meet industry best practices that go beyond regulatory requirements (VFPA, 2021). The EcoAction Program also provides discounted harbor dues to vessels that reduce emissions, underwater noise, and other environmental impacts (Port of Vancouver, 2020). The Enhancing Cetacean Habitat and Observation (ECHO) Program was established to reduce effects of shipping activities on at-risk whales found throughout the southern coastal waters of B.C.

Regulations Applicable to Maintenance Dredging

Active marine vessels must comply with applicable international, national, and local regulations with respect to air emissions. Similar to other in-water construction activities, maintenance dredging must also comply with a number of applicable national and provincial environmental regulations with respect to the potential for adverse impacts on protected species and habitats.

<u>Air Emission Standards, Regulations, Thresholds</u>

International, national, and local regulation compliance for marine vessels focuses on reducing diesel PM, NOx, and reactive organic gases (ROG) emissions from diesel vessel engines. The International Maritime Organization (IMO) mandates fuel requirements for commercial vessels. A sulphur cap was implemented this past January (2020) for most commercial vessel fuels (less than 0.5%) (IMO, 2020). IMO targets for 2030 and 2050 call for additional reductions in air pollutants and GHGs, particularly CO2.

The entire West Coast of Canada and the U.S., including Hawaii, is part of the much more stringent North American Emission Control Area (ECA). While the IMO standard for sulphur is 0.5% as of January 2020, the North American ECA standard is 0.1% since 2015. The ECA also limits NOx emissions by requiring ships constructed on or after January 2011 comply with the ECA Tier II NOx standard and those constructed on or after January 2016 comply with the Tier III NOx standard (IMO, n.d.).

Ships may also need to comply with more stringent regulations at berth. The California Air Resources Board (CARB) requires operators to reduce at-berth emissions from auxiliary engines by 80% while in California Ports (CARB, 2020). Formal emissions regulations specific to British Columbia and other provinces have not been identified at this time. The adoption of future national and/or provincial regulation is likely imminent given this overall trend in other parts of the world. The timing of this adoption is less certain and may depend on population growth and public and industry changes and pressures.

The B.C. Low Carbon Fuel Standard (LCFS) only accounts for diesel and gasoline used in B.C., however, by 2030, its commitments aim to also cover fuels used by the marine industry (Synergy, 2021). Due to increasing carbon emissions, it is likely that marine fuels will be incorporated into the BC-LCFS. To comply with the BC-LCFS, there are two requirements for preliminary incorporation:

(1) Minimum renewable content requirement of 5% annual average renewable content in gasoline and 4% renewable content in diesel; and,

(2) Carbon intensity of a fuel must decrease by 1.09% annually (Synergy, 2021).

A Part 3 Agreement under the Renewable and Low Carbon Fuel Requirements Act allows fuel suppliers to earn credits by taking actions to increase the use of low carbon fuel. (Synergy, 2021).

<u>Noise Standards, Regulations, and Thresholds</u>

There are no present federal laws or standards regulating anthropogenic (human-caused) ocean noise in Canada. The IMO has worked to develop international guidelines to minimize underwater noise, however, these guidelines are voluntary and are not binding in Canada unless adopted into Canadian legislation (World Wildlife Fund-Canada, 2013). For in-water dredging activities, Canada uses approaches to mitigate ocean noise similar to those for seismic air guns. Such measures are applied when marine species may be disturbed from the underwater construction activity, or as required for an environmental assessment. Ocean noise has previously been assessed under the Canadian Environmental Assessment Act (CEAA). Assessment includes the potential effects project-related activities may pose to marine mammals listed in Canada's federal endangered species law, Species at Risk Act (SARA). The Act prohibits destroying any part of a listed endangered, threatened, or extirpated species' critical habitat. Acoustic quality is considered a component of a specie's critical habitat, and must be legally protected (DFO and WWF-Canada, 2013).

A project may be denied approval or have approval postponed if failure to mitigate adverse environmental impacts from project-related activities that produce underwater ocean noise. Dredging vessels, however, have a low sound intensity and do not appear to be strictly regulated with respect to noise. While dredging vessels have low sound intensity, they may still alter behaviour of marine mammals and interfere with their communication, feeding, and breeding (Port of Vancouver, 2020).

While there are presently no comprehensive noise standards, measures must be taken to comply with subsections 34.4(1) and 35(1) of the Federal Fisheries Act. To comply with the Act's fish and fish habitat protection provisions, measures must be implemented to avoid causing death of fish and/or harmful alteration, or destruction of fish habitat in the dredging area. Additionally, under the Fisheries Act, dredging activity must comply with Section 7 of the Marine Mammal Regulations, which prohibits the disturbance of marine mammals by any activity other than fishing.

PRACTICAL RECOMMENDATIONS TO IMPROVE EFFICIENCIES

Hopper Dredge Sizing

The current dredge performing work under current and previous VFPA contracts has been FRPD 309, a 4,630 m^3 TSHD built in 1983 and owned and operated by Fraser River Pile and Dredge. Analysis of current dredge performance, the most heavily utilized disposal sites, and future efficiencies formed the basis of considerations for determining the optimized TSHD capacity for future work. FRPD 309 has proven capable of meeting project volume demands of approximately 3.5M m^3 removed annually over the past five years with a supplemental 450,000 m removed via Cutter Suction Dredge. Of this volume, 1.6M m^3 has been disposed of at upland sites while the remaining 1.7M m^3 has been disposed of at sea.

Areas of interest for future hopper dredge sizing include draft considerations for all disposal areas, air draft to allow the dredge access to reaches beyond the Pattullo and Skytrain bridges, and load size optimization to allow the dredge to discharge entire loads at a single site. Further, separate dredge material placement needs for other regional projects requiring large quantities of fill material is a consideration for the size of dredge on VFPA contracts. Finally, the optimal dredge size should consider the minimum capacity needed to meet project objectives in the event of a mechanical shutdown that consumes all available schedule float.

The first dredge size to be considered will offer a 4,000 m^3 capacity. The FRPD 309 has a historical haul volume of 70% versus the industry average of 75%, representing approximately 230 m^3 of haul capacity per load that may be gained by a more efficient dredge of the same size. While a 4,000 m^3 TSHD would result in smaller loads than the FRPD 309, a newly constructed dredge would include upgraded systems and components that have been introduced to the market in the forty years since the FRPD 309 was built. A future dredge would be anticipated to perform at a higher level of efficiency, minimizing the difference between existing and anticipated haul volume per load. A smaller hopper dredge may also allow a future dredge to discharge full loads at the smaller upland placement locations, rather than either light loading the hopper or requiring multiple disposal discharges to empty a single load.

The second dredge size to be considered would allow for 6,000 m^3 of hopper capacity. Advantages to a substantially larger hopper would be an increase in the production rate of the dredge as a larger hopper would equate to more material per load and fewer transits to disposal. This may increase the number of available float days in the schedule, providing a buffer against a mechanical shutdown preventing the contractor from completing their obligations to VFPA. Similarly, a larger hopper volume would allow the contractor to supply other regional projects requiring large amounts of fill material. Secondarily, a larger available material volume removed from the Fraser River would be available to supply the local sand market in the months of June to September when shoaling rates are the highest. The material could be transported to fill locations outside of those currently identified for Fraser River dredging contracts. Such material could be placed in support of regional beneficial reuse initiatives and projects.

Specifications Assessment

The basis of recommendations for improvement of operational efficiencies stem from the study of the existing contract specifications with the intent to locate areas of improvement. Project specifications indicate that there are multiple areas of disposal related operations that may be addressed to improve efficiencies.

The specification details that it is the responsibility of the contractor to determine the method of disposal for all material removed from within the dredging limits. The introduction of a structured disposal approach and a greater level of Port control over material disposal destinations may yield an increase in the efficiency of material placement as disposal is completed in a manner that is the most supportive of VFPA goals. On a contract cycle basis, the Port Authority may determine the volume of dredged material that should be placed offshore or upland and make budget decisions accordingly. Existing specification language indicates that approximately 1M cubic metres (m^3) is disposed offshore on an annual basis, however annual averages from 2017 to 2020 result an average of 1.86M m^3 placed offshore each year. Approximately half of the material for offshore disposal is sourced from the furthest reach from the offshore disposal site, Stevenston Cut KM7-12. Alternative placement of material from Stevenston Cut KM7-12 may improve the emissions generated during round trip transit from the dredge prism to the disposal site. Reduction of the extended transit distance to the disposal site may have two additional advantages in the increase in beneficial use of dredged material and an increase in working efficiency due to a reduction in revenue hours dedicated to transit. An alternative placement site for Stevenston Cut KM7-12 would require identification and permitting of a new disposal location, either nearshore or upland that may have beneficial use.

Mainland Sand & Gravel is currently the primary disposal site used for upland material placement and is located near No. 5 Road Reach at KM18. Though this location is situated near the geographical centre of the project, the amount of material placed to the east and west of the Mainland Sand & Gravel site is not equal. Approximately 300,000 m^3 is placed to the east of the Mainland Sand & Gravel site while 900,000 m^3 is placed to the west. An increase in operating efficiency may result from identification and permitting of a new upland disposal site to the west of Mainland Sand & Gravel, allowing for shorter transit distances, sail times, reduced fuel consumption, and increased production. Specifications state that alternative sites have been identified that could be used for future land reclamation or habitat creation. It has not been determined whether any of these sites have been developed or permitted for upland material placement. If the alternative sites previously identified by VFPA to the west of Mainland Sand & Gravel are still viable options for future material placement, an upland site located nearer to the source locations of the majority of upland material may be incorporated into the specifications for upcoming contracts.

Use of in river disposal sites and transfer pits may be an operational area to be adjusted to minimize secondary material handling, specifically in terms of the transfer pits. Specification language indicates that at the transfer pits, material is deposited by the TSHD to be re-dug by the cutter suction dredge (CSD) and pumped to the upland disposal site. It may be advantageous to VFPA to require a single TSHD or CSD that is capable of pumping directly to land rather than involving a second dredge that would increase fuel consumption and emissions generation associated with work at the transfer pits. The final area of possible modification to increase operational efficiency is the identification of those reaches that experience significant monthly shoaling patterns in October through December that may be more effectively addressed through increasing the dredge depth of the dredging prism to allow advanced maintenance digging in August and September to minimize the return efforts required in the last quarter of the year. This solution may require a greater upland site capacity in the months of August and September being attributed to advanced maintenance work with the understanding that the additional material removed under that effort may be offset by the decrease in upland site placement in the months of October through December, opening up capacity for material from other locations.

ALTERNATIVE FUEL CONSIDERATIONS

The purpose of this section is to discuss alternative fuel technologies available for dredge vessels and potential alternatives for application.

LNG Dual Fuel

In the last decade the international dredging industry has begun and develop fuel alternatives that may be more environmentally friendly than Marine Diesel Oil (MDO). At the present, the most feasible solution to replacement of MDO as the primary fuel powering dredge operations is the optimization of dredge equipment to utilize both traditional fuel sources as well as alternatives fuels available at select ports. This dual fuel method has been applied to hopper dredges in the European marketplace.

The European dredging industry leads the market in the application of dual fuel dredging with international dredge companies Van Oord, DEME, Boskalis, and IHC Royal leading this effort. Conversion of existing equipment to incorporate LNG fuel capabilities was pioneered in 2019 by Damen Ship Repair & Conversion with the modification of the hopper dredge Samuel de Champlain. The conversion of the Samuel de Champlain included changes to the dredge's internal structure to allow for installation of two

LNG tanks and replacement of the diesel engines with dual fuel engines and associated upgrades to electrical and control systems.

The largest obstacle to dual fuel applications on VFPA contracts exists with the infrastructure required to successfully supply dredge equipment with LNG. Currently there are three methodologies for transfer of LNG to vessels, two of which may be more readily available to VFPA. The truck-to-ship transfer option is likely the most frequently employed because of the adaptability of the process of an LNG truck directly connecting to the vessel wharf side. Norway has successful implemented this technique, supplying 61 Norwegian vessels with LNG, a majority of which are coastal ferries and platform supply vessels (Guy & Laribi, 2020). A potentially more flexible option may be the ship-to-ship transfer method, which can be performed both wharf side as well as in coastal waters. The capacity of the LNG vessel would be substantially greater than LNG truck transfer, however LNG vessel size may be limited by existing bathymetry or size limitations of Port locations and geography. This transfer option requires specialized LNG vessels that have high cost and limited availability due to the storage equipment and control systems required to maintain the temperature and pressure necessary to maintain LNG in its fluid state. The final option for fuel transfer is shore-to-ship, the most cost intensive option of the three but also the most stable and suitable for long term use.

The European Alternative Fuels Observatory (EAFO) maintains a register of port facilities reporting LNG bunkering capabilities as well as their bunkering method and start-up year. While shore-to-ship transfer capabilities are among the most common listed, the EAFO does not note which facilities have successfully initiated the transfers. SEA-LNG, a conglomerate of Port Authorities and LNG industry representatives, indicates that as of January 2020, twelve bunkering facilities were in operation with a further twenty-seven in development or ready to be commissioned by the end of 2022 (SEA-LNG, 2020).

As reported by SEA-LNG, Vancouver is currently host to two LNG truck-to-ship locations, both operated by Fortis BC (SEA-LNG Bunker Navigator, 2020). Vancouver has one ship-to-shore and one shore-to-shore location undergoing plan development to be operated by Seaspan. Vancouver also has one bulk LNG bunkering location at the Tilbury LNG Facility with two ship-to-ship vessels in development to be commissioned in 2023 to be operated by Seaspan and Cryopeak LNG Solutions Corporation in partnership with Island Tug & Barge. VFPA is conveniently placed to take advantage of currently available truck-to-ship LNG transfer methods if future dredges are able to utilize both MDO and LNG fuel sources.

Developmental Fuels – Hydrogen Fuels

There are no active marine hydrogen deployments within Canada, however the Hydrogen Strategy for Canada published December 2020 indicates that studies for the application of marine hydrogen are underway in the provinces of Ontario and British Columbia (Ministry of Natural Resources, 2020). Further, the Hydrogen Strategy notes that hydrogen may find its initial marine applications in the supply of shore power and auxiliary power.

Hydrogen fuel is being explored as a feasible alternative to typical marine diesel fuel with blue hydrogen and green hydrogen at the forefront of development. Hydrogen currently used for industrial purposes is grey hydrogen, a derivative of natural gas that has a large CO_2 component for every part of hydrogen created. To improve upon this method, blue hydrogen captures the CO2 generated and either disposes of the CO_2 or uses it beneficially. Green hydrogen utilizes an alternative method to produce hydrogen, electrolyzing water into hydrogen and oxygen components. While green hydrogen is the most environmentally friendly option, especially when water is electrolyzed using a renewable electrical energy source, it is also the most expensive. The International Renewable Energy Agency (IRENA) reports that green hydrogen is two to three times more expensive than blue hydrogen (IRENA, 2020). IRENA predicts that the cost of green hydrogen will decrease through 2050 as alternative electrical energy sources become increasingly available and cost effective.

IHC Royal received an approval in principle to begin early-stage development of a hydrogen powered hopper dredge intended for use a maintenance vessel in the Dutch coastal environment. The Low Energy Adaptive Fuel (LEAF) dredge will be powered by green hydrogen, emitting water vapor as a result of hydrogen-based operation. Design development began in 2019 with the goal of completion in 2024. In 2017, Energy Observer launched a vessel of the same name powered by compressed hydrogen in combination with fuel cells and batteries (Æsøy et al., 2021). Emerging technologies and developments in alternative energy sources primarily consisting of compressed or liquified hydrogen may include a combined application of one or more energy sources to produce an effective result for short range use, such as maintenance dredging.

One of the most significant challenges to be addressed before green hydrogen can be adopted as an effective marine fuel alternative pertains to the storage and transfer of hydrogen fuel. The physical space required to store compressed hydrogen renders it an ineffective option for marine applications. Liquified hydrogen must be stored at approximately -253°C and in low pressure conditions to prevent evaporation of liquified hydrogen (Æsøy et al., 2021), presenting a challenge for storage onboard a vessel. Liquified hydrogen is approximately 2.5 less energy dense than LNG and therefore would require a storage container of increased size (Æsøy et al., 2021). The limited space available within the footprint of a hopper dredge's deck will likely lead to innovation of storage tanks that may be integrated into the structural frame of the hopper dredge to avoid interference with the dredge's split hull capabilities.

The 2020 Hydrogen Strategy for Canada looks beyond the ready availability of green and blue hydrogen as a reliable source of marine fuel and anticipates diversification of hydrogen fuels, including generation of an energy-rich combination of hydrogen and captured atmospheric carbon to create a liquid fuel source to be used in marine vessels (Ministry of Natural Resources, 2020). In the meantime, the arrival of IHC Royal's LEAF hopper dredge in 2024 will mark the first use of hydrogen in powering maintenance dredging activity and a step towards VFPA harnessing hydrogen power sources for use on dredging contracts.

Developmental Fuels - Ammonia

Ammonia can be used as a direct fuel or as a hydrogen carrier (Brown 2018). Current technologies being explored include proton-exchange membrane fuel cells (PEMFCs), solid oxide fuel cells (SOFCs), and internal combustion engines. Proton-exchange membrane fuel cells require ammonia to be stored in a fuel tank and used as a hydrogen carrier (International Chamber of Shipping 2018). The hydrogen then feeds the fuel cell and generates zero carbon power. Solid oxide fuel cells and internal combustion engines use ammonia fuel directly.

In January of 2020 the Viking Energy, a supply vessel, will be modified to be run off a 2 MW direct ammonia fuel cell (Brown, 2020). This is the first ammonia fuelled demonstration vessel proposed and will be operational by 2024. In 2020, Color Line announced an ammonia case study that proposes to convert the world's largest RORO cruise line to ammonia fuel. The RORO cruise ship the 'Color Fantasy' operates in Norway and currently burns 25,000 tons of bunker fuel each year. After conversion, the Color Fantasy will require 60,000 tons of green ammonia annually. There are several other marine vessel ammonia-fuel projects proposed for the coming years.

ENVIRONMENTAL IMPACT CONSIDERATIONS

Environmental Components

<u>Draghead Selection</u>

The work performed by the dredging industry can have significant adverse impacts to the environments being deepened, maintained, or modified. One of the most visible consequences of dredge work are turbidity plumes present in the water column that may have detrimental effects on marine habitats if left uncontrolled. It is understood that work to date under VFPA dredge contracts complies with environmental regulations pertaining to turbidity and environmental mitigation, however there may be room for improvement through the selection and installation of environmentally advantageous "green" dredge components that further lessen the environmental footprint left in the wake of maintenance dredge work.

Research conducted in support of this effort has included communications with dredge industry leaders in the environmental mitigation space. Focusing primarily on improvements that may be made to trailing suction hopper dredges to decrease potential environmental consequences, industry partners have indicated that outside of procedural adjustments such as disposal speed, analysis of material transport and tidal flow, and controlled material disposal in a tightly defined region, two of the most critical component upgrades to be considered should be the draghead design and functionality as well as in-hopper means of reducing sediment released into the water through overflow.

Draghead design selection can be an important feature of dredge production efficiency but the functionality of the draghead can impact the environmental results of dredge operations. By nature, a TSHD draghead functions through injection of water into the material to soften the sediment, allowing a turbulent slurry of water and sediment to be drawn into the pipeline for eventual placement in the hopper. In more compact materials, the jet system in the draghead is a supplement to the use of cutting teeth or blades to excavate bottom material. All dragheads produce some nearbed turbidity that may be transported through the water column to areas outside the dredge footprint. The geometry of the dragheads being used in current and previous maintenance cycles is not known, however it is recommended that a draghead suited to unconsolidated river deposits primarily comprised of silt and coarse to medium sand.

Dragheads under consideration to VFPA include those offered by IHC-Royal, VOSTA LMG, and Holland MT. The IHC type draghead may be well suited to use on maintenance method projects with VFPA because it is the most universal component, capable of removing silt deposits as well as compact sand with some percentage of small rock or gravel present. The IHC-type draghead includes a self-adjusting visor that can also be hydraulically fitted to improve visor control and therefore slurry containment within the draghead, decreasing the external turbidity generated by draghead activity. VOSTA LMG's universal draghead includes a swell compensation system intended to control the amount of contact the draghead has with the bottom as well as an adjustable water flap that supplies additional flow when digging soft sediments. Dragheads considered for this project from Holland MT are also universal type but with an emphasis placed on replaceable and wear-resistant components that may make Holland MT dragheads an effective choice for long term use in multiple digging environments.

Overflow Control

Turbidity generation as a result of hopper overflow water discharge can be a considerable source of re-suspended sediment in the water column that may result in adverse environmental impacts. It has been an industry practice to recirculate hopper overflow water to be used as draghead jet water through use of "green pipelines", but the next step is to decrease the amount of sediment that remains suspended in the water standing in the hopper before it is discharged as overflow to make room for more material in the hopper.

Components for consideration under this study may be sourced from IHC Royal and VOSTA LMG. IHC Royal's Plumigator provides an improved means of capturing and discharging hopper overflow through "airless" characteristics resulting from the absence of hydraulic cylinders causing the entrainment of air and fine sediment in the overflow water to be discharged. To decrease turbidity in the overflow, the Plumigator strives to produce non-turbulent movement of overflow from the hopper through to the discharge. As demonstrated by Figure 2, the Plumigator's unique design of three stacked inlets, the highest above the waterline and the lower inlets submerged, minimizes turbidity within the hopper through passive flow, allowing suspended material a greater time to settle out of the overflow water before it is removed from the hopper. While the Plumigator is typically installed on new dredges, it can be retrofitted and installed on existing equipment. The Plumigator has been successfully installed on TSHD platforms in the European market with compelling evidence of effectiveness in open water environments.

Figure 1. Comparison between typical overflow systems and the IHC Plumigator design

Lastly, a component of the Plumigator that aids in its reduction of turbulent flow of hopper overflow to be discharged is use of butterfly values, also referred to as “green valves”. In a standard overflow system, the turbid movement of water continues down the pipeline and to the discharge. Discharge of an already turbid mixture of water and suspended sediment does not encourage material to more rapidly settle out of the water column when released from the dredge. The Plumigator uses a butterfly valve to keep the overflow pipe full, with a steady, calm flow through to the discharge. Use of the butterfly valve allows the control of overflow velocity, providing suspended material the opportunity to further settle out of the water column.

VOSTA LMG offers their overflow weir with anti-turbidity system which consists of a fixed lower portion and an adjustable upper portion controlled by a hydraulic cylinder that uses continuous positioning to make adjustments to overflow weir height. The option of an additional anti-turbidity system (ATS) including a flap that may be adjusted from the wheelhouse as needed. It is not clear whether VOSTA LMG’s overflow weir includes a butterfly valve to decrease turbidity of overflow released from the dredge.

The combination of draghead selection and implementation to an environmentally conscious overflow system will lead to an increased environmental efficiency for dredging work conducted under VFPA through the reduction of visible turbidity plumes, reuse of overflow as jet water which keeps suspended sediments with the dredge system, and reduction of nearbed turbidity plumes that may have harmful effects on marine life.

Equipment Recycling

This study does not assume contracts in the immediate future will include use of a newly constructed dredge. Beyond the immediate contract cycle, the opportunity exists for a newly constructed dredge to be introduced to the VFPA maintenance dredging contract. Construction of new dredge equipment offers the opportunity to encourage environmentally conscious decision making by means of a green passport under IMO Resolution A.962(23), IMO Guidelines on Ship Recycling. A green passport originates with the physical construction of the ship, including an inventory of all materials used during construction, specifically focusing on the amount and location of hazardous or potentially hazardous materials onboard the vessel. The purpose of the green passport is to travel with the dredge throughout its lifecycle to the point of disposal. The information contained in the green passport will be updated with design and equipment changes, allowing all possible materials to be recycled or disposed of through environmentally conscious methods.

This forethought into material selection, identification and documentation of type and location of hazardous materials onboard the dredge, and commitment to global sustainability and recycling initiatives may provide long term means of promoting environmentally conscious dredging practices from vessel construction through to retirement.

CONSIDERATIONS FOR DREDGE AUTOMATION AND CONTROL SYSTEMS

Remote Monitoring

Remote monitoring has emerged in the dredging industry over the last decade as a reliable means of inspecting both mechanical and hydraulic dredging efforts while also enabling remote control and intervention in production software platforms in real time. As a secondary benefit, remote monitoring platforms offer the ability to for IT teams or engineering staff to remotely address software difficulties within production platforms such as DredgePack that might otherwise result in lengthy operational shutdowns and a decrease in overall efficiency.

Considerations for selection of the most appropriate remote monitoring platform are dependent on multiple factors including the level of remote support desired, the purposes of monitoring, and the desired integration of imaging systems. The lowest level of remote monitoring may be most applicable for projects in need of remote technology support while engineering staff is regularly present onboard, and a secondary form of hydrographic survey is readily available. The lowest level of monitoring may be provided by organizations such as BeyondTrust, which allows remote access to the dredge computer and provides access to observe production software platforms to address issues as needed. BeyondTrust access allows both engineering staff and technical support to access the dredge's computer system to upload survey or dredge files or to troubleshoot software related issues impacting dredging performance. BeyondTrust would not require a change in the primary production software platform, DredgePack.

For projects that do not have imaging and engineering support readily available, a more comprehensive form of remote monitoring may be appropriate. DSC Dredge, LLC offers a variety of remote platform systems including complete remote control of operating systems, remote systems management and data logging, and maintenance data collection to aid in calibration and service needs. All DSC Dredge, LLC software offerings include remote viewing of the dredging computer. Such access to a dredge platform during active operations provides the opportunity to make adjustments to real-time operating parameters that may improve efficiency. DSC's maintenance tool specifically may be a useful application for dredging equipment that operates over a prolonged period with short periods of time where maintenance or repairs may be done without interrupting production requirements.

Separately from platforms focused solely on remote access, Teledyne's PDS TSHD platform is specifically oriented to provide industry leading data collection and surface visualization of the dredge surface while also providing operators with a greater level of information on draghead behavior to improve production. The Dredge Terrain Model (DTM) produced by the PDS system clearly shows high and low spots present on the dredge surface that are updated in real-time as the dredge progresses, incorporating new data as soon as it is available to maintain the most accurate representation of the dredge surface possible. This capability may allow operators to specifically target high spots while present in a specific reach rather than waiting for survey confirmation that may require a return to clean-up areas of remaining above grade. Additionally, the hydrographic survey data collected by the PDS system may be used by VFPA to confirm material removal for payment rather than requiring a secondary conditional survey.

It should be noted that BeyondTrust or DSC Dredge, LLC's products may be combined with PDS TSHD for remote access to troubleshoot software difficulties while also supplying visual representations of the dredge surface.

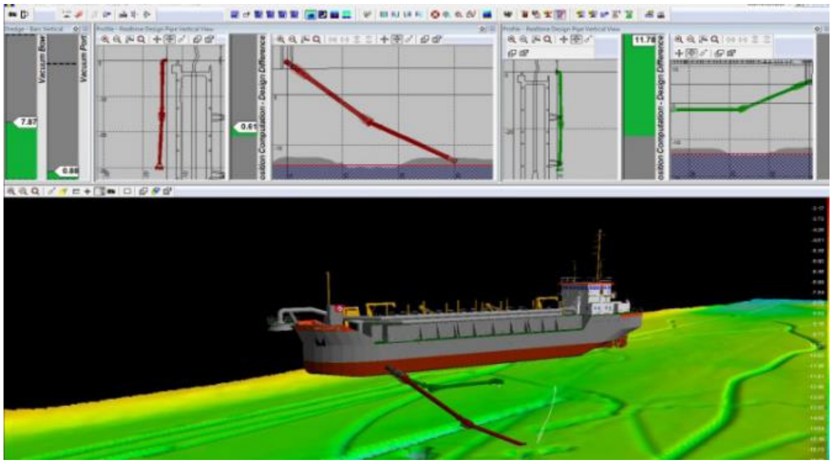

Figure 2. Teledyne PDS Visual Representation

Production Automation

Dredge production automation builds upon the foundation of remote monitoring and expands the operational capabilities to include active control of dredge operations and automation of selected dredge systems and components to improve efficiency. Typical automation systems integrate software and hardware components that work in tandem. Dredge automation systems serve to monitor desired conditions such as draghead jet flow, draghead position, and material flow density to make adjustments that will improve performance and efficiency.

DSC Dredge, LLC offers a platform designed to implement control draghead position, material flow, or full production. DSC Dredge's automation package includes the management, maintenance, and remote access tools previously mentioned with the additional benefits of flow control, comprehensive production monitoring, draghead position control, slurry dilution, material cave-in or slope failure detection, and full production control. Dredge production

IHC Royal's Dredge Control System (DCS) for TSHD and CSD equipment offers a robust and customizable option for implementation of a partial or full automation system onboard a selected dredge. While the DCS is highly customizable to meet the needs of the client, the common areas of monitoring, control, and automated management in terms of active dredge production are found in monitoring and adjusting material density, flow speed, and level of solids and water contained in the hopper. Beyond these areas of control, DCS offers production and operational management through control of overflow ducts, dredge pumps, gantry positioning, and swell compensation to maintain optimal levels of drag head position, suction, material flow through dredge pipelines, and wear on primary dredge components. To achieve this level of management, DCS presents options for control through manual and automatic means as well as implementation of artificial intelligence to produce an efficient and effective outcome.

The platforms considered by this study can be implemented on existing dredge equipment or integrated into the construction of new dredge platforms. Utilization of one or more of the recommended monitoring and automation softwares may require installation of sensors and other associated hardware in a drydock setting.

CONCLUSIONS

Determination of the means and methods that will produce the greatest uplift in operational efficiency, environmental sustainability, and overall performance includes a range of considerations spanning from results of emissions exceedances to the physical components and systems to be installed onboard a TSHD. The areas of analysis performed by M&N have shed light on the ways in which VFPA may position itself and its contracts to support its sustainability initiatives through greater control over specification directives while also seeking recommendations for upgrades to software platforms and system components that will foster greater sustainability through focused areas of improvement. Assessments of alternative fuels and their integration into commercially available dredge systems is likely the most promising means of decreasing the environmental impact of dredging operations in the coming decades. While emerging technologies in the fuel sector may require additional years of development, remote monitoring, visualization, and automation systems that can be installed on new or existing dredges will move the needle towards greater efficiency and thereby less wasted emissions through determination of optimal equipment operating states and identification of specific areas of shoaling or navigational concern that may be targeted rather than captured through larger clean-up efforts.

The study of emissions regulations and recommendations to improvements to areas of current and historical exceedances as compared to California Air Resources Board (CARB) emissions regulations is an ongoing effort that VFPA seeks to understand. M&N's partner Synergy has developed a baseline against which to compare FRPD dredge emissions and performance and emissions regulations and thresholds, providing a clearer picture of the existing landscape and the avenues of focus that VFPA may be interested in pursuing. This assessment of current contract documents and technologies coming into the dredging market are intended to build a foundation of recommendations that may be immediately implemented for the upcoming Fraser River dredging contract cycle.

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DATA AVAILABILITY

No data, models, or code were generated or used during the study.

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