USACE EXPANDED USE OF ARCHIVAL DREDGING DATA

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ABSTRACT

The US Army Engineer Research and Development Center (ERDC) is undertaking efforts to mine archival dredging data from the Resident Management System (RMS), an enterprise database of contracts issued by the U. S. Army Corps of Engineers (USACE) that can be used for advanced data analytics and improved cost engineering practices. The RMS houses daily dredge production records that offer in-depth granularity for many aspects of dredging operations. These include but are not limited to daily production totals, haul distances/pipeline lengths, cycle times, weather conditions, fuel usage, effective working times, and miscellaneous delays. Use of RMS production records on a broad scale will allow USACE to provide meaningful trends through time for relevant quantities such as duration of hauling runs to/from hopper placement sites, relative magnitudes of production time lost due to moving out of the way of ship traffic, and more realistic projections for the actual duration of dredging contracts and the resulting implications for regional contract vehicles. These data mining efforts provide USACE with a better understanding of weather and seasonal delays and how these might influence the scheduling of contracts. In addition, having a better understanding of daily production parameters will assist USACE efforts with federal and state resource agencies for permitting and lead to better coordination with port stakeholders for contract scheduling.

It is common practice for USACE Cost Engineers to use past performance records as a supplement to the USACE Cost Engineering Dredge Estimating Program (CEDEP) when creating the independent government estimates (IGEs) for dredging contracts, though the availability of these past performance records varies widely across Districts. Understanding the factors that affect overall productivity for each project is essential in creating a fair and reasonable estimate, and past performance records are the best indicator of future results for certain metrics. Dredge cycle times serve as one of the more important factors in determining overall duration of any dredging project. For larger jobs that require more than five hundred cycles, a cycle time miscalculation of a few minutes per cycle can noticeably impact the accuracy of the total estimated job duration. By using nationwide past performance datasets that include the entire dredging fleet, USACE can be more precise on cycle times in one specific location and look at broad scale trends on dredge cycle duration in relation to a myriad of variables. Similar analysis of past non-effective working times can be used to track delay trends for specific projects, providing cost engineers with logical assumptions for anticipated recurring delays to productivity. When looking at this data nationally rather than locally, it can be used for better and more accurate scheduling of USACE dredging projects. It may also show seasonal delays for a given region due to traffic variability, weather, tides/currents, etc. Use of these and similar analytics towards creation of a searchable and filterable historic dredge production database will allow USACE to provide in-depth analysis to the factors that affect productivity nationally and refine estimation and scheduling practices. This work discovers high-level productivity trends by

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dredge type, size, and region, serving as a proof-of-concept of some of the contributions and benefits that could be realized through systematic mining of the historic RMS dredge production database.

Keywords: Dredging operations, productivity, data mining, Resident Management System (RMS)

INTRODUCTION

With over 150 dredging contracts awarded annually, the US Army Corps of Engineers (USACE) has a vast portfolio of maintained waterways requiring a wide variety of dredge types and applications (USACE, 2022) (USACE, 2022). This includes deep and shallow draft channels and harbors, coastal and inland waterways, in-channel, and upland placement of dredged material, as well as specialized beneficial use practices (Wilkens, Suedel, & Mitchell, 2019) (McFall, Brutsché, Priestas, & Krafft, 2021). Dredge performance can change significantly for each differing dredge type and the nature of the work to be completed. With such a diverse portfolio of dredging applications it can be difficult to accurately cost and schedule these projects without a true understanding of the constraints that are inherent to each type of project, and/or each individual project (Nachtmann, Mitchell, Rainwater, Gedik, & Pohl, 2014). Historic dredging production data gives the best insight into these constraints and is used heavily by the USACE when creating anticipated schedules and government estimates (Loney, Cotterman, Brown, & Mitchell, 2019). While the USACE Cost Engineering Dredge Estimating Program (CEDEP) is the tool used by the Corps for creating all Independent Government Estimates (IGE) for dredging contracts (USACE, 2017), past production data is often used to verify, and if needed, adjust the CEDEP output. These past performance dredging records offer insight into the daily production values and the outside influences that may affect performance. In some of the larger ports and harbors across the nation, dredging production can be slowed greatly due to marine traffic using the channel. Dredging operations can also be slowed or even shutdown due to weather, tides, and water currents. Past performance records show the average "non-effective" time for any given project as well as the cause of that non-effective time. By studying these records for a given project, a cost engineer will have a better understanding of normal traffic and weather delays and can adjust the effective working time within the estimate accordingly. Similarly, cost engineers rely on past performance data to verify and/or update the total estimated cycle time for operation of a hopper dredge or scow (USACE, 2021). Operations and Maintenance (O&M) dredging projects typically use recurring placement sites (USACE, 2012), making past dredging data a very strong indicator or how long a cycle may take. As previously noted, use of these historic records on a district level for dredge scheduling and estimation is common practice, though apart from this application, historic records are seldom utilized other than to track broad cost and productivity trends. This work mines and analyzes historical dredge production data from the Resident Management System (RMS), to contribute to the general understanding of maintenance dredging effective time and production. The analysis is made with data collected from major dredges (hoppers and cutterheads), between 2010-2020, and aggregated at both daily and project level. This work serves as a proof-of-concept on the type of analysis that could be done with RMS data, and its applications.

RESIDENT MANAGEMENT SYSTEM (RMS) DREDGING DATA

The Resident Management System (RMS) is used by the USACE for construction oversight and contract execution for all types of construction projects (USACE, 2021). In particular, dredging contracts are administered using the RMS daily production worksheets that contain project specific information and productivity entered by the contractor, which are reviewed by USACE quality assurance personnel for progress payments. These daily production worksheets contain a multitude of data points ranging from specific cycle time activities and non-effective time breakouts to length of discharge pipeline, daily quantities removed, which dredge and placement areas are being used, weather, and fuel usage, just to name a few. The RMS program itself creates dredge production summary reports which pull information from selected fields from each daily report. The RMS dredge production summaries are used as the basis for the information presented in this report. While the RMS data is disaggregated to allow for highly detailed production analysis, the confidential nature of the data limits this publication to contain high-level aggregate results. Nevertheless, the analysis shown in this paper contributes to the general understanding of maintenance dredging effective time and production U.S.-wide. The main limitation of the RMS data for the purpose of this work is the heterogeneity in reporting templates and formats on historical data of select USACE districts.

DREDGING DATA APPLICATIONS

Cost Estimating

Recently, the ERDC has undertaken several initiatives using historic dredge production records in differing ways. This includes work for the Cost Engineering Community of Practice (CoP), the Navigation CoP, and ERDC internal data analysis (USACE, n.d.). For these efforts, the RMS data has been the main source of historic dredging production data (CEDEP validation, Dredge Schedule Optimization, Dredge Production Analysis). The RMS daily performance forms provide in-depth granularity for dredging operation for each day dredged. While each USACE District generally has its own dredge production files, the majority of USACE is using the RMS for tracking daily performance. Although the RMS is familiar to contractors working on USACE projects, the vast amount of data contained within in the RMS has rarely been used on a broad scale. As such, the ERDC Coastal and Hydraulics Laboratory (CHL) has downloaded available RMS dredging records for advanced data analysis. This dataset will allow districts to review dredging production records from around the country, filtered by defined parameters, such as pipeline length, haul distances, dredge size, etc. This information will allow cost engineers to compare the aspects of their dredging projects with similar type projects from the surrounding regions, providing critical insight to production and the factors that affect it. These national dredging records become especially useful for districts with smaller dredging programs, who may see changing contractors/dredges in their respective regions. Rather than relying solely on past production data from a class of dredges that may no longer be working in that area, the district can evaluate regional dredging efforts with differing sized dredges and placement distances to find the best fit for their intended project. Specifically, this data will allow cost engineers to compare average sailing speeds, duration of specific cycle time activities, and duration of pipeline activities over differing classes of dredges. This type of information is critical for reflecting actual field activities in the estimates. Further, with more regional type contracts being used by USACE, an analysis of daily production data will assist cost engineers in understanding project limitations in adjacent districts and ensure quality estimates for regional contracts.

The ERDC has obtained RMS data for over 450 unique dredging (hopper/cutterhead) contracts with daily production information that is currently being applied to several differing initiatives and trend analyses (USACE, 2017). As mentioned, the CEDEP is the official dredge estimating program for the USACE. By USACE policy CEDEP needs to be periodically validated to ensure that the assumptions and equations being used by the program are accurate (USACE, 2016). Cost engineers from the Jacksonville District (SAJ), Portland District (NWP), and USACE Cost Engineering Center of Expertise located in Walla Walla District (NWW), have joined CHL in performing a validation study for the production and unit cost output of the CEDEP by using historical RMS dredge data.

Scheduling Optimization

In recent years, the USACE has been working across district and division boundaries to optimize scheduling of USACE dredging projects to maximize the industry dredging fleet (Loney, Cotterman, Brown, & Mitchell, 2019; Mitchell, Wang, & Khodakarami, 2013).. If similar dredging projects can be sequenced into one regional contract, that provides longer working durations for the winning contractor, reduces the amount of "back and forth" mobilization and demobilization, and lowers cost allowing USACE to perform more dredging operations (Dunkin & Mitchell, 2015). Supplementing dredge scheduling optimization with daily production records from varying sized dredges in unique projects, improves understanding of the non-effective working times and cycle times that typically add to the duration of a given project. Additional trends seen from daily RMS production data analysis such as recurring seasonal delays (weather/traffic), productivity versus placement distance, percent Effective Work Time (EWT) versus dredge size, can also help inform the optimization model to provide an accurate scheduling output given known parameters such as dredges available for work.

RMS DATA SAMPLE

CHL has compiled over 450 RMS individual dredging (hopper and cutterhead) contract production summary reports from across the nation from 2010-present. As compared to the number of contracts within the Dredging Information System (DIS) (USACE, 2022), this represents roughly 30.42% of the dredging projects; specifically, 44.14% of Hopper dredging projects and 26.13% of cutterhead projects. Figures 1 and 2 illustrate the total number of contracts sampled and the total amount of daily records by region and dredge type. The West Coast and Great Lakes regions were not included in this evaluation due to small data representation.

The regional groupings for this effort include projects located in the Gulf, North Atlantic, and South Atlantic (Figure 3). The North Atlantic is comprised of the New England, New York, Baltimore, Philadelphia, and Norfolk USACE Districts. The South Atlantic is comprised of the Wilmington, Charleston, Savannah, and Jacksonville USACE Districts, and the Gulf is represented by the Mobile and Galveston Districts. New Orleans District (MVN) daily dredge production summaries were not used for this effort due to the non-standard report structure. While several dredging operations take place every year in MVN, their data is being aligned with the other districts for inclusion into future versions of this effort.

Cutterhead dredges have been categorized by size. The definitions of size bin classifications and the total number of records for each category from the RMS sample are shown in Table 1. A very small portion of projects (and daily records) does not contain information on cutterhead diameter size. Such records were still used for analysis that did not consider diameter size.

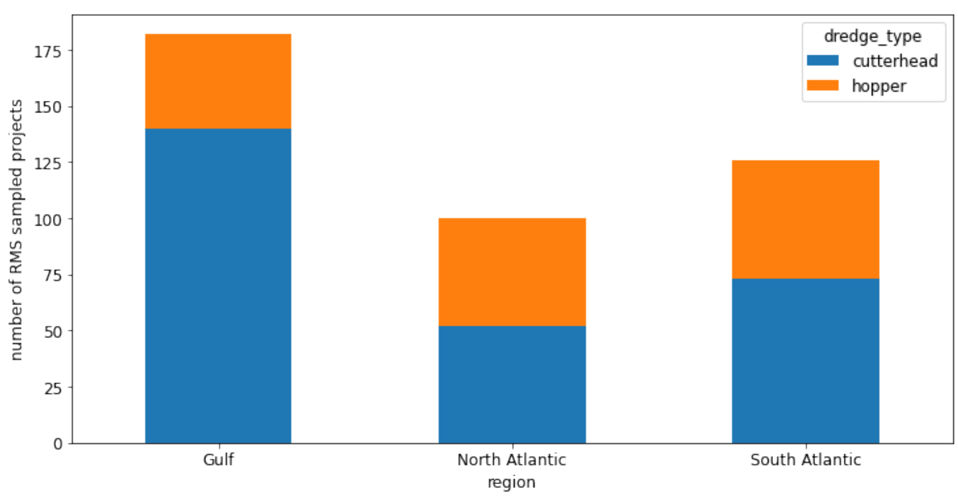

Figure 1. Number of RMS sampled projects, by region and dredge type

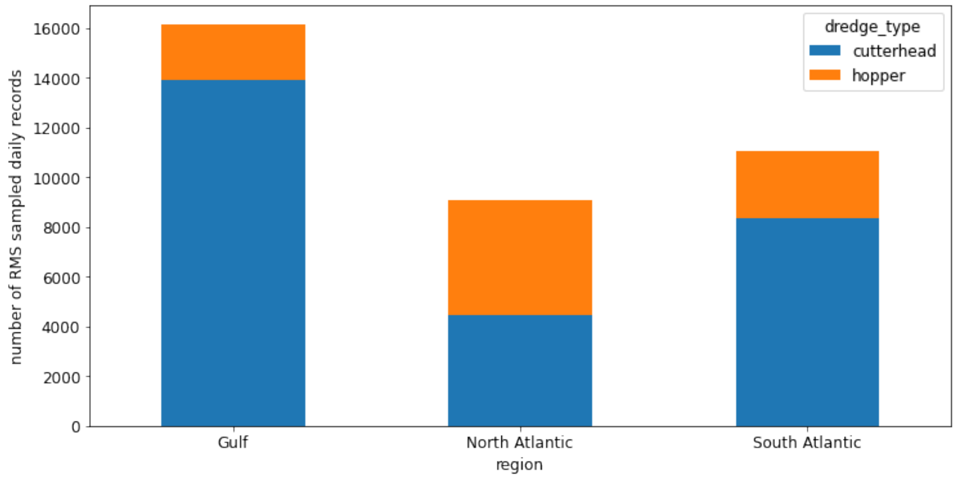

Figure 2. Number of RMS sampled daily records, by region and dredge type

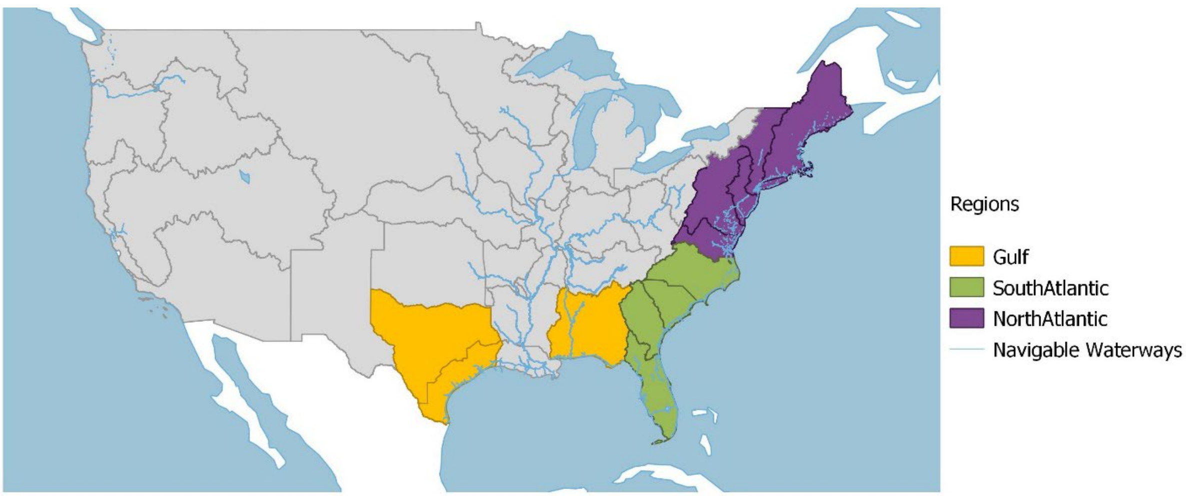

Figure 3. Geographic regions

Table 1. Sample number of projects and daily records by cutterhead size and region

Cutterhead Size	Number of projects				Number of daily records			
	North Atlantic	South Atlantic	Gulf	Subtotal projects in all regions	North Atlantic	South Atlantic	Gulf	Subtotal daily records in all regions
Small (diameter <18in)	12	10	9	31	1270	819	989	3078
Medium (diameter between [18-26in])	14	48	96	158	1346	5666	9730	16742
Large (diameter >26in)	25	12	31	68	1782	1504	2781	6067
Unknown	1	3	4	8	50	338	404	792
Total	52	73	140	265	4448	8327	13904	26679

DREDGE PRODUCTION DATA ANALYSIS

CHL has been using the dredge production summary reports obtained from RMS to compare dredge performance on a national and regional level with varying inputs. The material presented below has been regionalized to increase data groupings and reduce singling out districts, vessels, or contractors. This high-level analysis is intended to be used as a proof of concept for informing dredge cost engineering and scheduling optimization efforts. The following set of figures show some of the early comparisons and results regarding cycle time and productivity for hoppers and cutterhead dredges by region and dredge size.

RMS Cycle Time and Variables Analyzed

The RMS generates a dredge production summary report for each dredging contract using information from individual daily production worksheets. Each production summary report includes information on the time spent by the dredge in each part of the dredging cycle. RMS production summary reports and the variables analyzed in this work vary per type of dredge.

Hopper Dredge Variables Used

The paragraphs below explain a typical dredging cycle for hopper dredges and show the relationship between the different variables used in this work. A brief description of these variables is presented in Table 2.

For Hopper dredges, the following are the daily dredging cycle time activities in RMS, measured in time-spans (hh:mm):

Dredging time = operating time + non-effective time + lost time (1)

The operating time (i.e. "effective time") is further detailed in RMS as follows:

Operating time = pumping time + turning time + time to dump + dumping time + time to cut + connect time + disconnect time (2)

Using the above information, the daily dredging cycle time was broken down into activities that allowed for an analysis of time spent in pumping material out of the channel bottom, versus the time spent in transporting the extracted material to and from the disposal sites:

Dredging time = Effective time "Dredging" + Effective Time "Transporting material" + Non-effective time + Lost time (3)

The following variables were derived, calculated as a time percentage of total daily cycle dredging activities:

Effective time "Dredging" = 100 x pumping time / dredging time (4)

Effective Time "Transporting material" = 100 x (turning time + time to dump + dumping time + time to cut + connect time + disconnect time) / dredging time (5)

Non-effective time = 100 x non-effective time / dredging time (6)

Lost time = 100 x lost time / dredging time (7)

Table 2. Variables used for production analysis of hopper dredges (USACE, 2010)

Variable name	Units	Description	Time measure
Dredging time	hh:mm	Total hopper cycle time, i.e. time when actual production is taking place plus allowable downtime.	Daily
Operating time	hh:mm	Portion of the hopper cycle time spent by the dredge in “effective” work, when actual production is taking place, such as pumping material out of the channel bottom or transporting material to/from disposal sites. (USACE, 2008)	Daily
Non-effective time (hh:mm)	hh:mm	Portion of the hopper cycle time when the dredge is operational but no production is taking place, such as making changes to pipelines, cleaning trash from the suction head, minor operating repairs, and moving between locations. (USACE, 2008)	Daily
Lost time (hh:mm)	hh:mm	Portion of the hopper cycle time when the dredge is not operational, normally due to a lack of required crew, major repairs and alterations, drydocking, cessation, and collisions (USACE, 2008).	Daily
pumping time	hh:mm	Portion of the hopper cycle time spent pumping material out of the channel bottom.	Daily
turning time	hh:mm	Portion of the hopper cycle time spent between finishing pumping material out of the channel bottom, and starting to travel towards the placement site.	Daily
time to dump	hh:mm	Portion of the hopper cycle time spent traveling towards the placement site.	Daily
dumping time	hh:mm	Portion of the hopper cycle time spent disposing the material on the disposal or placement site.	Daily
time to cut	hh:mm	Portion of the hopper cycle time spent transiting to the dredge cut from the placement site	Daily
connect time	hh:mm	Portion of the hopper cycle time spent connecting to pipeline for hopper pumpout	Daily
disconnect time	hh:mm	Portion of the hopper cycle time spent disconnecting from pipeline after hopper pumpout	Daily
Effective time “Dredging”	% of dredging time	Percentage of the hopper cycle time spent pumping material out of the channel bottom.	Daily
Effective Time “Transporting material”	% of dredging time	Percentage of the hopper cycle time spent in all activities pertaining the disposal of material.	Daily
Non-effective time (percent)	% of dredging time	Percentage of the hopper cycle time when the dredge is operational, but no production is taking place, such as making changes to pipelines, cleaning trash from the suction head, minor operating repairs, and moving between locations. (USACE, 2008)	Daily
Lost time (percent)	% of dredging time	Percentage of the hopper cycle time when the dredge is not operational, normally due to a lack of required crew, major repairs and alterations, drydocking, cessation, and collisions (USACE, 2008).	Daily
Average gross production	cy/day	Volume of material dredged per day, in average, during a given contract.	Contract average
Average travel time to/from dumping site	minutes/load	Time spent in all activities pertaining the disposal of material per load, in average, during a given contract.	Contract average

Other RMS hopper dredging variables used for this effort are the Average gross production (measured in cy/day), and the Average travel time to/from dumping site (measured in minutes per load). These variables are calculated per contract by averaging daily records.

Average travel time to/from dumping site (minutes/load) = (8)
Average turning time (minutes/load) +
Average hauling time (minutes/load) +
Average time-to-cut (minutes/load) +
Average connect/disconnect(minutes/load) +
Average dumpling time (minutes/load)

Cutterhead Dredge Variables Used

RMS cutterhead production summary reports contain a total dredging cycle time comprised of variables measured as time-spans (hh:mm) shown in equation (9). A brief definition of variables used in this work is provided in Table 3. The following equations show the relationship of variables used.

Dredging time = pumping time + handling pipelines + handling anchor lines + (9)
clearing pump and pump lines + clearing cutter or suction head +
changing location of plant or job + loss due to natural elements +
moving out of way of traffic + shoreline and shore work +
minor repairs + miscellaneous + lost time

To allow for the production analysis the daily cutterhead dredging cycle time activities were grouped as follows:

Dredging time = Percent of Effective Time (EWT) + changing location + (10)
avoiding ship traffic + work on lines and cutter/suction head +
maintenance and weather delays + other

The following variables were calculated as a time percentage of total daily cycle dredging activities:

Percent of Effective Time (EWT) (“Dredging”) = 100 x pumping time / dredging time (11)

Changing location = 100 x changing location of plant or job / dredging time (12)

Avoiding ship traffic = 100 x moving out of way of traffic / dredging time (13)

Work on lines and cutter/suction head = 100 x (handling pipelines + handling anchor lines + clearing pump and pump lines + clearing cutter or suction head) / dredging time (14)

Maintenance/weather delays = 100 x (minor repairs + loss due to natural elements) / dredging time (15)

Other = 100 x (shoreline and shore work + miscellaneous + lost time) / dredging time (16)

Lastly, this work considers the average gross production (measured in cy/day) per contract and the length of the discharge pipe (ft) used each day by each dredge.

Table 3. Variables used for production analysis of cutterhead dredges *(USACE, 2010)*

Variable name	Units	Description	Time measure
Dredging time	hh:mm	Total cutterhead cycle time, i.e. time when actual production is taking place plus allowable downtime.	Daily
pumping time	hh:mm	Portion of the cutterhead cycle time spent by the dredge in "effective" work, when actual production is taking place, such as pumping material out of the channel bottom or transporting material to/from disposal sites. (USACE, 2008)	Daily
handling pipelines	hh:mm	Portion of the cutterhead cycle time spent due to handling pipelines.	Daily
handling anchor lines	hh:mm	Portion of the cutterhead cycle spent due to handling anchor lines.	Daily
clearing pump and pump lines	hh:mm	Portion of the cutterhead cycle time spent due to clearing pump and pump lines.	Daily
clearing cutter or suction head	hh:mm	Portion of the cutterhead cycle time spent due to clearing cutter or suction head.	Daily
changing location of plant or job	hh:mm	Portion of the cutterhead cycle time spent due to changing plant location.	Daily
loss due to natural elements	hh:mm	Portion of the cutterhead cycle time loss due to natural elements.	Daily
moving out of way of traffic	hh:mm	Portion of the cutterhead cycle time spent due to moving out of way to vessel traffic.	Daily
shoreline and shore work	hh:mm	Portion of the cutterhead cycle time spent due to shoreline and shore work.	Daily
minor repairs	hh:mm	Portion of the cutterhead cycle time spent due to minor plant repairs.	Daily
miscellaneous	hh:mm	Portion of the cutterhead cycle time spent due to miscellaneous work.	Daily
lost time	hh:mm	Portion of the cutterhead cycle time when the dredge is not operational, normally due to a lack of required crew, major repairs and alterations, drydocking, cessation, and collisions (USACE, 2008).	Daily
Percent of Effective Time (EWT)	% of dredging time	Percentage of the cutterhead cycle time spent in removing material out of the channel bottom.	Daily
changing location	% of dredging time	Percentage of the cutterhead cycle time spent due to changing plant location.	Daily
avoiding ship traffic	% of dredging time	Percentage of the cutterhead cycle time spent due to moving out of way to vessel traffic.	Daily
work on lines and cutter/suction head	% of dredging time	Percentage of the cutterhead cycle time spent due to handling pipe and anchor lines, clearing pump and pump lines, and clearing cutter or suction head.	Daily
maintenance/weather delays	% of dredging time	Percentage of the cutterhead cycle time loss due to minor repairs and natural elements	Daily
other	% of dredging time	Percentage of the cutterhead cycle time spent due to shore work, miscellaneous, and lost time (normally due to a lack of required crew, major repairs and alterations, drydocking, cessation, and collisions) (USACE, 2008)	Daily
average gross production	cy/day	Volume of material dredged per day, in average, during a given contract.	Contract average
discharge pipe length	ft	Length of the discharge pipe connecting the dredge with the disposal site.	Daily

Production Analysis

The following paragraphs contain the high-level dredging data analysis from RMS. First, average production statistics per project (CY/day) are compared across regions and dredge types. Next, the analysis focuses on hoppers highlighting daily cycle time activity percentages by region and changes in productivity as a function of travel time to/from material dumping sites. Lastly, for cutterheads, cycle time activity percentages are observed by region and by cutterhead size concluding with notes on productivity versus discharge pipe length.

Figure 4 contains boxplots of the average gross daily production (cy/day) obtained by dredge type and region. These show not only the average production rate but also the range of production rates achieved by each type of dredge. The South Atlantic and Gulf, hopper dredges achieve a noticeably higher production than cutterheads, yet in the North Atlantic the average productivity between hoppers and cutterheads is almost identical. Further, the higher end productivity realized by the cutterheads in the North Atlantic is higher than the hopper dredges. Higher production rates for cutterheads in the North Atlantic is likely tied to the fact that the placement sites, especially the offshore sites in the North Atlantic region are a greater distance from the digging area than in the other regions forcing hoppers to spend longer travel times to/from placement sites at the expense of pumping material out of the channel bottom[4]. In contrast, the Gulf region, which shows the highest productivity by hopper dredges generally has shorter placement site distances. Figure 5 shows the time percentages of the hopper dredging cycle by region.

Hopper Dredge Production Analysis

This section analyzes the percentage of time spent in different cycle time activities by hopper dredges in different regions. In Figure 5, note the dark green "Effective Time: transport to/from placement" in the North Atlantic as compared to the Gulf and South Atlantic. While hopper dredges in the Gulf and South Atlantic spend 36.1% and 41.9%, respectively, of the cycle time hauling material, hopper dredges in the

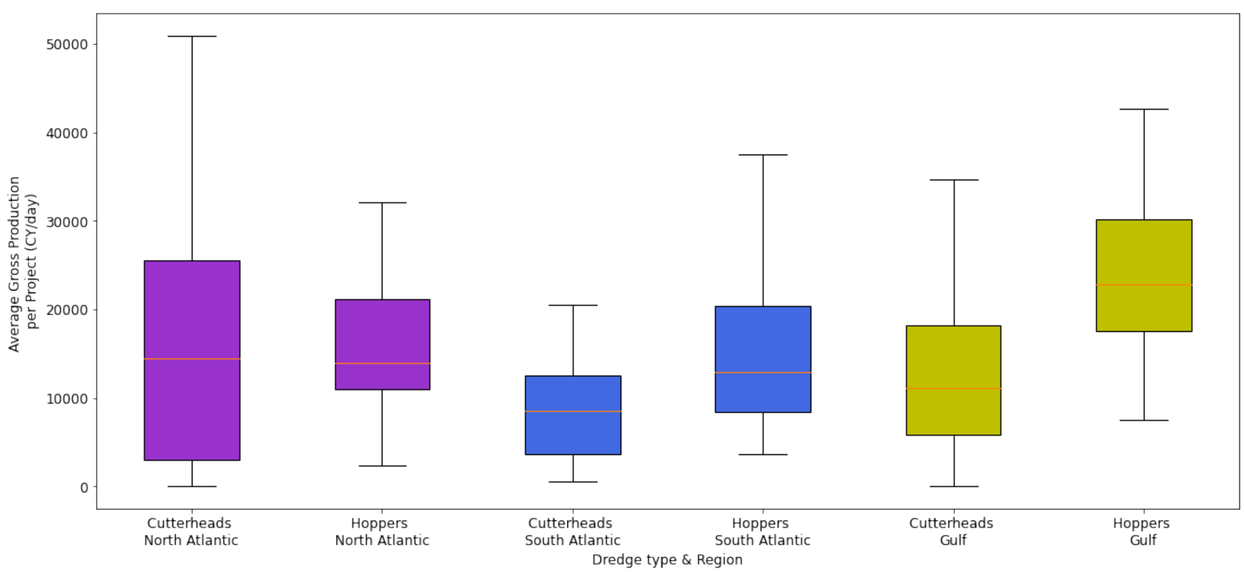

Figure 4. Production (cubic yards dredged per day), by dredge type and region. Production averages calculated form project-level data.

[4] Cutterhead dredging operations are inherently different than the hopper dredges. Hopper dredges pump material into the vessel and traverse the waterway to the placement site, cutterhead dredges stay on the dredging location and continuously pump material through pipeline to a selected discharge location.

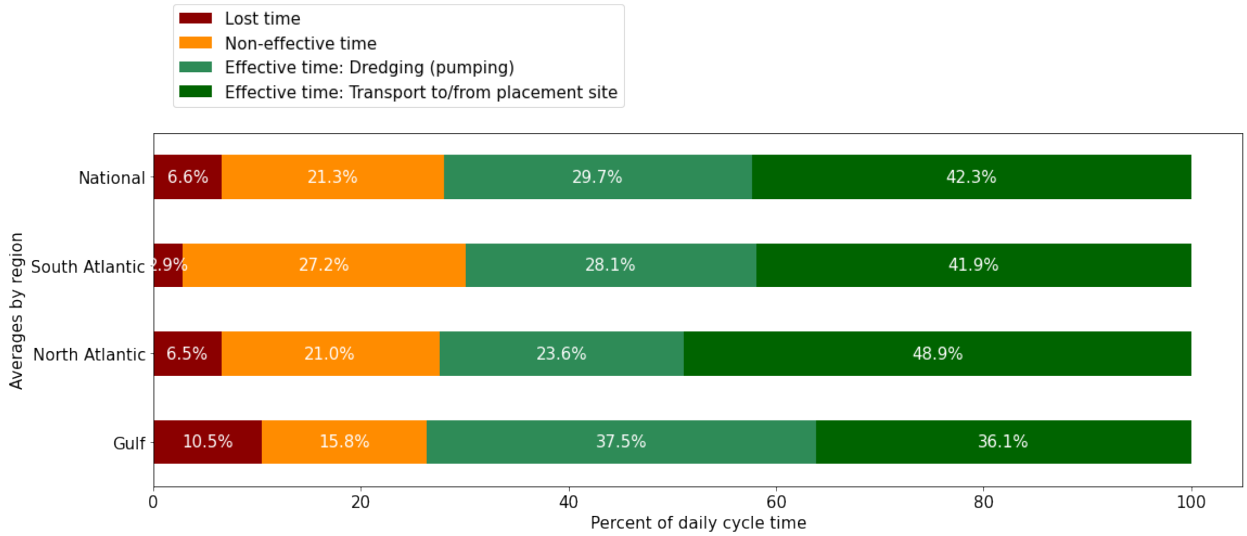

Figure 5. Hopper dredging cycle time percentages, by region. Activity and region averages are calculated from daily production data.

North Atlantic spend 48.7% of cycle time transporting to and from the placement site. This additional time spent transporting material is reflected directly as a shorter dredging portion of the effective time. The Gulf region inversely, has the highest percentage of dredging time with the lowest in transporting time.
Notably, hopper dredges in the Gulf region lost a higher percentage of cycle time than in the South and North Atlantic regions. Lost time may be due to a lack of required crew, major repairs and alterations, drydocking, cessation, and collisions.

Next, the authors analyze hopper's average daily production as a function of travel time to and from placement site (Figure 6). Each point of Figure 6 corresponds to a project in RMS. The vertical axle represents the projects' average daily volume of material dredged per day (measure in cubic yards/day), and the horizontal axis represents the travel time to and from the dumping site in minutes per load. Since the distance to placement sites (in miles) is not directly available in RMS, the travel time to and from the disposal site is used as a proxy. Figure 6 shows that the distance to placement sites in minutes) in North Atlantic is longer than in other regions and up to 500 minutes per load. It is intuitive that a longer travel distance to place material for each cycle results in a longer travel time and less productivity per day. This trend is confirmed by the data in Figure 6 for all regions. The daily production data shows that for the projects in the North Atlantic region, the reduction in production as function of the distance to dumping sites is less pronounced than in other regions. Contractors may be implementing practices to compensate for lower daily production from longer distance to dumping sites in North Atlantic such as traveling at relatively higher speeds at the expense of higher fuel consumption. Considering the trendline at National level, 10 minutes of additional travel time to/from placement sites cause an average reduction of productivity in the order of 660 cy/day. Over a several month duration, this variance in productivity becomes significant. This information is important as a deciding factor to allocate disposal sites to projects (USACE, 2012; Wilkens, Suedel, & Mitchell, 2019).

The range of production values per day are much lower within the North Atlantic (35,234 cy/day) than in the Gulf (57,052 cy/day) or in South Atlantic (55,132 cy/day) (Figure 6). This could be attributed to the inherent difference in sediment types in each region, the size of hopper vessel being used, and/or the distance to placement site.

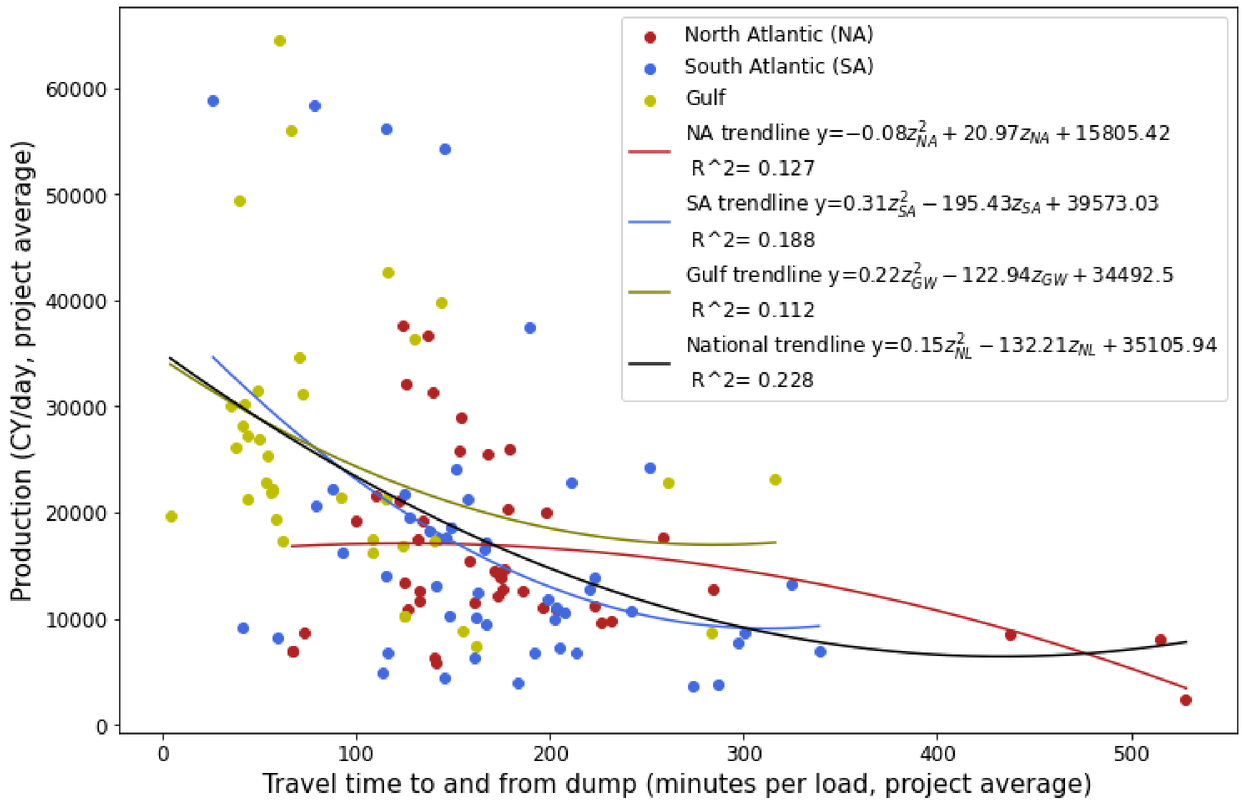

Figure 6. Production (cubic yards dredged per day) versus distance to dump site, by region. Since the distance between the dredging and dumping sites is not available in RMS, the travel time between those sites is used as proxy (in minutes per load). Project-average data displayed.

Figure 7 shows the frequency of occurrences for total travel times to and from placement sites. Based on the data included in this report, the vast majority of USACE hopper dredging projects rely on placement sites within 150 minutes round trip. The project shown to the far right had a vessel that took over 750 minutes (12.5 hours) to make one cycle to and from the placement site.

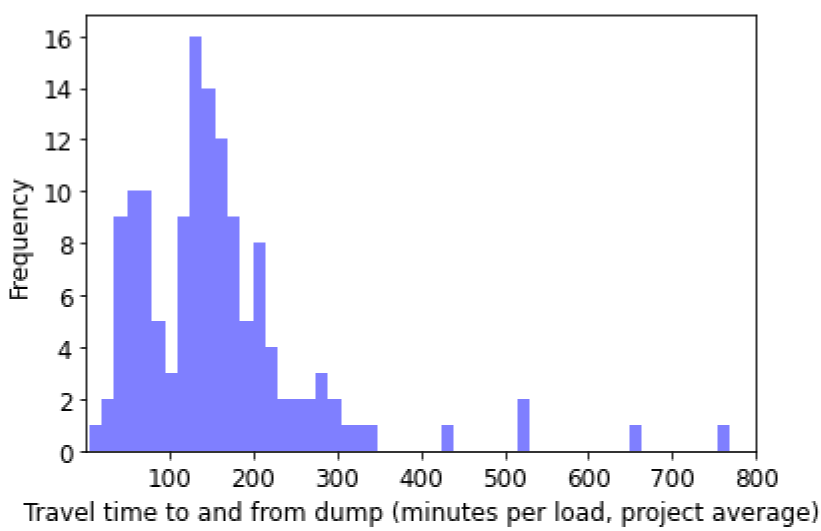

Figure 7. Histogram of distance to dumping/placement site, measures as travel time (minutes)

Cutterhead Dredge Production Analysis

Cutterhead dredging operations are inherently different than the hopper dredges. Hopper dredges pump material into the vessel and traverse the waterway to the placement site. Cutterhead dredges stay on the dredging location and pump material through pipeline to a selected discharge location. As such, there are different activities that are tracked for cutterhead performance Pipeline dredge production can be impacted from needing to move off the dredging location in the channel for transiting vessel traffic (Welp, n.d.). The North Atlantic region has the least amount of traffic interference (Figure 8). This could indicate that more vessels are traversing the Gulf and South Atlantic waterways during dredging season than in the North Atlantic, or it could simply mean that vessels have more space to pass without impacting dredge operations. This could be explored in the future by using Automatic Identification System (AIS) vessel counts in conjunction with dredging dates and locations. While many factors need to be considered when scheduling dredging operations (Nachtmann, Mitchell, Rainwater, Gedik, & Pohl, 2014), reducing the time dedicated to move out of the way of traffic by scheduling dredging operations during seasons of lower traffic would be beneficial for the dredge operation and the impacted vessel traffic. A seasonal analysis needs to be performed but is out of the scope of this work.

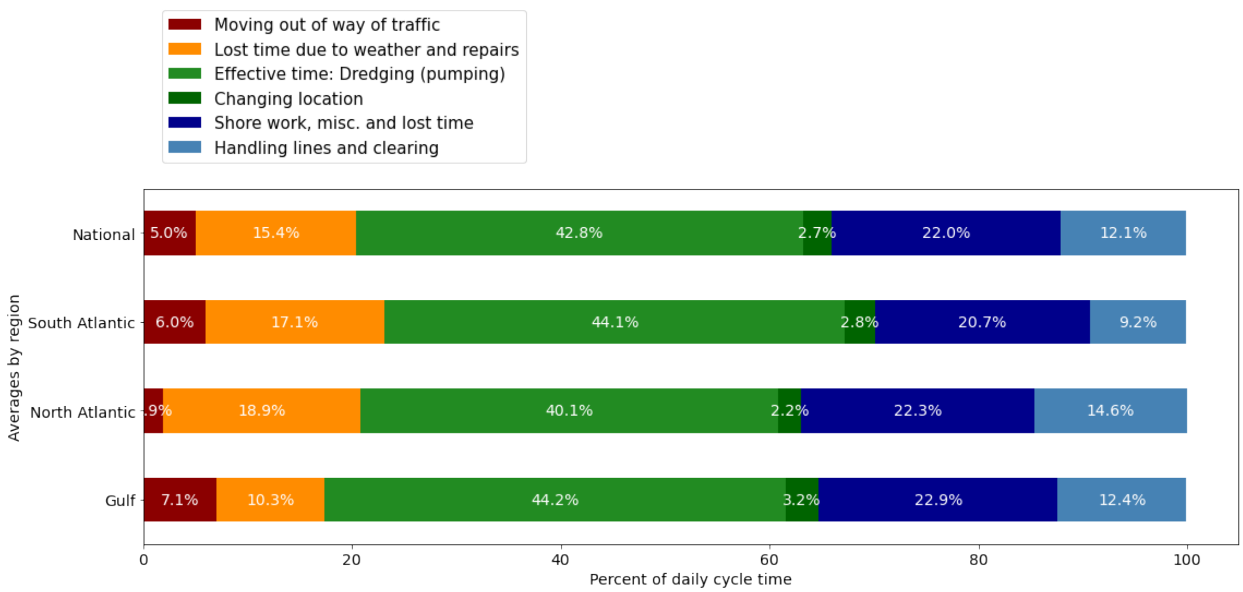

Figure 8. Cutterheads' dredging cycle time percentages, by region. Activity and region averages are calculated from daily production data.

Cycle time activities by cutterhead dredge size are presented in Figure 9 expressed as percentage of total dredging time. It is unclear why the lost time due to weather and repairs (orange portion of the horizontal bars) is higher for large dredges then the small and medium dredges. With all regions and dredge sizes being used at similar times of the calendar year, it is expected that weather delays by dredge size are similar. If so, then the observed lost time reflects higher repair needs on site with larger cutterhead dredges. The small dredges spent the most time handling and clearing pipeline. It is unknown whether this is from pipeline being plugged and needing assistance, or just reworking them for placement changes. From Figure 9, medium size dredges are the most efficient in the cutterhead fleet.

An analysis of the number of days that USACE projects used differing lengths of discharge pipeline by dredge size follows (Figure 10). The pipeline length can be used as a proxy for the distance between the digging location and the placement site. The majority of USACE projects require less than 15,000 linear feet of pipeline, though there are several jobs requiring well over 40,000 linear feet (7.5 miles). The medium

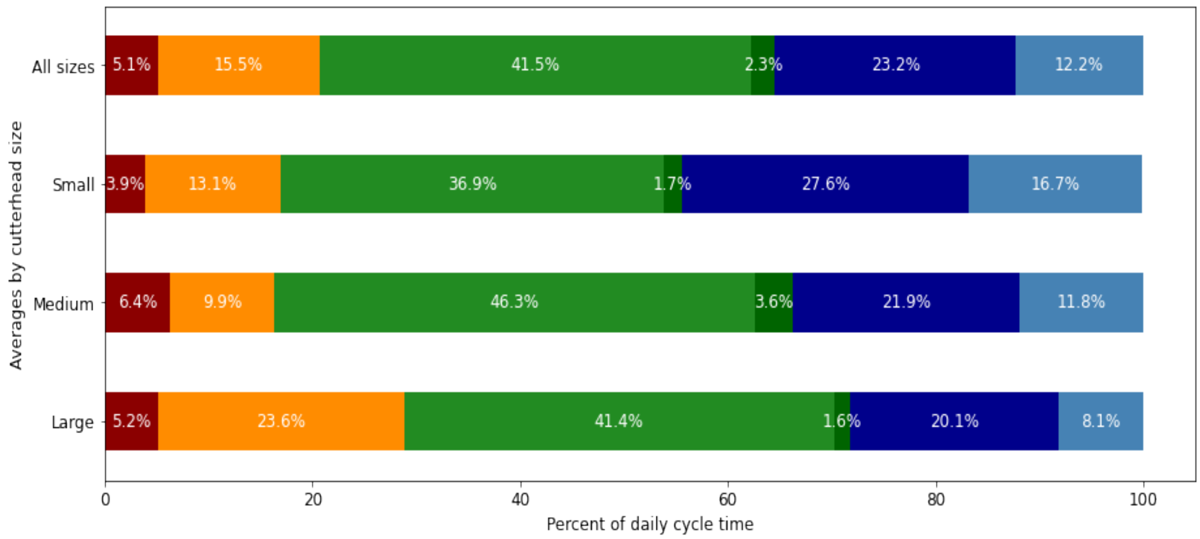

Figure 9. Dredging cycle time percentages, by cutterhead size. Activity and size averages are calculated from daily production data.

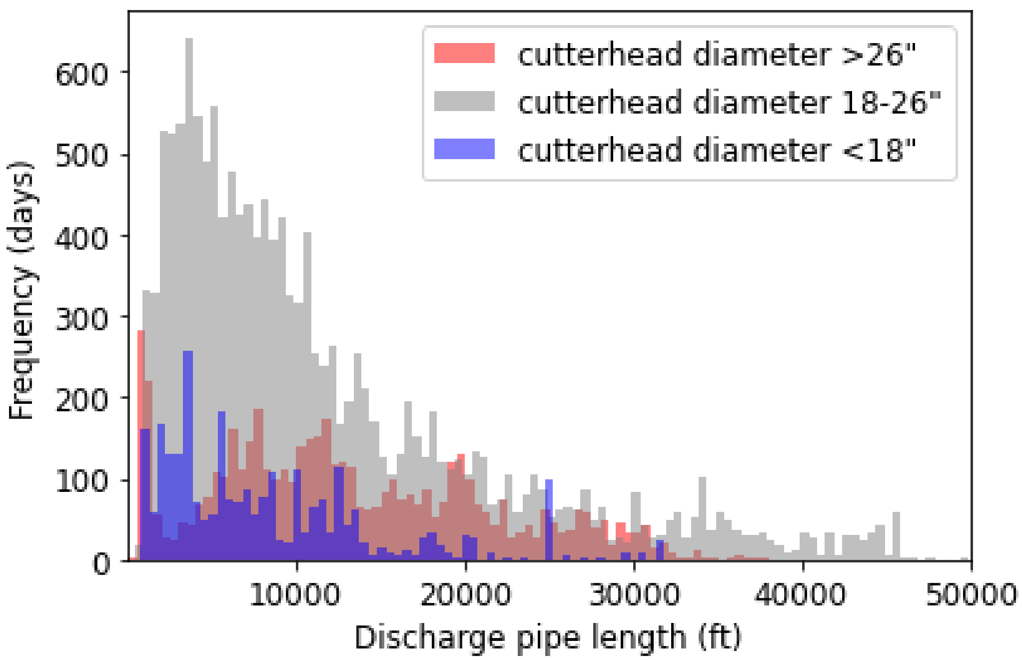

Figure 10. Histogram of discharge pipe length (feet), by cutterhead size. Daily data displayed.

class of cutterheads are generally pumping the longest distances. Production in cy/day was evaluated as a function of pipeline length. The main findings of such effort were that production trendlines were relatively flat for all cutterhead size groupings. The average production by cutterhead size is 24,412 cy/day for large dredges, 11,318 cy/day for medium dredges, and 3,142 cy/day for small dredges.

Lastly, an analysis of percent effective time (EWT) for cutterhead dredges is shown in Figure 11. Each boxplot in Figure 11 shows basic statistics (average, minimum, maximum, and interquartile range) for each group of cutterheads, categorized by region and size. The most interesting data point may be the green box at the right end of Figure 11, evidencing the difference in percent effective time of the large dredges in the Gulf compared to the large dredges in other regions. The small and medium dredges generally maintain percent effective working time over each region. Moreover, the small dredges working on the Gulf region present the lowest minimum and average percent effective time. Figure 11 indicates that the mobilization of larger cutterhead plant to the Gulf region results in a better use of the cutterhead fleet in terms of percent effective time compared to other regions. It is currently unknown why this discrepancy in effective time for large dredges in the Gulf exists.

CONCLUSION

This work provides an overview of the on-going efforts by the USACE in mining, analyzing, and using historic dredge production from the RMS. Hopper and cutterhead dredge production data is analyzed by region (Gulf, South Atlantic, and North Atlantic) and cutterhead size, with more than 36,000 daily records from over 400 projects contracted by the USACE to the private industry across 10 years. This work focuses on the relative percentual time spent by dredges in each of the activities of their production cycles. Highlights of this analysis are that hopper dredges in the North Atlantic spend in average 48.7% of cycle time transporting to and from the placement site, more than dredges in other regions, due to longer distance to disposal sites and at the expense of a reduced pumping time. The analysis explores productivity changes

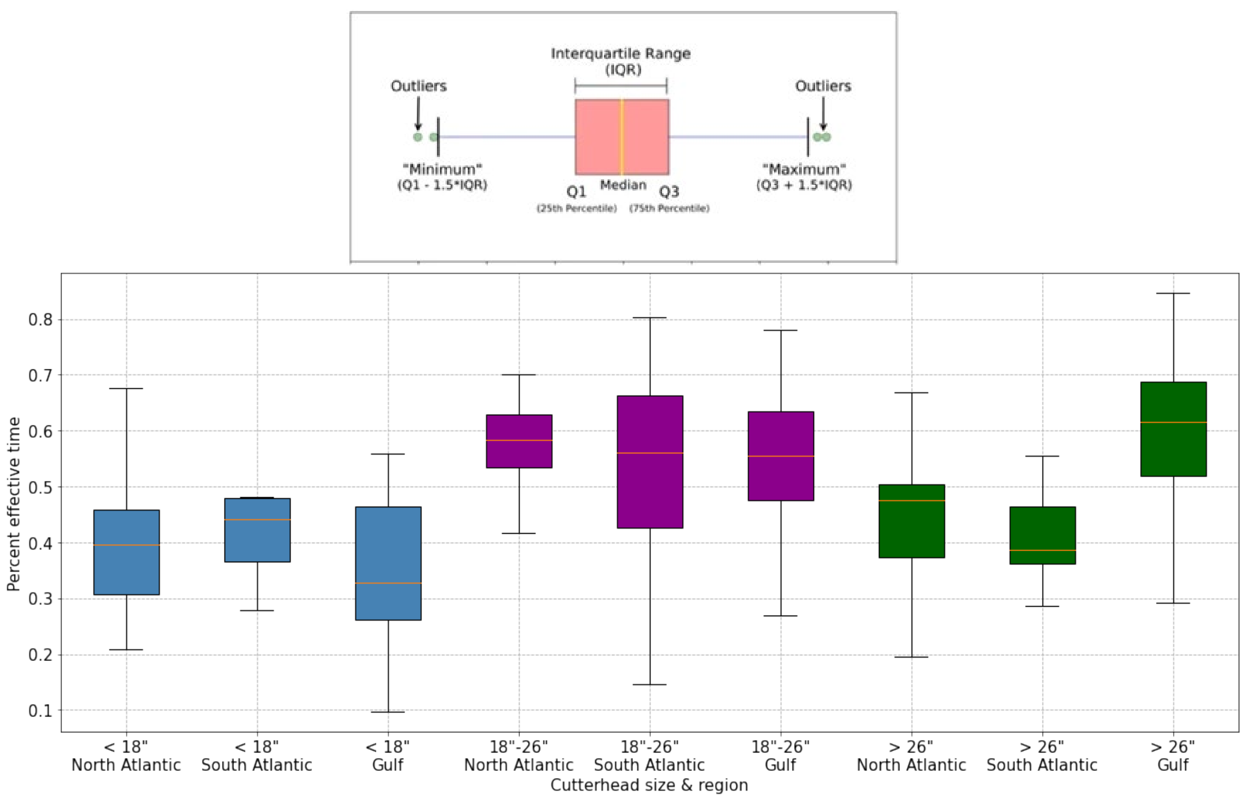

Figure 11. Boxplots showing Percent effective time (time spent pumping material from the channel bottom, as a percentage of the total daily dredging cycle time), by cutterhead size and region. Averages are calculated from daily production data.

(in terms of average volume dredged per day) as a function of distance to disposal sites. For hoppers, the data confirms theoretical assumptions, indicating that hopper dredge production declines as a function of distance to the placement site while cutterhead production remains consistent. The data evidences that the majority of USACE cutterhead projects require less than 15,000 linear feet of pipeline, though there are jobs requiring over 40,000 linear feet (7.5 miles). In addition, for cutterheads, this work evidences and compares percent effective time by cutterhead size and region. The large cutterheads are most effective in the Gulf region.

In the future, seasonality analysis may be made in regard to traffic and weather trends, and how they affect dredging production data from MVN, the West, and Great Lakes divisions where several dredging contracts take place each year will be incorporated into the analysis. RMS data informs future dredge schedule optimization, cost engineering, and regional contracting efforts.

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