DREDGING KNOWLEDGE BASE EXPERT SYSTEM

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ABSTRACT

A Dredging Knowledge Base Expert System (DKBES) provides U.S. Army Corps of Engineers dredging operations managers with a direct service to support a sound decision making process concerning their operations. A DKBES will retain hard won knowledge and experience in the face of entire communities of retiring Corps employees and contractors. Furthermore, a DKBES provides rapid, simple, and efficient analytical results that allow corps managers to "do more with less" when confronted with depleting resources and rising demand. This paper discusses how the DKBES uses a knowledge base to define and structure all of the pertinent data associated with the dredging process. This paper further describes data analysis involved to develop intelligent decisions and forecasts in dredging operations. Finally, this paper provides a simplified hypothetical dredge project scenario in a Corps district based on estimated budget and dredge material placement site availability and how the DKBES formulates analysis and makes the final decisions.

Keywords: Dredging decision support, object oriented knowledge structure in engineering, rules based programming, optimization programming, dredging information.

INTRODUCTION

A knowledge base expert system (KBES) serves to incorporate a wide variety of knowledge pertaining to a particular field to solve multiple specific functions and procedures that all relate to each other to form a common goal. A KBES, or more simply ES, uses a wide variety of tools to complete these tasks. Tools range from simple heuristic information (expert judgment) to elaborate statistical analysis. Most importantly, an ES serves to provide a calculated decision from the multitude of data, information sources and the analytical tools replicating human decisions with far more speed and accuracy. In effect, the ES augments human decision in a humanly approachable problem.

The DKBES serves to augment human decisions in managing dredging assets and resources. These assets and resources contain tangible elements such as funding, navigation channels, dredge material placement sites (DMPS) and contractor's dredge vessel availability. Intangible resources include environmental sustainability regarding beneficial use of the dredge material or socio-economic merit with contracting to a small or minority owned business. These factors combined can form absolutes for decision-making or just tip the balance when facing equal possibilities. Managing these resources means constructing a database of all known resources. The knowledge base forms a hierarchy of these databases to extract only information needed when it is needed.

As an example, the DKBES constructs hypothetical dredge scenarios for a given dredge channel location based on its associated resources. These resources include navigation channels with associated dredge material volume, available dredges for the dredge project, DMPS availability and capacity and all their associated factors.

OBJECTIVES

The DKBES starts with an example dredge scenario to provide proof-of-concept that a KBES can assist a Corps operations manager achieve his/her goals. This hypothetical dredge uses Louisiana coastal dredging operations in the New Orleans Corps of Engineers District (MVN) as the proving ground. This example scenario will compare several schedules of dredging and dredge material placement using all available resources. The DKBES will then analyze which dredge can dredge a navigation channel combinations effectively and perform the dredging operation within time, cost, DMPS capacity and operational constraints. The rules based programs filters out which sequences can provide the most effective time, cost and beneficial use of the dredge material. These resulting scenarios can then provide a general decision support tool for operations managers.

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DKBES STRUCTURE

The DKBES organizes dredge resources and factors as objects according to their physical properties. In the data structure, objects are classified as vessels, geographic locations, dredge projects and sedimentation rate. The DKBES designs this data structure so that common objects share common attributes. These data remain in the program for future projects, and users never need to enter the same data twice.

Geographic Location Objects

Geographic locations branch off into dredge channel and DMPS. These areas are very different as far as dredging is concerned, but very similar in terms of geography. They both share common attributes such as location (Latitude-Longitude or State Plane Coordinates (SPC)), area, Corps district jurisdiction, and other relevant geographic information. The data structure, then branches these objects off into their subclasses of dredge-channel and DMPS where their specific attributes further define them. Figure 1 describes the relationship between these attributes.

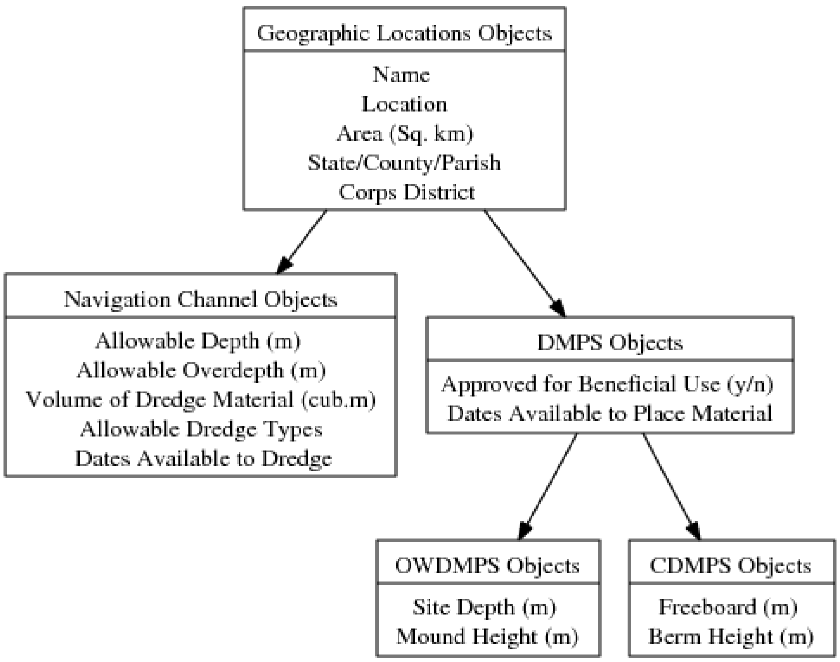

Figure 1. Geographic objects in the DKBES.

Navigation channels contain attributes for channel reach (river miles, station numbers, etc.), volume of dredge material in the channel, authorized depth, allowable over-depth, dates available to dredge, and what types of dredges typically dredge the channel (Hopper, Pipeline, Bucket, etc.).

DMPS objects contain their specific attributes such as area and beneficial use alternatives. Beneficial use alternatives indicate whether the DMPS meets Environmental Protection Agency (EPA) and other federal, state and local agencies' requirements as a wetland so that dredge material will create or restore a wetland conducive to indigenous wetland habitats. This factor becomes increasingly important for dredging operations as Corps districts adopt more beneficial use policies for dredge material. DMPS objects further divide into confined or open-water. Confined DMPS, or CDMPS objects contain attributes regarding berm height and free-board. Open water DMPS, or OWDMPS objects contain attributes for depth and mound height. Figure 2 describes these attributes. These attributes coupled with the DMPS area directly determine the dredge material capacity of the DMPS.

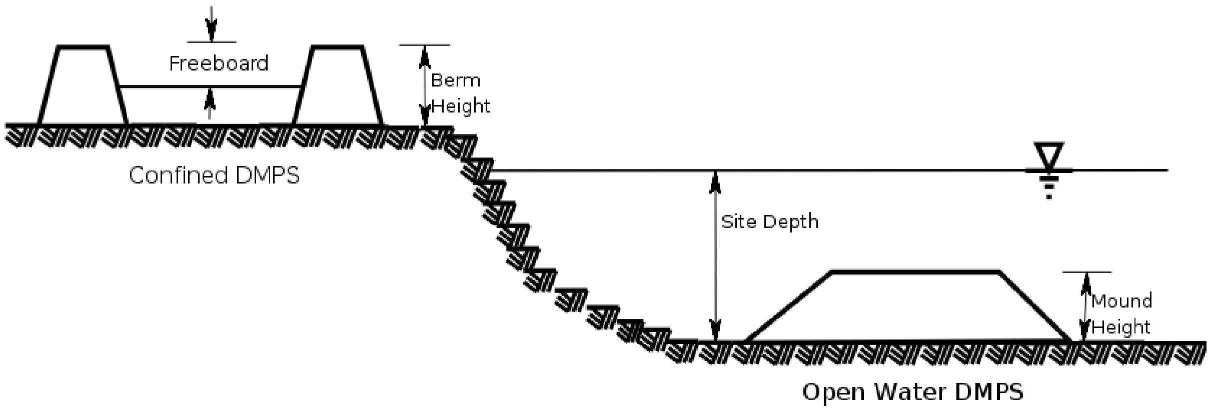

Figure 2. Confined and open-water DMPS illustrating geometry of clearance and freeboard to determine remaining capacity.

Dredge Objects

Dredge objects define the attributes associated with the dredge plants hired for Corps dredge contracts. Dredge objects stem from vessel objects and further branch off into different types of dredges such as pipeline, hopper, bucket, backhoe, etc. Each specific dredge type holds its own specific dredge attributes. General dredge attributes include dredge name and company, maximum dredge depth, and whether or not a dredge is compliant with the Corps of Engineers Silent Inspector (SI) Program. Figure 3 lists specific attributes concerning types of dredges. The DKBES can use dredge attributes to determine the dredge maximum production rate as well as operational cost. Certain socio-economic and regulatory information may also be helpful to users such as whether a dredge complies with SI standards necessary for Corps dredge contracts on hoppers, scows and, eventually, pipelines. Small business and/or minority owned information could also determine eligibility requirements for certain Corps dredge contracts.

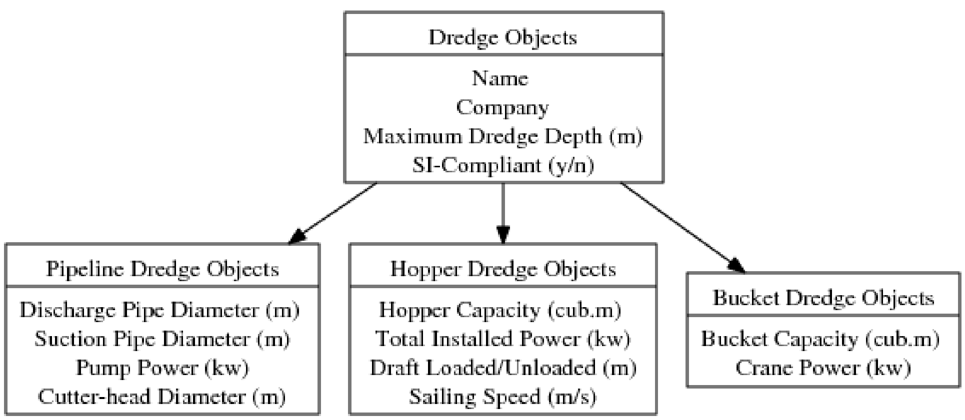

Figure 3. Dredge objects in the DKBES.

DREDGE PROJECT SCHEDULING

The DKBES constructs dredge contracts based on the actual dredge channels. The user specifies what dates the channel is available for dredging along with the volume of dredge material in the channel. This volume represents channel survey volume. The DKBES program then looks for dredge and DMPS objects available during this time period. Although a dredge and/or DMPS may not be available for the entire channel dredge period, the program looks for the coinciding dredge window where all three basic elements present a dredging opportunity with a

Navigation Channel, dredge, and DMPS. Figure 4 illu end dates, location, contractor name and dredge type. These data are available from the IWR at: http://www.iwr.usace.army.mil/ndc/. A MySQL database then queries cost, time and volume for these dredge contracts within Southeast Louisiana. Figures 6-9 illustrate the empirical relationship between volume vs. cost and volume vs. time for SWP and Atchafalaya Bay Channel. Regression analysis power fit determined empirical formulae for cost and time based on volume shown in Equations 1-2 and Table 1.

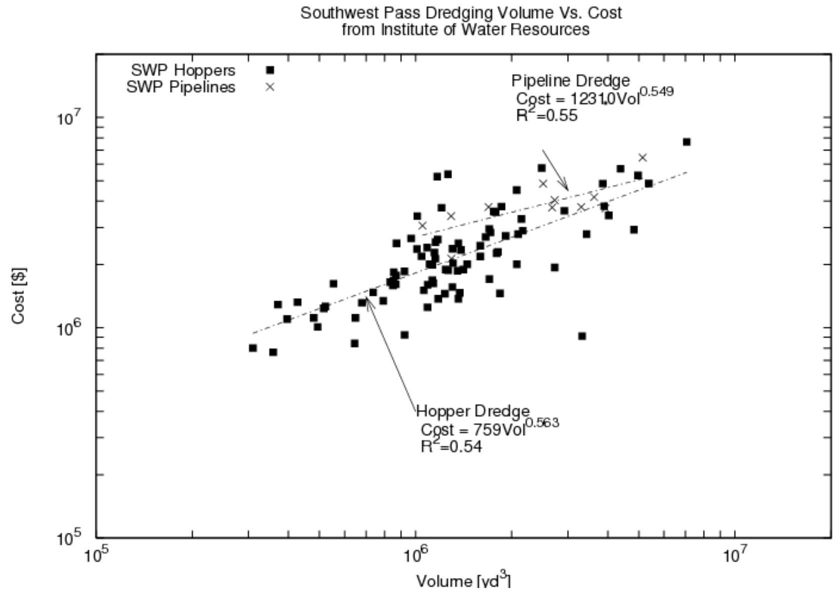

Figure 6. Volume and cost relationship for hopper and pipeline dredges on SWP.

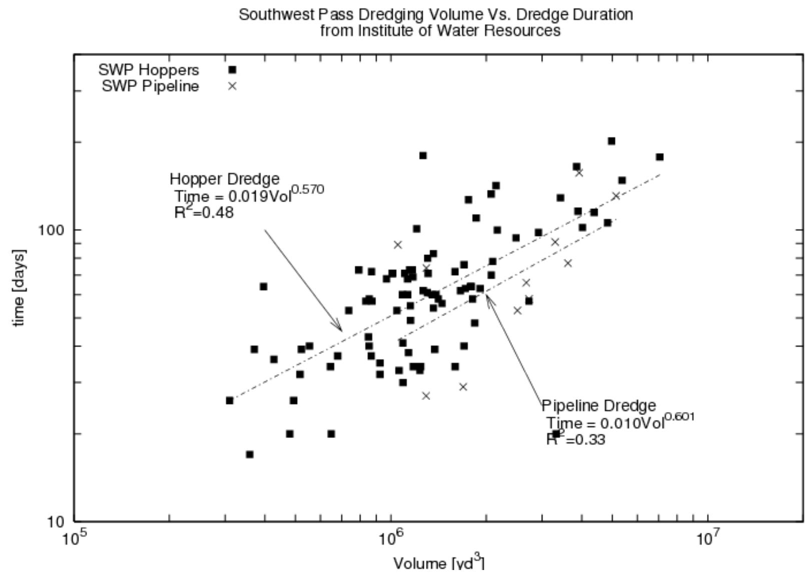

Figure 7. Volume and time relationship for hopper and pipeline dredges on SWP.

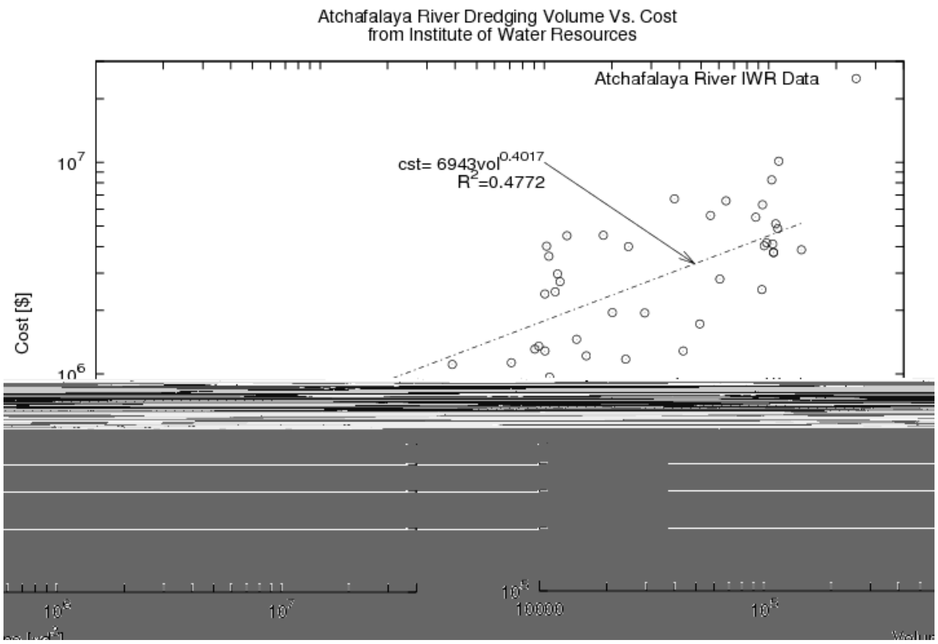

Figure 8. Volume and Cost relationship for pipeline dredges on Atchafalaya Bay Channel.

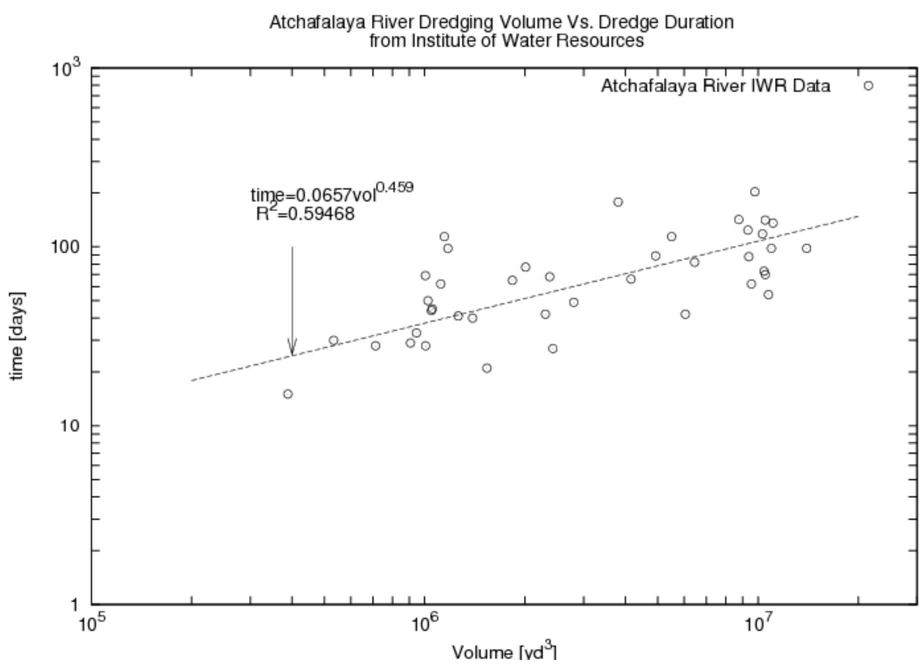

Figure 9. Volume and time relationship for pipeline dredges on Atchafalaya Bay Channel.

$$Cost\left[\$\right]=a\ \ Volume\left[yd^{3}\right]^{b} \tag{1}$$

$$Time\left[days\right]=c\ \ Volume\left[yd^{3}\right]^{d} \tag{2}$$

Table 1. Southeast Louisiana cost and time parameters.

	Cost		Time	
	a	b	c	d
Southwest Pass (SWP)				
pipeline	1231	0.549	0.010	0.601
hopper	759	0.563	0.019	0.570
Atchafalaya Bay				
pipeline	6943	0.4017	0.066	0.459

The DKBES example scenario determines the cost and time estimate for each dredge job based on these formulae. However, if the dredge project involves a pipeline dredge exceeding a pipeline length of 10km (6.2mi), the program determines the cost proportional to the volume and pipeline length by a factor of \$0.33per (m^3km) (\$0.41per (yd^3mi). The program computes the pipeline length as well as sailing distance as the straight-line distance between the channel and DMPS.

DREDGE SEQUENCES

Once the DKBES constructs dredge jobs, it moves on to sequencing these dredge jobs. Two or more dredge jobs make up a dredge sequence. A dredge job represents the match-up of navigation channel and dredge plant with a DMPS. The dredge sequence composes dredge jobs into a sequence of operations namely because a district will typically need to dredge several areas in close conjunction and succession. The DKBES automatically composes these dredge sequences so that all of the specified navigation channels get dredged within their time window. The advantage of using the DKBES to compose the sequences is that the DKBES (besides handling repetitive actions faster) only schedules a navigation channel for dredging once per contract, preventing duplicates. Furthermore, the DKBES program automatically detects and deletes sequences that schedule a dredge to be in two places at the same time. Thus, the DKBES schedules a rational and viable operational sequence. Figure 10 describes the dredge project sequencing process.

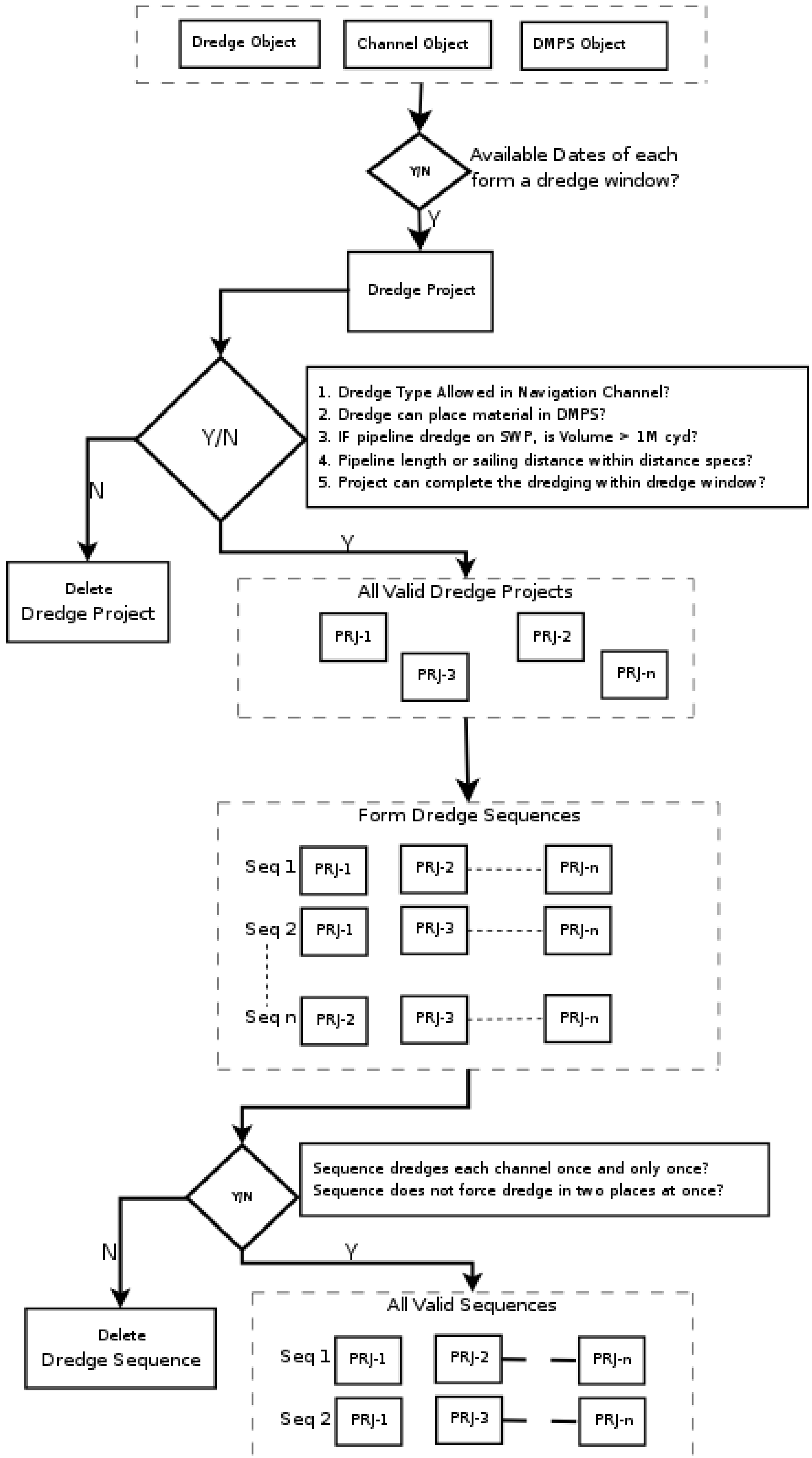

Figure 10. Flow chart of dredge job and dredge sequence construction.

EXAMPLE SCENARIO

The example DKBES scenario starts with a hypothetical dredge problem in Southeast Louisiana within the New Orleans District of the U.S. Army Corps of Engineers. The example looks at two primary dredging locations, SWP on the Mississippi River and Atchafalaya Bay Channel on the Atchafalaya River (see Figures 11, 12, and 13). The example looks at these two locations to schedule dredge jobs on these channels with the available hypothetical resources. This example scenario demonstrates the capabilities and current limitations of the DKBES.

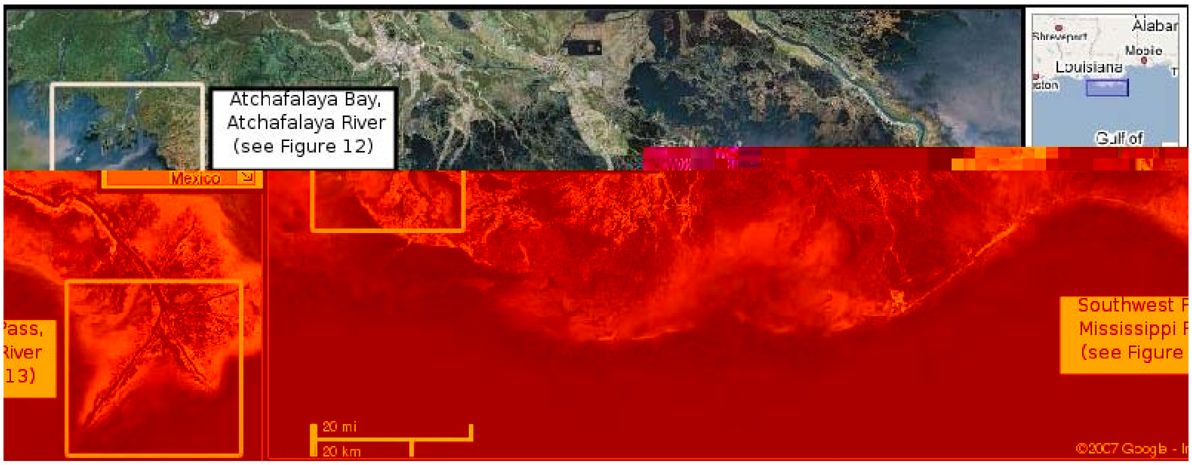

Figure 11. Overview of example scenario area including SWP and Atchafalaya Bay.

SWP and Atchafalaya Bay represent significant dredging responsibilities by MVN. Each area represents significant cost and volume of dredge material. Annual costs average \$8.2M and \$19.5M for Atchafalaya Bay and SWP, respectively. Dredge material volumes average 10.7Mm^3 (13.8Myd^3) and 10.1Mm^3 (13.2Myd^3) for Atchafalaya Bay and SWP, respectively. Contractors and the Corps dredge SWP predominately by hopper and occasionally by pipeline and dredge Atchafalaya Bay predominately by pipeline according to IWR data. These areas represent straightforward dredging methods but rather complicated dredge scheduling.

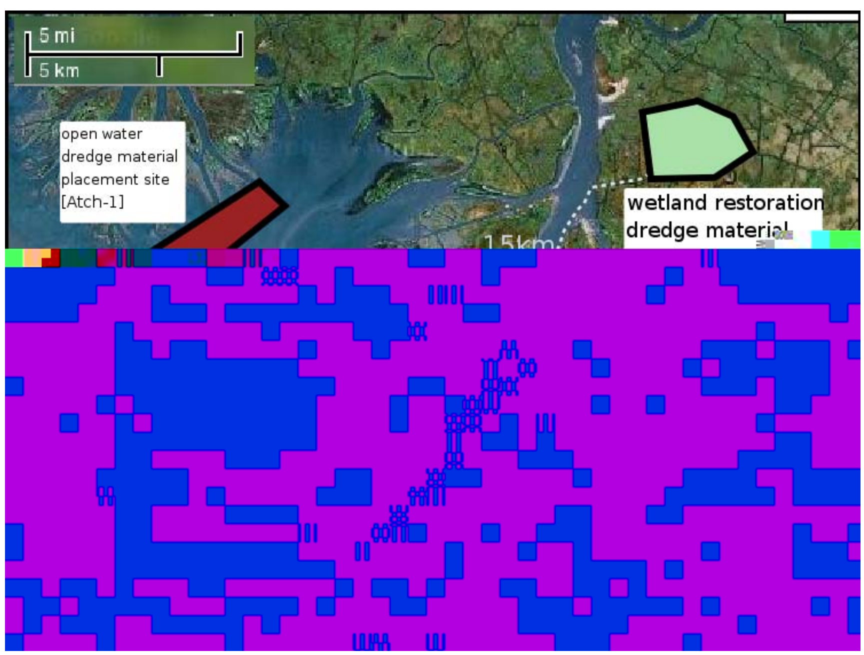

Figure 12. Atchafalaya Bay Navigation Channel and adjacent DMPS.

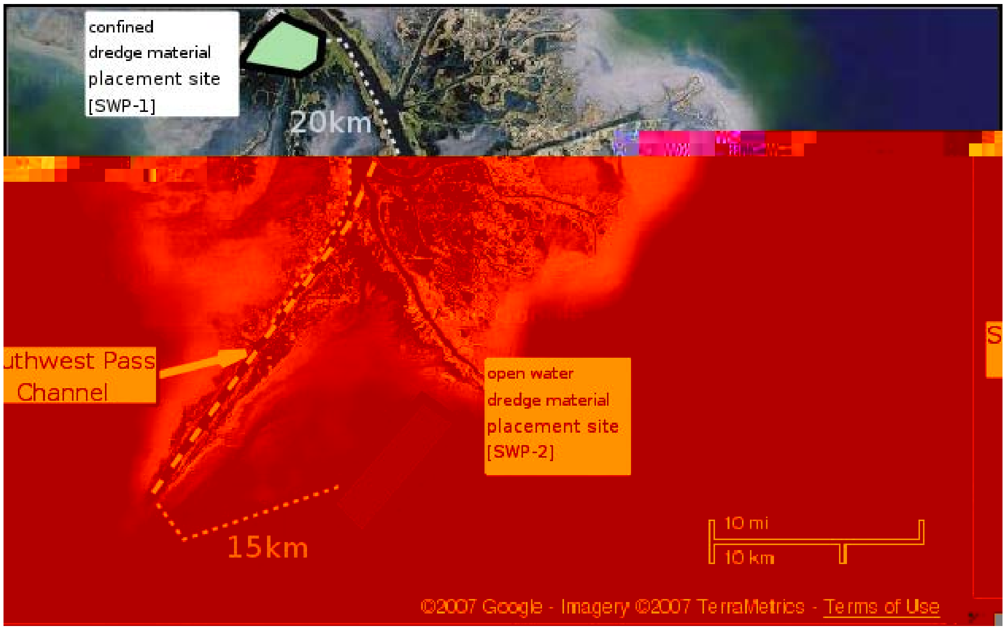

Figure 13. SWP navigation channel and adjacent DMPS.

Example Scheduling Inputs

The example scenario starts with dredging both channels once in the first half of the year according to their hypothetical dredge windows and a hypothetical dredge volume. Both dredge channels are available intermittently during periods of environmental blackouts due to fish or bird migrating seasons. Both dredge channels have two nearby DMPS (one confined, one open-water) to place the material (see Figures 12 and 13). The example scenario uses two contractor hopper dredges and two contractor pipeline dredges with varying availability dates. Figure 14 illustrates this example time-line. The example scenario assigns 600,000m^3 (780,000yd^3) and 610,000m^3 (793,000yd^3) of dredge material to Atchafalaya Bay and SWP, respectively.

The DKBES program uses this dredge schedule to formulate all possible combinations of dredge-channel-DMPS based on dredge window. The program filters out any invalid combinations based on heuristic controls. For instance, the 6100,000m^3 (798,000yd^3) volume of material in SWP is not enough to warrant pipeline dredge, only hoppers. The DKBES program then analyzes each dredge job for cost, expected duration and beneficial use of dredge material and its cost.

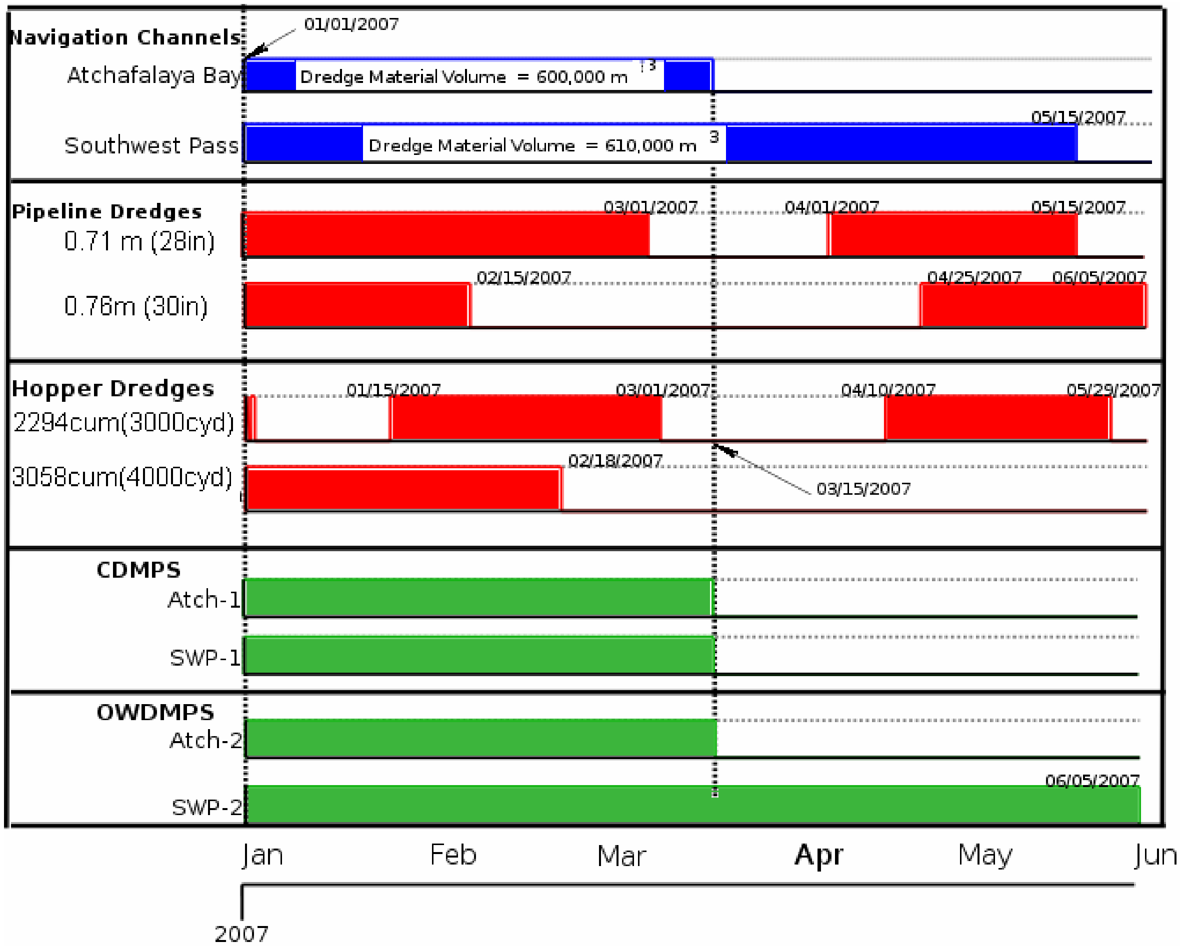

Figure 14. Time-line of navigation channels, dredges and DMPS for example scenarios.

Example Output

With the given scenario in Figure 14 and associated values, the DKBES identifies eight possible valid dredge solutions shown in Table 2. Four of these solutions use the 600,000m^3 (780,000yd^3) of dredge material in Atchafalaya Bay in the DMPS, [Atch-1], approved for beneficial use of dredge material. The increased pipeline length associated with this project shows these four projects raise the total cost to $5.2M from $2.8M of the four projects that pump the material along a shorter pipeline to the OWDMPS.

Variations of the Example Scenario

A second sample scenario looks at a variation of the first. Scenario 2 increases the dredge material volume in SWP to 1.2Mm^3 (1.56Myd^3) to trigger a key response. Now, pipeline dredges are eligible to dredge in SWP. Pipeline dredges dredge at a historically faster production rate according to the regression analysis in Figure 7. Hopper dredges cannot dredge this volume of material within the prescribed dredge window. Therefore, the DKBES program deletes all hopper dredge jobs as invalid in SWP. Pipeline dredges incur higher production cost as illustrated in Figure 6. Table 3 reflects this higher cost in the dredge solution.

Scenario 3 looks at the same volume of dredge material as in scenario 2 with the added condition of the CDMPS, [SWP-1] approved for beneficial use. The DKBES produces the same pipeline sequences as in scenario 2 with the 1.2Mm^3 (1.6Myd^3) of dredge material in SWP for beneficial use bringing the total to 1.8Mm^3 (2.3Myd^3) for the cost of $6.4M as shown in Table 4 sequence 3.

Table 2. Summary of DKBES Scenario 1 Dredge Sequences.									
Dredge Sequence		Channel	Volume(m^3)	Cost($)	Dates	Dredge Size	Dredge Type	DMPS	DMPS Type
Seq. 1	a	[Atchafalaya-Bay-1]	600,000	1,454,221.37	Jan 01,2007-Mar 01,2007	[0.71m (28in)]	Pipeline	[Atch-2]	OWDMPS
	b	[Southwest-Pass-1]	610,000	1,372,089.60	Jan 15,2007-Mar 01,2007	[2294m^3 (3000yd^3)]	Hopper	[SWP-2]	OWDMPS
		Total Cost = $2,826,310.97							
		Total Wetlands Beneficial Volume[m^3] = 0							
Seq. 2	a	[Atchafalaya-Bay-1]	600,000	1,454,221.37	Jan 01,2007-Mar 01,2007	[0.71m (28in)]	Pipeline	[Atch-2]	OWDMPS
	b	[Southwest-Pass-1]	610,000	1,372,089.60	Jan 01,2007-Feb 18,2007	[3058m^3 (4000yd^3)]	Hopper	[SWP-2]	OWDMPS
		Total Cost = $2,826,310.97							
		Total Wetlands Beneficial Volume[m^3] = 0							
Seq. 3	a	[Atchafalaya-Bay-1]	600,000	1,454,221.37	Jan 01,2007-Feb 15,2007	[0.76m (30in)]	Pipeline	[Atch-2]	OWDMPS
	b	[Southwest-Pass-1]	610,000	1,359,380.17	Jan 15,2007-Mar 01,2007	[2294m^3 (3000yd^3)]	Hopper	[SWP-2]	OWDMPS
		Total Cost = $2,826,310.97							
		Total Wetlands Beneficial Volume[m^3] = 0							
Seq. 4	a	[Atchafalaya-Bay-1]	600,000	1,454,221.37	Jan 01,2007-Feb 15,2007	[0.76m (30in)]	Pipeline	[Atch-2]	OWDMPS
	b	[Southwest-Pass-1]	610,000	1,372,089.60	Jan 01,2007-Feb 18,2007	[3058m^3 (4000yd^3)]	Hopper	[SWP-2]	OWDMPS
		Total Cost = $2,826,310.97							
		Total Wetlands Beneficial Volume[m^3] = 0							
Seq. 5	a	[Atchafalaya-Bay-1]	600,000	3,787,530.00	Jan 01,2007-Mar 01,2007	[0.71m (28in)]	Pipeline	[Atch-1]	CDMPS
	b	[Southwest-Pass-1]	610,000	1,372,089.60	Jan 15,2007-Mar 01,2007	[2294m^3 (3000yd^3)]	Hopper	[SWP-2]	OWDMPS
		Total Cost = $5,159,619.60							
		Total Wetlands Beneficial Volume[m^3] = 600,000							
Seq. 6	a	[Atchafalaya-Bay-1]	600,000	3,787,530.00	Jan 01,2007-Mar 01,2007	[0.71m (28in)]	Pipeline	[Atch-1]	CDMPS
	b	[Southwest-Pass-1]	610,000	1,372,089.60	Jan 01,2007-Feb 18,2007	[3058m^3 (4000yd^3)]	Hopper	[SWP-2]	OWDMPS
		Total Cost = $5,159,619.60							
		Total Wetlands Beneficial Volume[m^3] = 600,000							

Table 2. Summary of DKBES Scenario 1 Dredge Sequences.

Dredge Sequence	Channel	Volume(m^3)	Cost($)	Dates	Dredge Size	Dredge Type	DMPS	DMPS Type
Seq. 7 a	[Atchafalaya-Bay-1]	600,000	3,787,530.00	Jan 01,2007-Feb 15,2007	[0.76m (30in)]	Pipeline	[Atch-1]	CDMPS
b	[Southwest-Pass-1]	610,000	1,372,089.60	Jan 15,2007-Mar 01,2007	[2294m^3 (3000yd^3)]	Hopper	[SWP-2]	OWDMPS
	Total Cost = $5,159,619.60							
	Total Wetlands Beneficial Volume[m^3] = 600,000							
Seq. 8 a	[Atchafalaya-Bay-1]	600,000	3,787,530.00	Jan 01,2007-Feb 15,2007	[0.76m (30in)]	Pipeline	[Atch-1]	CDMPS
b	[Southwest-Pass-1]	610,000	1,372,089.60	Jan 01,2007-Feb 18,2007	[3058m^3 (4000yd^3)]	Hopper	[SWP-2]	OWDMPS
	Total Cost = $5,159,619.60							
	Total Wetlands Beneficial Volume[m^3] = 600,000							

Table 3. Summary of DKBES Scenario 2 Dredge Sequences.

Dredge Sequence		Channel	Volume (m^3)	Cost ($)	Dates	Dredge Size	Dredge Type	DMPS	DMPS Type
Seq. 1	a	[Atchafalaya-Bay-1]	600,000	1,454,221.37	Jan 01,2007-Feb 15,2007	[0.76m (30in)]	Pipeline	[Atch-2]	OWDMPS
	b	[Southwest-Pass-1]	1,200,000	2,677,494.31	Jan 01,2007-Mar 01,2007	[0.71m (28in)]	Pipeline	[SWP-1]	CDMPS
		Total Cost = $4,131,715.68							
		Total Wetlands Beneficial Volume[m^3] = 0							
Seq. 2	a	[Atchafalaya-Bay-1]	600,000	1,454,221.37	Jan 01,2007-Feb 15,2007	[0.76m (30in)]	Pipeline	[Atch-2]	OWDMPS
	b	[Southwest-Pass-1]	1,200,000	2,677,494.31	Jan 01,2007-Mar 01,2007	[0.71m (28in)]	Pipeline	[SWP-2]	OWDMPS
		Total Cost = $4,131,715.68							
		Total Wetlands Beneficial Volume[m^3] = 0							
Seq. 3	a	[Atchafalaya-Bay-1]	600,000	3,787,530.00	Jan 01,2007-Feb 15,2007	[0.76m (30in)]	Pipeline	[Atch-1]	CDMPS
	b	[Southwest-Pass-1]	1,200,000	2,677,494.31	Jan 01,2007-Mar 01,2007	[0.71m (28in)]	Pipeline	[SWP-1]	CDMPS
		Total Cost = $6,465,024.31							
		Total Wetlands Beneficial Volume[m^3] = 600,000							
Seq. 4	a	[Atchafalaya-Bay-1]	600,000	3,787,530.00	Jan 01,2007-Feb 15,2007	[0.76m (30in)]	Pipeline	[Atch-1]	CDMPS
	b	[Southwest-Pass-1]	1,200,000	2,677,494.31	Jan 01,2007-Mar 01,2007	[0.71m (28in)]	Pipeline	[SWP-2]	OWDMPS
		Total Cost = $6,465,024.31							
		Total Wetlands Beneficial Volume[m^3] = 600,000							

Table 4. Summary of DKBES Scenario 3 Dredge Sequences.

Dredge Sequence		Channel	Volume (m^3)	Cost ($)	Dates	Dredge Size	Dredge Type	DMPS	DMPS Type
Seq. 1	a	[Atchafalaya-Bay-1]	600,000	1,454,221.37	Jan 01,2007-Feb 15,2007	[0.76m (30in)]	Pipeline	[Atch-2]	OWDMPS
	b	[Southwest-Pass-1]	1,200,000	2,677,494.31	Jan 01,2007-Mar 01,2007	[0.71m (28in)]	Pipeline	[SWP-1]	CDMPS
		Total Cost = $4,131,715.68							
		Total Wetlands Beneficial Volume[m^3] = 1,200,000							
Seq. 2	a	[Atchafalaya-Bay-1]	600,000	1,454,221.37	Jan 01,2007-Feb 15,2007	[0.76m (30in)]	Pipeline	[Atch-2]	OWDMPS
	b	[Southwest-Pass-1]	1,200,000	2,677,494.31	Jan 01,2007-Mar 01,2007	[0.71m (28in)]	Pipeline	[SWP-2]	OWDMPS
		Total Cost = $4,131,715.68							
		Total Wetlands Beneficial Volume[m^3] = 0							
Seq. 3	a	[Atchafalaya-Bay-1]	600,000	3,787,530.00	Jan 01,2007-Feb 15,2007	[0.76m (30in)]	Pipeline	[Atch-1]	CDMPS
	b	[Southwest-Pass-1]	1,200,000	2,677,494.31	Jan 01,2007-Mar 01,2007	[0.71m (28in)]	Pipeline	[SWP-1]	CDMPS
		Total Cost = $6,465,024.31							
		Total Wetlands Beneficial Volume[m^3] = 1,800,000							
Seq. 4	a	[Atchafalaya-Bay-1]	600,000	3,787,530.00	Jan 01,2007-Feb 15,2007	[0.76m (30in)]	Pipeline	[Atch-1]	CDMPS
	b	[Southwest-Pass-1]	1,200,000	2,677,494.31	Jan 01,2007-Mar 01,2007	[0.71m (28in)]	Pipeline	[SWP-2]	OWDMPS
		Total Cost = $6,465,024.31							
		Total Wetlands Beneficial Volume[m^3] = 600,000							

Table 5. Dredge Scenario 3 sequence 3 beneficial use of dredged material.

DMPS Name	State	County/Parish	State Plane Coordinates[km]	Start–End Date	Volume(m^3)	Cost
[Atch-1]	Louisiana	Terrebonne	24N,-2E	Jan 01, 2007–Feb 15, 2007	600,000	$3,787,530.00
[SWP-1]	Louisiana	Plaquemines	-5.0N,95.0E	Jan 01, 2007–Mar 01, 2007	1,200,000	$2,677,494.31
Total cost: $6,465,024.31 for 1,800,000m^3						

DKBES RESULTS

The DKBES example scenario accurately constructed several possible future states given the dredge windows of opportunity. All example scenarios comply with the heuristic controls. The first scenario does not allow pipeline dredges on SWP due to the <770,000m^3 (1Myd^3) rule. Scenarios 2 and 3 reversed the situation with a 1.2Mm^3 (1.56Myd^3) dredge material volume on SWP. The program deleted hopper dredge projects on SWP and only allowing pipeline dredges. For this situation, the power equation, Equation 2, projected that only hoppers can get the job done under the given dredge window. However, hoppers have successfully completed projects of this size within this time window on SWP in the past according to Figure 7. The low coefficients of determination (R^2) in Figures 6-9 suggest that a power fit regression may not accurately predict time and cost. These regression equations only provide an estimate for production time and cost. Future developments will include a more refined cost and time computing method from attributes of the dredge and channel already available within the DKBES architecture.

The DKBES program further successfully scheduled each dredge to a navigation channel and DMPS according to their available dredge windows. Tables 3 and 4 reflect this. The program also avoided scheduling a dredge for two locations at the same time, preventing a cross wired situation. Therefore, the DKBES scheduled a viable and feasible dredge solution.

The output from the DKBES on the dredge scheduling presented valuable information for dredge operations managers to view the possible future states of their dredging resources in terms of cost, DMPS capacity and beneficial use of the dredge material. The tables for scenarios 1, 2 and 3 show summaries of the cost, duration, and dredge vessel use on each dredge sequence.

Figure 15 and Table 5 also respectively show examples of the DMPS remaining capacity and summary of beneficial use of the dredge material for Scenario 3. These figures provide operations managers with a snapshot of the future states of their DMPS and how they will need to address the permitting process associated with approving a location for dredge material placement with federal, state and local regulatory agencies.

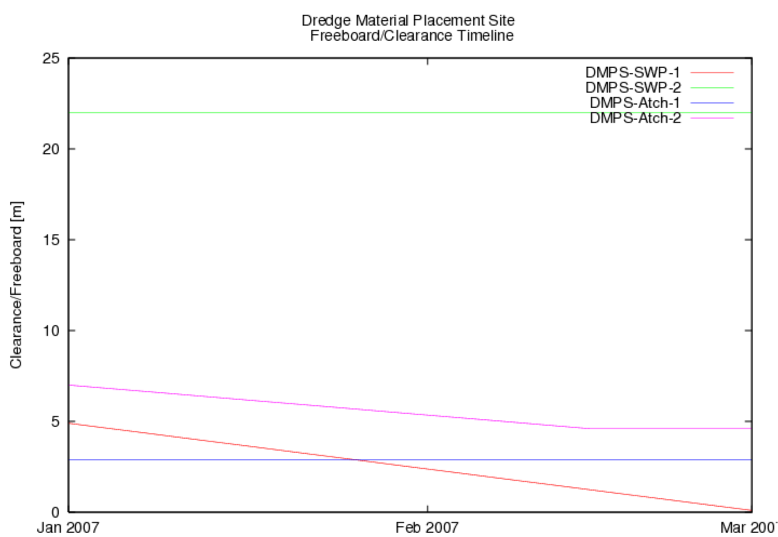

Figure 15. Time-line of DMPS capacity for Sequence 3 of Scenario 3.

The DKBES currently encounters several limitations. The most relevant of which remains the inability to combine production of two or more dredges on a single navigation channel project. As previously mentioned, scenarios 2 and 3 deleted all hopper dredge projects since the estimated time of completion exceeded the dredge window. However, if two dredges worked in conjunction, they could finish on time. Therefore, handling dual dredge operations and joint ventures remains a point of improvement for the DKBES. Furthermore, the DKBES has yet to incorporate ready reserve Corps dredges such as the *Wheeler*. Such limitations do not present an insurmountable challenge. Rather, the basic structure of the DKBES provides for many possible routes of improvement by expanding upon the existing applications.

CONCLUSIONS

The DKBES successfully forms a simple but effective scheduling tool for the existing dredge scenario in Southeast Louisiana. The DKBES forms a foundation to base the pertinent information of the dredging operation. These basic objects associated with the dredging process formed the multitude of combinations and sequences associated with the application. Heuristic knowledge and logic controls filtered out the viable and effective solutions providing a general operational support tool. The DKBES program made several rough estimates to reach a conclusion and encountered some limitations. However, the advantages gained in accurate and confident decision support far outweigh limitations.

Further developments of the DKBES will ultimately function on the Corps' operational level. As previously mentioned, the DKBES serves to augment operations manager's decision-making process. The DKBES certainly shows the potential for phase-in and trial operations in the near future.

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