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14. ABSTRACT
This TOP describes procedures for assessing the fording ability of military wheeled and tracked vehicles and the effectiveness of fording kits. The types of fording (shallow water, deep water, and underwater) are considered with respect to safety hazards; performance, including water ingress and egress capability; effects on vehicle operation on land; and endurance. Fording kits are assessed for time required for installation, ease of application, proper fit, reliability, functional suitability, and safety. When applicable, comparisons are made between the vehicle/kit under test and comparable standard equipment.

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 02-2-612A 8 May 2019
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FORDING

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*This TOP supersedes TOP 02-2-612 Fording, dated 21 November 2007.

1. SCOPE.

a. This Test Operations Procedure (TOP) describes procedures for analyzing the fording ability of military wheeled and tracked vehicles and the effectiveness of fording kits. The types of fording (shallow water, deep water, and underwater) are considered with respect to safety hazards; performance, including water ingress and egress capability; effects on vehicle operation on land; and endurance. Fording kits are analyzed for time required for installation, ease of application, proper fit, reliability, functional suitability, and safety. When applicable, comparisons are made between the vehicle/kit under test and comparable standard equipment.

b. Amphibious vehicles, which are tested according to TOP 02-2-501[1**], are not included in this document.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Item	Requirement
Fording basin	See Appendix B, Figure B-1 and B-2
Underwater fording facility	See Appendix B, Figure B-3
Safety equipment	Life jackets, life rings, emergency signaling equipment, rescue craft, rescue equipment, scuba diving equipment, vehicle recovery equipment, and communication equipment

Note: These facilities are currently available at Aberdeen Test Center (ATC) and Yuma Test Center (YTC). Specific details pertaining to fording basins can be found in TOP 01-1-011B[2], Vehicle Test Facilities at ATC and YTC.

2.2 Instrumentation.

Item	Maximum Error of Measurement
Depth markings on side of vehicle (outside)	±2.5 centimeters (cm) (±1 inch (in.))
Depth markings on side of vehicle (inside)	±2.5 cm (±1 in.)
Sonar depth measuring equipment	±0.3 meters (m) (±1 foot (ft))
Sounding rod	±2.5 cm (±1 in.)
Slope gage	±1 degree
Engine tachometer	±0.5 percent full scale
Toxic gas measuring equipment	See TOP 02-2-614[3]

** Superscript numbers correspond to Appendix E, References.

a. Additional instrumentation may be used to monitor and record specific vehicle parameters and/or operation of specific vehicle systems. All instrumentation should be installed in a manner that will not interfere with vehicle operation, or allow water intrusion to compromise the test vehicle or results from the test.

b. If applicable, vehicle bus data should be recorded before, during, and after fording and analyzed after the fording event. Water intrusion in the vehicle electronics system can cause substantial problems and faults that may not be evident immediately during the fording event.

3. REQUIRED TEST CONDITIONS.

3.1 Selection of Test.

a. Select the type of fording test(s) based upon requirements. There are three modes of fording: shallow water, deep water, and underwater. All modes involve contact of the wheels or tracks with the ground. Distinguishing features of these modes are as follows:

(1) Shallow Water Fording. The vehicle engine air intake, driver, and cargo are not underwater and no special kit application is required.

(2) Deep Water Fording. This condition may require the application of a kit containing seals and snorkels. One or more hatches are always above water for use as an escape route and visual observation. The depth of deep water fording for each type of vehicle will vary depending upon the extent of protection provided.

(3) Underwater Fording. The vehicle is operated under the surface of the water and requires snorkels for engine and/or crew compartments. Extensive sealing is required for this mode of operation. The fordable water depth for this mode is governed by the height of the snorkel, at least 0.6 m (2 ft) of which should be above the water surface.

b. The three modes are shown in Figure 1.

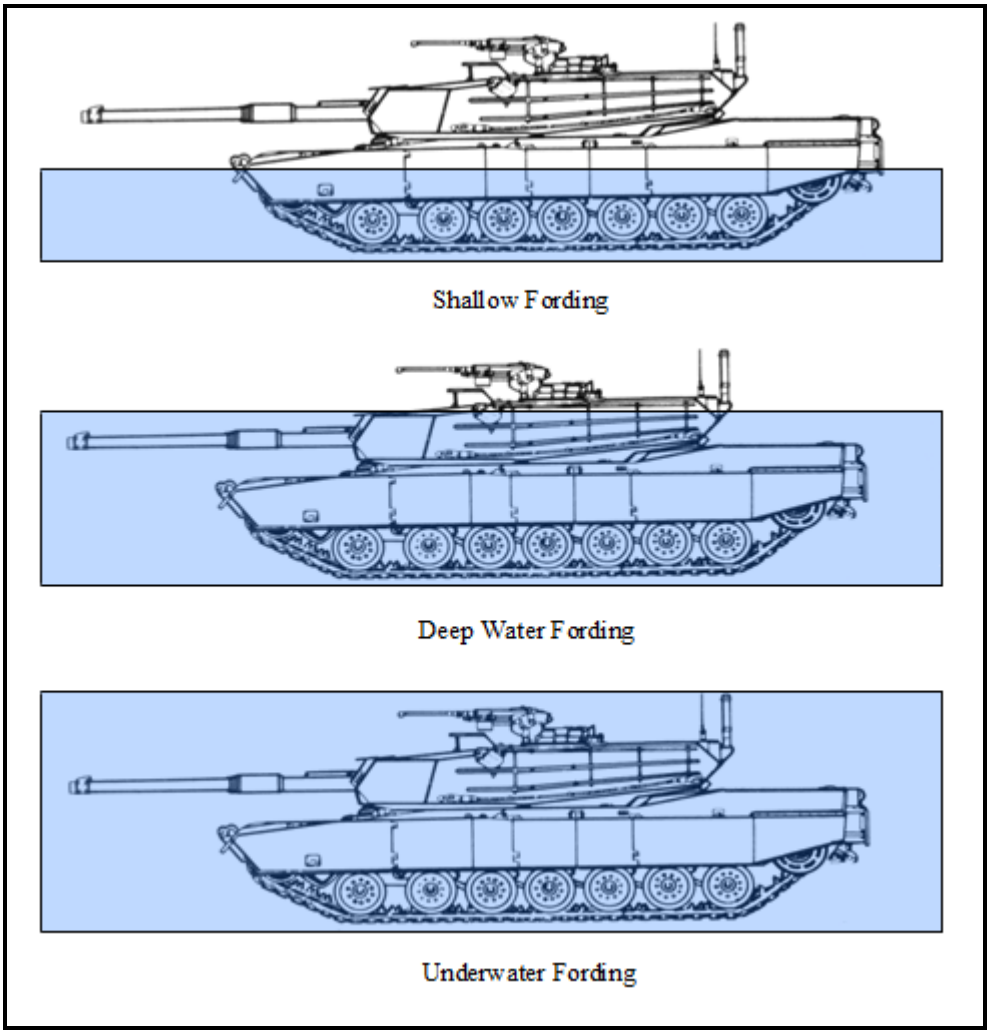

Figure 1. Water fording modes.

c. The three modes of fording can be conducted in fresh or salt water. Salinity of the water in the fording basin can be adjusted to specific levels as identified in the detailed test plan (DTP).

Note: Salt can damage the structure of the fording basin, therefore it is necessary to ensure the fording basin is constructed in a manner that allows salt water.

3.2 Preliminary Activities.

a. Use the procedures described by the following publications prior to conducting the required test types:

Title	Publication No.
Vehicle Characteristics	TOP 02-2-500[4]
Preliminary Operation	TOP 02-2-505A[5]

b. Particular attention should be given to the ignition system, intake and exhaust systems, generator and electrical system, turret seal, door and hatch seals, and all openings or holes in hull or bulkheads. Inspect all visible wiring for insulation damage; fording should not occur until wiring is repaired. Follow the prescribed fording preparation procedures as detailed in the vehicle technical manual (TM). If applicable, ensure engine cooling fan switch is operational.

c. Conduct pre-fording inspections on vehicle systems to ensure proper operation prior to the fording event. Examples of systems to assess include, but are not limited to, those presented in Table 1.

TABLE 1. EXAMPLE OF SYSTEMS TO BE ASSESSED PRIOR TO FORDING EVENT

SYSTEMS
Central Tire Inflation System (CTIS)
Interior and exterior lights
Black-out mode lights
Winch
Charging system
Export power generator and associated outlets
Heat and air conditioning (A/C) systems
Trailer lights and trailer air supply
Turret operation
Steering
Braking
Acceleration
Driveline locks
Batteries
North Atlantic Treaty Organization (NATO) slave port
Fuse panels

d. If the vehicle design includes a high voltage system (greater than 28 volt (V)), the system will be analyzed for occupant safety prior to conducting any fording test. Safety analysis should include assessment of the system's ground fault protection. Additional inspection and testing may be required based on system type, layout, and design.

e. The vehicle shall be marked on the exterior and interior with water level lines to indicate water depth limits during testing.

f. The test officer shall mark the maximum allowable water line (MAWL) on the interior of the test vehicle. If the water rises above the MAWL, the test vehicle must be immediately removed from the water and the test aborted.

g. During fording operations in a basin, if the vehicle design includes an active or semi-active suspension, installation of suspension stops or similar devices should be considered prior to fording to prevent a large change in vehicle ride height in the event suspension failure occurs.

h. Mount video recorders inside the vehicle, angled toward water level lines and any other areas deemed critical to the test.

i. Flood the vehicle floor to a limited depth, excluding water sensitive components, to provide an indication of leakage points; e.g., at bottom plates. When this is being accomplished, the bilge pump intake should be under water and should be checked for proper functioning and capacity. Provisions for preventing debris from entering the pump intake should also be checked. Furthermore, the full floor shall be inspected to ensure debris that could clog the pump is not present.

j. Test vehicles and direct test support vehicles shall be suitably equipped with fully charged fire extinguishers capable of extinguishing electrical, fuel, or oil fires. Test vehicle operators shall inspect the fire extinguishers daily during test operations to make sure seals have not been broken and the extinguishers remain fully charged.

k. Attach tow cables to the test vehicle, with the free end of each cable tied down on top of the vehicle for ready access during emergency recovery operations. A recovery vehicle, such as an M88, shall be in place and ready for an emergency extraction of the test vehicle in the event the test vehicle becomes immobile in the water. See paragraph 4.4, Fording with High Voltage Systems, for additional guidance.

l. Collect oil, fuel, and lubricant samples from all sources that will be exposed to water to chemically analyze for pre-fording water contamination. Samples should be collected from the lowest point in the system's sumps or reservoirs.

m. Establish emergency exit procedures (see Appendix A) and provide adequate exit instructions in this regard to the test personnel.

n. If it appears that the installation of the fording kit may alter the engine exhaust in a way to cause safety problems for crew, carbon monoxide will be measured in accordance with TOP 02-2-614.

o. Record the test vehicle odometer reading prior to any fording operation.

4. TEST PROCEDURES.

4.1 Shallow Water Fording.

Conduct testing as follows in a controllable-depth, fresh water fording basin (Appendix B, Figures B-1 and B-2), starting with the water level at the maximum required depth per vehicle specification:

a. Drive the vehicle into the water slowly in the forward direction, and stop the vehicle once maximum fording depth is reached. Inspect vehicle for water leakage and verify no abnormal vehicle operating conditions are present. If the vehicle inspection is unsatisfactory remove vehicle from fording basin.

b. If the vehicle inspection is satisfactory, shutdown the engine, wait 10 seconds and restart the engine following proper starting procedures as outlined in vehicle operator manual (OM). After restart with the engine at idle engine speed and vehicle stationary, soak in the basin at the maximum fording depth for 15 minutes. After 5- and 10-minutes of elapsed idle time, complete an engine shut down and restart. Both engine shutdowns/restarts should be completed in the same manner as initially conducted. The engine shutdown and restart times should not contribute to the 15 minute soak with the engine at idle speed.

c. After 15 minutes of stationary engine idle time, drive the vehicle forward slowly to the end of the basin. Once at the end of the fording basin, back the vehicle slowly to the opposite end of the basin, and then drive forward to exit the basin. Vehicle movement in the basin should be completed at a slow speed to prevent excessive wave formations. If necessary, vehicle should be stopped briefly before changing directions to allow wave formations to decrease in height.

d. Once outside the fording basin stop the vehicle to conduct an inspection. If vehicle inspection is determined satisfactory, operate the vehicle for a distance of at least 5 miles to ensure proper vehicle operation, and that operational temperatures of vehicle subsystems have been attained.

CAUTION: Steer control and braking should be functionally checked before operating at speeds in excess of 16 kilometers per hour (km/hr) (10 miles per hour (mph)). If braking is inadequate, the brake linings should be dried by repeatedly braking until normal braking is restored.

e. With the water level at the maximum depth, attempt vehicle operation in the basin at increased speeds in the forward direction. Maximum speed should be limited to that specified in the vehicle's TM, or 10 mph if a maximum speed is not provided. Vehicle speed should be increased incrementally to ensure safe operation.

CAUTION: Care should be taken not to reach speeds that could force water into the vehicle air-intake system.

f. After exiting the basin repeat the procedures in paragraph 4.1.d.

g. Conduct post-fording inspections and compare results to the pre-fording inspections completed during the procedures in paragraph 3.2.c.

h. If applicable, review data from instrumentation to ensure all vehicle systems remained operating throughout all fording events.

i. Collect oil, fuel, and lubricant samples and chemically analyze for water contamination. Samples should be collected from the lowest point in the system's sumps or reservoirs.

4.2 Deep Water Fording.

4.2.1 Fording Kit.

Install the fording kit in accordance with applicable TMs for the system that is being tested. Record items included and systems modified during installation of the fording kit.

4.2.2 Preparation of Vehicle.

Check the following features, as applicable, prior to entering the water:

a. Radio and intercom, including any exposed cabling.

b. Drain valves. Verify the drain valves are in the closed position. Drain plugs shall also be installed, when applicable.

c. Fuel caps (should be tight) and ensure fuel system cap vents are operating properly where applicable.

d. Bilge pumps. Check to ensure that bilge pumps are operational, intake screens are clear of obstructions, and the outlet valve is in place. Measure the bilge pump output and present the data in units of liters per minute (l/min) (gallons per minute (gal/min)). Compare the output to bilge pump specifications.

e. Gun muzzle plug(s) is installed and gun covers are in place if applicable.

f. Air pressurization systems (on vehicles so equipped). Check for leaks, valve functioning, etc. When engine shutdown is prescribed, the air pressurization system should maintain the required pressure during the shutdown period.

g. Configure vehicle to proper settings in accordance with vehicle's OM (i.e., driveline locks, tire pressure, suspension height, engine cooling fan, etc.).

h. Inspect differential, transfer case, and transmission vents to ensure the vents reach above the expected water line.

4.2.3 Emergency Breathing Apparatus.

If applicable, check that an emergency breathing apparatus is available for each crew member. This apparatus should include an air bottle with regulator valve and breathing tube, and a mask for each individual. Each crew member should be instructed and certified in the use of this equipment.

4.2.4 Test Site and Personnel.

a. Ensure that test control, recovery personnel and equipment are at the fording site prior to test operations.

b. Conduct a pretest safety meeting and instruct test personnel on fording operations and actions to take in case of emergency.

c. The number of persons permitted in test vehicles will be limited to the absolute minimum necessary to accomplish the test objectives and provide for safe operations.

4.2.5 Fording Operations.

In the absence of other specific guidance provided by the test sponsor, the following procedures shall be followed.

a. Drive the vehicle into the water slowly in the forward direction, and stop the vehicle once maximum fording depth is reached. Inspect the vehicle for water leakage and verify no abnormal vehicle operating conditions are present. If the vehicle inspection is unsatisfactory remove the vehicle from the fording basin.

b. If the vehicle inspection is satisfactory, shutdown the engine, wait 10 seconds and restart the engine following proper starting procedures as outlined in vehicle OM. After restart with the engine at idle engine speed and vehicle stationary, soak in the basin at the maximum fording depth for 15 minutes. After 5- and 10-minutes of elapsed idle time, complete an engine shut down and restart. Both engine shutdowns/restarts should be completed in the same manner as initially conducted. The engine shutdown and restart times should not contribute to the 15 minute soak with the engine at idle speed.

c. After 15 minutes of stationary engine idle time, drive the vehicle forward slowly to the end of the basin. Once at the end of the fording basin, back the vehicle slowly to the opposite end of the basin, and then drive forward to exit the basin. Initial vehicle movement in the basin should be completed at a slow speed to prevent excessive wave formation. If necessary the vehicle should be stopped briefly before changing directions to allow wave formations to decrease in height. The final drive forward through the basin should be completed at a higher speed but not exceeding 5 mph unless otherwise stated in the vehicle's TM.

CAUTION: Care should be taken not to reach speeds that could force water into the vehicle air-intake system.

d. Once outside the fording basin stop the vehicle to conduct an inspection. If the vehicle inspection is determined satisfactory, operate the vehicle for a distance of 10 miles to ensure proper vehicle operation and that operational temperatures of vehicle subsystems have been attained.

CAUTION: Steer control and braking should be functionally checked before operating at speeds in excess of 16 km/hr (10 mph). If braking is inadequate, the brake linings should be dried by repeatedly braking until normal braking is restored.

e. Conduct post-fording inspections and compare results to the pre-fording inspections completed during the procedures in paragraph 3.2.c.

f. If applicable, review data from instrumentation to ensure all vehicle systems remained operating throughout all fording events.

g. Collect fuel, oil, and lubricant samples and chemically analyze fuel, oil, and lubricants for water contamination. Samples should be collected from the lowest point in the system's sumps or reservoirs.

4.3 Underwater Fording.

a. Perform all preparations and follow all of the procedures as outlined in Section 4.2, Deep Water Fording.

b. Inspect underwater fording components to ensure proper fit and function.

c. Inspect and perform functional checks on the air supply system for the crew as well as the engine prior to entering the water.

d. Secure life jackets for quick release.

e. Inspect and verify all emergency breathing apparatuses are operational and stowed near a manned crew station.

f. Attach a slender vertical indicator near the vehicle front to aid the director in maintaining directional orientation.

4.4 Fording with High Voltage Systems.

a. When conducting any of the fording operations described in paragraphs 4.1 through 4.3 with high voltage systems (i.e., hybrid electric vehicles, electric vehicles, vehicles with integrated starter generators, or high power alternators), additional safety procedures shall be followed to avoid personal injury from electrocution.

b. If an electrical fault occurs during fording operations (as observed by vehicle warning systems or an external measurement of chassis voltage potential relative to ground), the vehicle operator shall slowly drive the vehicle from the fording basin and park the vehicle away from other personnel. The engine shall be shut down and the vehicle operators shall not exit the vehicle for 20 minutes or until the absence of electrical potential of the vehicle chassis to ground can be verified. Other on-site test personnel shall not approach or touch the vehicle during the 20 minute period or until the absence of electric potential is verified.

c. Prior to conducting a fording test, the test center should establish specific recovery procedures if an electrical fault occurs during fording operations and the vehicle becomes immobilized.

5. DATA REQUIRED.

5.1 Preliminary Activities.

a. Vehicle identification and description.

b. Test facility and course descriptions used throughout all testing.

c. Detailed results of vehicle systems assessed during pre-fording inspections.

d. If applicable to the test vehicle, results from occupant safety assessment on high voltage systems.

e. If applicable to the test vehicle, carbon monoxide levels with and without fording kit installed.

f. Indications of leaks and actions taken.

g. Measurements and/or photographs detailing interior and exterior water level lines and MAWL on the interior.

5.2 Shallow Water Fording.

a. Depth(s) of fording.

b. Actions taken, if any, to reduce possibilities of leakage.

c. Observations of leakage.

d. Vehicle performance abnormalities, or problems experienced.

d. Duration of fording event.

e. Maximum safe allowable speed achieved during fording operations.

f. Comparison between pre- and post-fording inspections on vehicle systems.

g. Comparison between pre- and post-fording chemical analysis of water contamination in vehicle fluids.

h. If applicable, review vehicle bus data for abnormalities throughout the fording event that were not apparent at the time of test.

5.3 Deep Water Fording.

a. Fording Kit Installation:

(1) Time, man-hours, and number of personnel required for installation.

(2) Special tools required, if any.

(3) Difficulties encountered, if any.

(4) Adequacy of installation instructions.

(5) Adequacy of on-board stowage for crew-installed fording kit components.

b. Fording Test:

(1) Depth(s) of fording.

(2) Location and amount of leakage observed in each area, if any.

(3) Adequacy of bilge pumps, if applicable.

(4) Vehicle performance abnormalities, or problems experienced.

(5) Duration of fording event.

(6) Vehicle speeds attained.

(7) Human factors observations – adequacy of vehicle operation relative to steering, engine operation, speed, safety, starting, vehicle control, and psychological responses of personnel, and space requirements for emergency and escape routes.

(8) Comparison between pre- and post-fording inspections on vehicle systems.

(9) Comparison between pre- and post-fording chemical analysis of water contamination in fuel, oil, and lubricants.

c. Follow-Up Land Operations:

(1) Adequacy of means provided to remove components of the kit, if applicable.

(2) Reusable components which have been removed. Any adverse effects on vehicle performance from kit components not removed.

(3) Time and man-hours required to remove all fording kit parts.

(4) Adequacy of instructions for removal of the fording kit.

(5) Difficulties in returning the vehicle to normal operating conditions.

(6) If applicable, review vehicle bus data for abnormalities throughout the fording event that were not apparent at the time of test.

5.4 Underwater Fording.

Obtain the same data as in paragraphs 5.1 through 5.3, as applicable.

6. PRESENTATION OF DATA.

Tabulate and chart all performance data and test conditions and present in the final report. An operational checklist is included in Appendix C.

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APPENDIX A. EMERGENCY EXIT PROCEDURES.

EMERGENCY EXIT PRACTICES.

The following items are important emergency procedures and should be covered by the standard operating procedure (SOP) for fording operation undertaken:

a. Emergency escape routes should be clearly established with procedures for use.

b. Personnel should be briefed on emergency escape procedures just prior to entering the water during fording operations.

c. Personnel should be instructed that the vehicle must be nearly filled with water or the pressure equalized on both sides of the hatches before the hatches can be opened.

d. Obstructions to escape routes should be eliminated where possible or adequately acknowledged by operating personnel.

e. Escape routes should be checked to ensure adequacy.

f. Emergency breathing equipment shall be provided to each crew member for all fording tests when warranted due to water depth and height of vehicle. Vehicle failures such as failures with active or semi-active suspensions where vehicle ride height could change should be considered during risk assessment.

g. During underwater fording, direct current (DC) portable light(s) should be temporarily mounted high in the vehicle interior, above the crew compartment, to light up aisle ways.

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APPENDIX B. EXAMPLES OF FORDING FACILITIES.

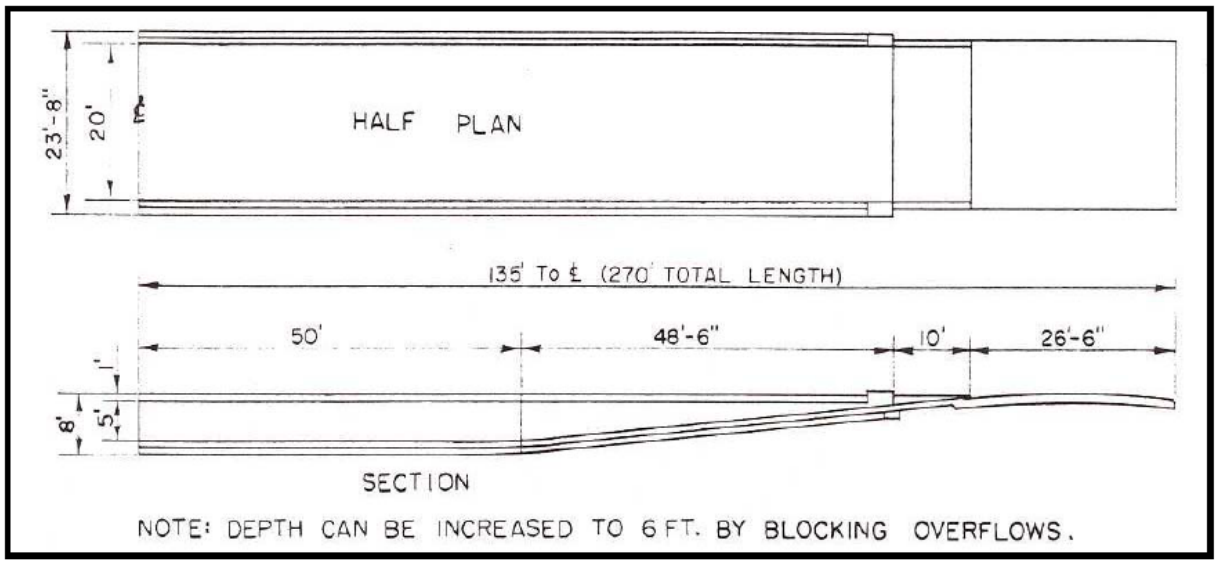

Figure B-1. Half plan and section of fording basin.

Figure B-2. Fording basin.

APPENDIX B. EXAMPLES OF FORDING FACILITIES.

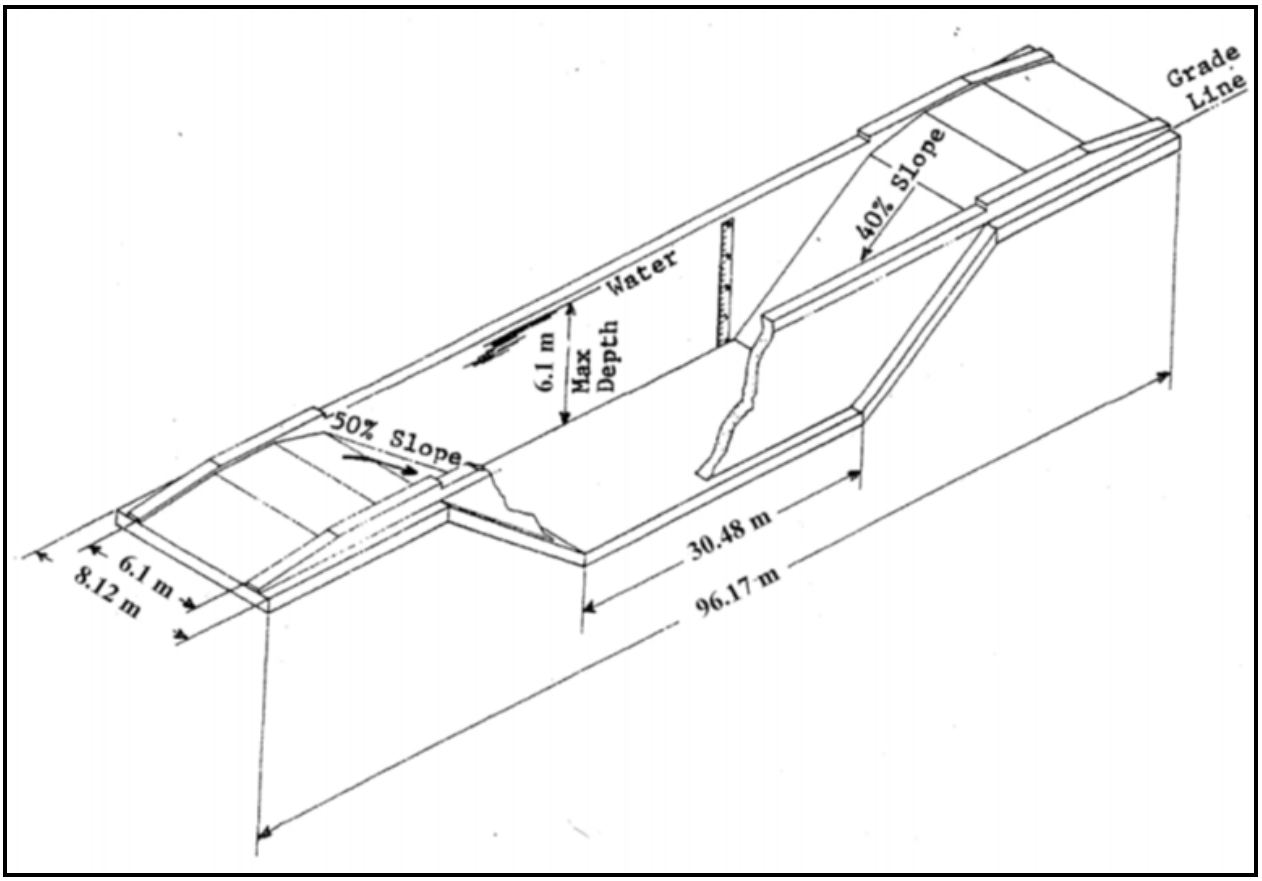

Figure B-3. Underwater fording facility.

APPENDIX C. OPERATIONAL CHECKLIST.

ITEM NO.	ITEM	COMMENT
1	Selection of Test-Shallow, deep or underwater. Prior to deep or under water fording, shallow water fording must be conducted.	
2	Mark externally and internally the water level line.	
3	Take oil, fuel and lubricant samples.	
4	Ensure the onboard fire extinguisher system is active.	
5	Ensure recovery cables are attached to the test vehicle.	
6	Have a recovery vehicle and crew available on stand-by or on site.	
7	Check vehicle floor for obvious water leakage areas and instruct the driver to monitor as required.	
8	Ensure air inlet and exhaust extensions are installed if required.	
9	Follow appropriate installation SOP and use the SOP's safety checklist. If a checklist is not available prepare a safety checklist.	
10	Establish emergency exit procedures in accordance with (IAW) Appendix A	
11	Ensure all personnel are equipped with appropriate personal protective equipment (PPE).	
12	Ensure correct water depth.	
13	Conduct a pre-test safety briefing.	
14	Verify communication equipment functions properly.	
15	Enter water, stop and start engine, record the actual time in the water, check for leakage.	
16	Exit water and operate vehicle.	
17	Enter water and determine maximum fording speed.	
18	Exit water and operate vehicle.	
19	Inspect the vehicle and take oil, fuel and lubricant samples.	
20	Record data IAW Section 5.	

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APPENDIX D. ABBREVIATIONS.

AC	air conditioning
ATC	Aberdeen Test Center
cm	centimeter
CTIS	central tire inflation system
DC	direct current
ft	foot/feet
gal/min	gallons per minute
IAW	in accordance with
in.	inch
km/hr	kilometers per hour
l/min	liters per minute
m	meter
MAWL	maximum allowable water line
mph	miles per hour
NATO	North Atlantic Treaty Organization
OM	operator manual
PPE	personal protective equipment
SOP	standard operating procedure
TM	technical manual
TOP	Test Operations Procedure
V	volt
YTC	Yuma Test Center

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APPENDIX E. REFERENCES.

1. TOP 02-2-501, Swimming Tests of Wheeled and Tracked Vehicles, 18 November 1980.

2. TOP 01-1-011B, Vehicle Test Facilities at Aberdeen Test Center and Yuma Test Center, 12 December 2017.

3. TOP 02-2-614, Toxic Hazards Test for Vehicles and Other Equipment, 31 October 2003.

4. TOP 2-2-500, Vehicle Characteristics, 14 February 2008.

5. TOP 2-2-505A, Inspection and Preliminary Operation of Vehicles, 22 October 2018.

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APPENDIX F. APPROVAL AUTHORITY.

CSTE-TM 8 May 2019

MEMORANDUM FOR

Commanders, All Test Centers
Technical Directors, All Test Centers
Directors, U.S. Army Evaluation Center
Commander, U.S. Army Operational Test Command

SUBJECT: Test Operations Procedure 02-2-612A Fording, Approved for Publication

1. Test Operations Procedure (TOP) 02-2-612A Fording, has been reviewed by the U.S. Army Test and Evaluation Command (ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army Evaluation Center. All comments received during the formal coordination period have been adjudicated by the preparing agency. The scope of the document is as follows:

a. This TOP describes procedures for assessing the fording ability of military wheeled and tracked vehicles, and the effectiveness of fording kits. The types of fording (shallow water, deep water, and underwater) are considered with respect to safety hazards; performance (including water ingress and egress capability); effects on vehicle operation on land; and endurance. Fording kits are assessed for time required for installation, ease of application, proper fit, reliability, functional suitability, and safety. When applicable, comparisons are made between the vehicle/kit under test and comparable standard equipment.

2. This document is approved for publication and will be posted to the Reference Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be accessed at https://vdls.atc.army.mil/.

3. Comments, suggestions, or questions on this document should be addressed to U.S. Army Test and Evaluation Command (CSTE-TM), 6617 Aberdeen Boulevard-Third Floor, Aberdeen Proving Ground, MD 21005-5001; or e-mailed to usarmy.apg.atec.mbx.atec-standards@mail.mil.

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Director, Test Management Directorate (G9)

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