ERDC/CERL TR-23-17

US Army Corps of Engineers®
Engineer Research and Development Center

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

Bridge Resource Inventory Database for Gap Emplacement Selection (BRIDGES)

Melissa V. Pham, William R. Fields, Dustin T. Brown, Dylan A. Pasley, Juan L. Davila-Perez, William D. Meyer, and Matthew D. Hiett

July 2023

Construction Engineering Research Laboratory

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

Cover image from William Allred, 2021, "SCNG, Army Reserve Practice Building Wet Gap Crossing," *National Guard*, August 10, 2021, https://www.nationalguard.mil/News/Article/2725834/scng-army-reserve-practice-building-wet-gap-crossing. Public domain.

ERDC/CERL TR-23-17
July 2023

Bridge Resource Inventory Database for Gap Emplacement Selection (BRIDGES)

Melissa V. Pham, William R. Fields, Dustin T. Brown, Dylan A. Pasley, Juan L. Davila-Perez, William D. Meyer, and Matthew D. Hiett

US Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
2902 Newmark Drive
Champaign, IL 61822

Final Report

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

Prepared for US Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Under Flex-4 (2363/FIF), “Enterprise Solution for Deployed Force Infrastructure Assessment and Site Selection”

Abstract

Wet gap crossings are one of the most complex maneuvers undertaken by military engineers, who, along with engineer planners, require better tools to increase the capacity for efficient use of limited bridging resources across the battlespace. Planning for bridging maneuvers often involves a complicated and inefficient system of ad hoc spreadsheets combined with an overreliance on the personal experience and training of subject matter experts (SMEs).

Bridge Resource Inventory Database for Gap Emplacement Selection (BRIDGES) uses interactive mapping and database technology in order to streamline the bridging planning process and provide answers to question about myriad scenarios to maximize efficiency and provide better means of data persistence across time and data sharing across operational or planning units.

Contents

Figures and Tables

Figures

Tables

Preface

This study was conducted for the US Army Engineer Research and Development Center under Flex-4 (2363/FIF), "Enterprise Solution for Deployed Force Infrastructure Assessment and Site Selection."

The work was performed by the Training Lands and Heritage Branch, of the Operational Science and Engineering Division, of the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Ms. Angela Rhodes was chief, Training Lands and Heritage Branch; Dr. George Calfas was chief, Operational Science and Engineering Division; and Mr. Jim Allen was the technical director for Environmental Quality and Installations. The deputy director of ERDC-CERL was Ms. Michelle Hanson, and the director was Dr. Andrew Nelson.

COL Christian Patterson was commander of ERDC, and Dr. David W. Pittman was the director.

This page intentionally left blank.

1 Introduction

Engineers and planners need better tools to increase their capacity to plan for the reuse of limited bridging resources across the battlespace. Planning for the process and tracking available inventory currently involves a complex and inconsistent system of spreadsheets combined with subject-matter expertise and operational experience. This makes it difficult to evaluate different scenarios or courses of action.

Interactive mapping and database technology can streamline this process and provide answers to questions about different scenarios more efficiently (both in terms of user interaction and dealing with data tracking along with data persistence and sharing).

1.1 Background

Wet gap crossings are one of the more complex maneuvers undertaken by military engineers. As outlined in *Maintaining an Armored Division's Momentum through a Wet Gap Crossing* (1st Calvary Division 2020), this operation involves multiple complex and interacting factors—posing significant risk to soldiers and logistical lines while acting as a potential bottleneck to operational tempo. Wet gap crossing is exceptionally resource intensive, which poses problems as the US Army shifts its focus (both capability and hardware procurement) away from counterinsurgency and back toward large-scale combat operations in theaters requiring significant wet gap crossing capacity. The factors are complicated further by the fact that "to conduct a successful and synchronized WGX [wet gap crossing], an armored DIV [division] must assign proper command and control, conduct deliberate WGX planning nested with the military decision-making process (MDMP), task organize critical enablers in order to project their capabilities, and practice aggressive traffic control through multiple crossing sites. These actions provide the maneuver commander with flexibility and options as the battle unfolds and they allow an armored DIV to maintain a steady tempo, quickly maneuver through vulnerable crossing sites, and exploit success on the far side of the WGX." (1st Calvary Division 2020, 1).

Current practice for bridging operational planning involves disparate and inefficient processes and tools. Highly experienced and competent soldiers are hampered by a lack of enabling technologies. Interactive mapping and data in a database will increase efficiency and simplicity for the people trying to do this work.

1.2 Objectives

Two tools used in tandem will increase efficiency and simplicity for the people trying to do this work: (1) interactive mapping and (2) data in a database. Interactive maps allow a user to point, click, and examine data in detail. A database enables a user to run queries against the data and get new information. It is smoother, quicker, and more effective than reconciling 10 different spreadsheets from several different people. This research project took advantage of an interactive mapping platform that is linked back to a database under the hood. Together they provide a powerful tool to track and plan wet gap crossings more efficiently and safely.

1.3 Approach

Interactive mapping and database technology can streamline the current spreadsheet and subject-matter-expert-based process and provide answers to questions about different scenarios more efficiently—both in terms of user interaction and in dealing with data tracking for persistence and data sharing. The resulting capability, the Bridge Resource Inventory Database for Gap Emplacement Selection (BRIDGES) tool, is useful both in the planning stages and for informing decisions in near real time during the operation.

When conceptualizing the components of this project, there is the database, and there are the interactive maps—these are two sides of the same coin, so to speak. In order to make the maps fully functional and useful to planners and operators, the project had to create the structure of the database, which ultimately leads to data that can be displayed on a map. This provides the opportunity through different modules to specify myriad planning factors, such as how many bridges a given plan has allocated to emplace.

There are three pillars to the BRIDGES tool:

1. Database (“under the hood”)
2. Display (interactive maps, symbology, and other illustrative components)

3. The physical bridge components "in the real world," along with attributional information such as how they are to be assigned, how they are to be tracked, or when they are to be emplaced and removed

The BRIDGES workflow is structured around three steps: identify gaps, define inventory, and track resources. These steps will be discussed in greater detail in Section 2. The capacity to put the information associated with each step in the workflow into a format that is more digestible as a final product is valuable. For instance, an end user might want to produce a map in pdf format for a brief or other communication or data sharing (rather than use BRIDGES' analytical capabilities). Creating static communication tools is a key and valuable component of the planning process for wet gap crossings. Finally, BRIDGES allows for the design and export of a map or something more sophisticated, such as an "execution matrix," which, rather than relying on a map-based display, more closely resembles data analytics visualizations in which a user can visualize salient metadata such as the emplacement data of specific bridge components and (more importantly) when in the process of the operation each of those components can be "pulled up" and moved forward in the battlespace to enable further forward progress in maneuver.

2 Implementation

To meet engineer and planner needs, the BRIDGES tool combines an interactive map with a database to facilitate schedules by tracking the location of bridge resources and components in both space and time to be used in mobility planning and operations. By using a geospatial database and a map-centric user interface, this approach can alleviate many of the elements currently complicating the process of both planning and executing wet gap crossings. The BRIGES workflow is structured around three steps.

2.1 BRIDGES workflow

2.1.1 Identify gaps

First, gaps are identified. Identifying gaps can be accomplished in a variety of ways—the two primarily focused on here are the use of geospatial data on gap characteristics as outputs from other decision support tools and the manual identification of gaps by planners using the BRIDGES' map user interface. Data import is built using a flexible Python library that can be used to accept a wide range of geospatial data formats, ranging from a comma-separated values file (CSV) to a shapefile and geopackage. The FY 21 prototype uses CSV as its proof-of-concept import format. Once gaps are imported or identified spatially, they are displayed on a map. Each gap is associated with relevant characteristics such as whether it is wet or dry and the gap length. These data can be used to provide constraints on which bridging resources are necessary and how they can be deployed.

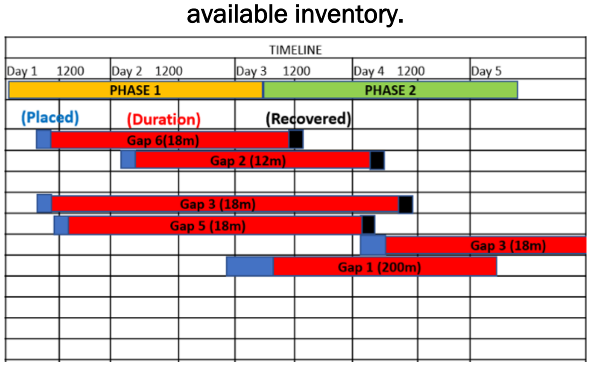
2.1.2 Define inventory

Second, the bridging inventory is described. BRIDGES is meant to track inventory at the level of major bridge components to provide the user with the ability to assign and track the individual components that make up an overall bridging system, such as interior bays, ramp bays, and bridge erection boats for the improved ribbon bridge (IRB). Bridge inventory can be imported in a similar way to gaps. Data would come from planning operations, and the software can be modified to accept multiple data formats. Or if preferred, the user can enter inventory components via BRIDGES' graphical user interface.

2.1.3 Track resources

Third, bridging resource are tracked as they are used, recovered, or damaged. Just as in the previous stage, this step also relies on input from previous planning operations. The planned date and time for the start and end of operational segments can be selected via a simple interface. After the operational periods are identified in the app (pulled from operational plans), BRIDGES allows for bridging resources to be assigned to various gaps. Figure 1 shows an illustrative construction matrix identifying the number of bridges deployed with information about gap width. The FY 21 prototype of BRIDGES does not export a matrix to this level of detail but does provide enhanced awareness for planners creating this type of document. See Section 4.2 for details on next steps regarding export features. A dialogue box can be used to associate bridge components with various gaps, identifying the associated stage of operations as one does so.

Figure 1. A construction matrix identifying the number of bridges deployed is directly associated with information about gap width. As resources are selected for use, they are subtracted from the available inventory.



It is possible to select multiple gaps and update bridge and stage information for them simultaneously. After associating bridge resource and stage information with a gap, a user can review more detailed information. A designated section of the GUI shows data imported about the gap itself—whether it was wet and its location. The start and end time of the specific bridging activity is included as well as whether deployment or recovery happens at night or during the day.

Finally, information about the number of bridge components used, damaged, or available to be reused is available. After planning for the deployment of bridge resources, military engineers and planners also want to plan for the recovery of them. The ability to update bridging inventory and usage plans is an impactful capability as planners and engineers move through different planned stages of operations.

2.2 Key functionalities

The BRIDGES research team has created a technical implementation of the aforementioned capabilities in an effort to meet its research goals. The ability to query a database either by time or location and thus to visualize when a given bridging capability is available, when components are planned for use, and where it will all occur is the most impactful component of BRIDGES and represents its primary contribution to improving the state of the art.

The database of bridge resources can be queried at each stage of operations, and it is possible to export summary data to show planned bridge deployments. The bridge resource database can also be queried to produce a matrix showing when bridge resources are deployed, in use, and recovered, and maps showing the gap locations can also be saved.

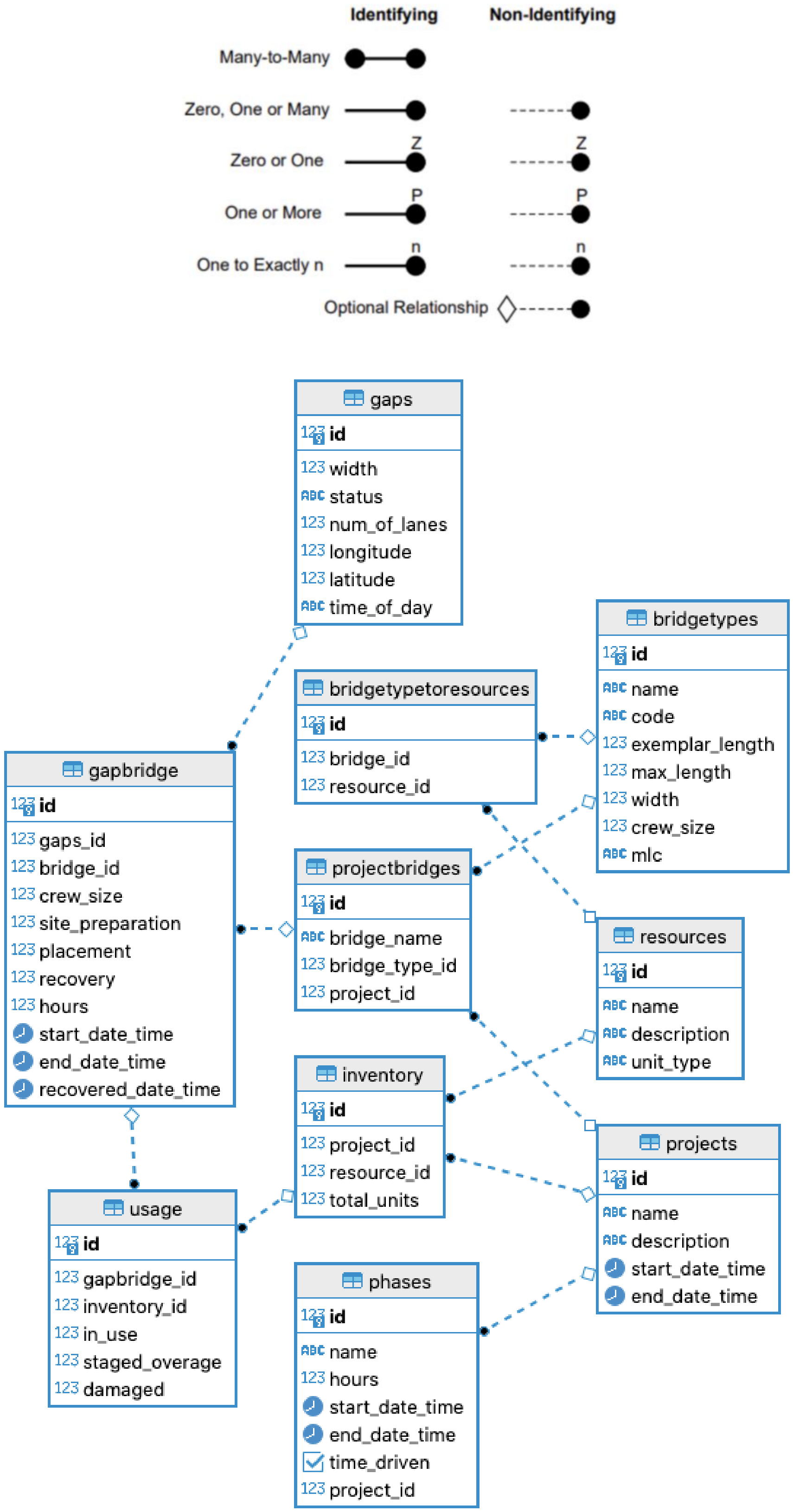
3 Software Design Documentation

Bridge Resource Inventory Database for Gap Emplacement Selection (BRIDGES) makes use of the Tethys platform, which uses the model view controller (MVC) software architecture pattern. Models are stored in model.py, controller in controller.py, and the views are in the templates folder. The public static directory that holds the css, images, and javascript files is in the public folder. The Tethys platform is powered by OpenLayers and uses the Django Python web framework. Ajax and jquery are also used as appropriate. Table 1 provides details about the database schema implemented in PostgreSQL. Users query this database about times and locations and are returned the relevant information about where and when given items or categories of items are located or planned to be used.

Table 1. PostgreSQL database schema.

Name	Description
BridgeType	table to create various bridge object types
ProjectBridge	table to name a bridge and associate it with a BridgeType
Phase	the concept that determines the movement of bridges at a specific gap, which can be either event driven or time driven
Gap	the area on the map that needs a bridge to cross
GapBridge	relationship between the Gap table and the ProjectBridge table
Project	highest level concept that determines what resources are available and the phases that need to take place at specific gaps
Resource	resources available for bridge construction
BridgeToResources	relationship between the bridge and resource table
Inventory	keeps track of the resources available over the entirety of the project
Usage	keeps track of which resources are being used at a specific GapBridge

Figure 2. Graphical representation of the database relationships generated by DBeaver. The standard that is used is IDEF1× notation.



4 Conclusions and Recommendations

Ultimately, this research effort has resulted in an interactive mapping platform which can be easily fielded via the United States Army Corps of Engineers (USACE) Model Interface Platform (UMIP).

The BRIDGES tool provides end users with the necessary capabilities to plan for bridging operations. First, BRIDGES provides the ability to pull in data from disparate sources via the tools outlined above in Section 3. Second, users need to be able to track key resource usage over a given timeframe (in this case, operational maneuvers) and especially need to be able to ascertain when operational bridging components can be broken down and pushed forward into the operational space. This capability is critical for planners to evaluate what construction or bridging activities will be done on day 1 versus day 4 and where those activities will be conducted.

4.1 Conclusions

BRIDGES provides a modern, technical approach for tracking bridging resources. In its narrow problem space, BRIDGES represents the shift from late twentieth-century technology and approaches epitomized by the Gulf Wars to fully twenty-first-century technology (e.g., a mapping platform rather than spreadsheets, which are essentially digital versions of the technology used as far back as the mid-twentieth century). The power of BRIDGES is the ability it gives a user to fully interact with a database in intuitive ways. Users can ask different questions of the database by using the BRIDGES interface to specify a new query, such as “How many armored vehicle launched bridges (AVLBs) do I have left?” or “On what day during operations do I have the most available?” without having to run a convoluted macro in Excel.

4.2 Recommendations for future research

While the BRIDGES tool is effective now, its usefulness is of a necessarily limited scope. Further research could and should build upon the success already achieved. For instance, BRIDGES would benefit from further investment to improve the output spreadsheet so that it can generate more sophisticated graphics, such as a Gantt chart or critical path method (CPM) diagram. Future iterations could improve on the visual product that tracks placement over time so the user can quickly identify resource and timing issues.

More straight forward additions would also be beneficial. For instance, the usefulness of BRIDGES would scale well with the incorporation of additional bridge types (such as those used by NATO partners).

Future research should identify a set of common queries that users require in order to tailor queries and data displays. For instance, it might be that for all the bridge resource components, it is critical for users to know the point on the timeline when the fewest of those components are available. Alternatively, insights gained from observing the tool in use might be most useful, such as “during phase two of offensive operations, the AVLBs are most often used for short-term crossings and are pulled up to use in more forward positions within 2–4 days.”

Ultimately, the BRIDGES tool needs to be tested with end users in a maneuver support, sustainment, and protection integration experiments (MSSPIX)–type environment to have military engineers and planners identify which questions they would ask this tool and where future researchers could expand or shore up capability.

Bibliography

1st Calvary Division. 2020. *Maintaining an Armored Division's Momentum through a Wet Gap Crossing*. 20-581. Fort Leavenworth, KS: Center for Army Lessons Learned. https://usacac.army.mil/sites/default/files/publications/1stCAVWetGapCrossing%2020200923v2.pdf.

REPORT DOCUMENTATION PAGE

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED START DATE	3. DATES COVERED END DATE
July 2023	Final Report	FY19	FY21

4. TITLE AND SUBTITLE
Bridge Resource Inventory Database for Gap Emplacement Selection (BRIDGES)

5a. CONTRACT NUMBER	5b. GRANT NUMBER	5c. PROGRAM ELEMENT
5d. PROJECT NUMBER	**5e. TASK NUMBER**	**5f. WORK UNIT NUMBER**

6. AUTHOR(S)
Melissa V. Pham, William R. Fields, Dustin T. Brown, Dylan A. Pasley, Juan L. Davila-Perez, William D. Meyer, and Matthew D. Hiett

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
2902 Newmark Drive
Champaign, IL 61822

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-23-17

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Engineer Research and Development Center (ERDC)
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Flex-4 (2363/FIF), “Enterprise Solution for Deployed Force Infrastructure Assessment and Site Selection”

14. ABSTRACT
Wet gap crossings are one of the most complex maneuvers undertaken by military engineers, who, along with engineer planners, require better tools to increase the capacity for efficient use of limited bridging resources across the battlespace. Planning for bridging maneuvers often involves a complicated and inefficient system of ad hoc spreadsheets combined with an overreliance on the personal experience and training of subject matter experts (SMEs).

Bridge Resource Inventory Database for Gap Emplacement Selection (BRIDGES) uses interactive mapping and database technology in order to streamline the bridging planning process and provide answers to question about myriad scenarios to maximize efficiency and provide better means of data persistence across time and data sharing across operational or planning units.

15. SUBJECT TERMS
Military planning; Stream crossing, Military; Military bridges; Military geography; Trafficability

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	C. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
Unclassified	Unclassified	Unclassified	SAR	20

19a. NAME OF RESPONSIBLE PERSON	19b. TELEPHONE NUMBER (include area code)
Matthew Hiett	