System Assessment and Validation for Emergency Responders (SAVER)

Handheld Underwater Metal Detectors Assessment Report

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SAVER
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FOREWORD

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions. Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts objective assessments and validations on commercially available equipment and systems, and develops knowledge products that provide relevant equipment information to the emergency responder community. The SAVER Program mission includes:

- Conducting impartial, practitioner-relevant, operationally oriented assessments and validations of emergency response equipment; and
- Providing information, in the form of knowledge products, that enables decision-makers and responders to better select, procure, use, and maintain emergency response equipment.

SAVER Program knowledge products provide information on equipment that falls under the categories listed in the DHS Authorized Equipment List (AEL), focusing primarily on two main questions for the responder community: "What equipment is available?" and "How does it perform?" These knowledge products are shared nationally with the responder community, providing a life- and cost-saving asset to DHS, as well as to Federal, state, and local responders.

The SAVER Program is supported by a network of Technical Agents who perform assessment and validation activities. As a SAVER Program Technical Agent, the Space and Naval Warfare Systems Center (SPAWARSYSCEN) Atlantic has been tasked to provide expertise and analysis on key subject areas, including communications, sensors, security, weapon detection, and surveillance, among others. In support of this tasking, SPAWARSYSCEN Atlantic developed this report to provide emergency responders with information obtained from an operationally oriented assessment of commercially available handheld underwater metal detectors, which fall under AEL reference number 03WA-01-UWMD titled Detector, Metal, Underwater.

Visit the SAVER website on First Responder.gov (http://www.firstresponder.gov/SAVER) for more information on the SAVER Program or to view additional reports on handheld underwater metal detectors or other technologies.

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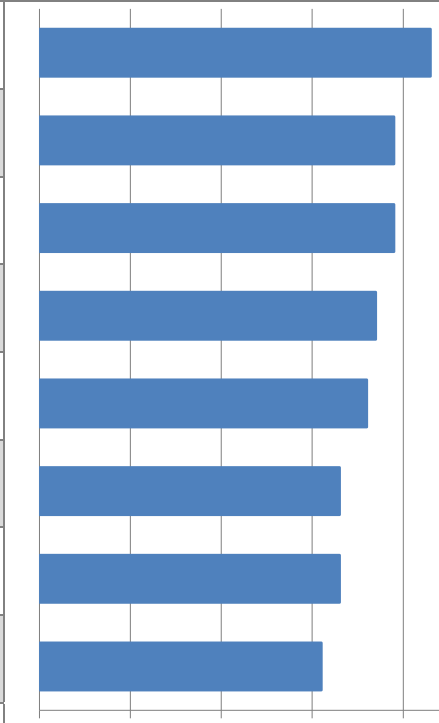
Handheld underwater metal detectors assist public safety divers with locating metallic objects underwater by providing visual, audible, and/or vibration alerts when these objects are detected. In August 2013, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of handheld underwater metal detectors.

Eight handheld underwater metal detectors were assessed by public safety divers. The criteria and scenarios used in this assessment were derived from the results of a focus group of public safety divers with experience using handheld underwater metal detectors. The assessment addressed 18 evaluation criteria in four SAVER categories: Capability, Deployability, Maintainability, and Usability. The overall results of the assessment are highlighted in the following table.

Product	Overall Score	Overall	Usability	Capability	Deployability	Maintainability
JW Fishers Mfg. Inc. Pulse 8X		**4.3**	4.3	4.3	4.3	4.4
Garrett Electronics Inc. Sea Hunter™ Mark II		**3.9**	3.8	4.1	3.3	4.0
Fisher® Research Labs CZ-21 QuickSilver		**3.9**	3.9	3.9	4.1	3.6
Aquascan International Ltd. Aquapulse 1B		**3.7**	3.9	3.5	3.8	3.5
Minelab Americas Inc. Excalibur II		**3.6**	3.7	3.7	3.3	3.6
Tesoro Electronics Inc. Tiger Shark		**3.3**	3.1	3.7	2.9	3.3
White's Electronics Inc. Surf PI Dual Field		**3.3**	3.2	3.5	2.9	3.7
Kellyco Metal Detectors Viper Hybrid Trident		**3.1**	3.1	3.1	3.1	3.4

1. INTRODUCTION

Handheld underwater metal detectors assist public safety divers with locating metallic objects underwater by providing visual, audible, and/or vibration alerts when these objects are detected. In August 2013, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of handheld underwater metal detectors. The purpose of this assessment was to obtain information on handheld underwater metal detectors that will be useful in making operational and procurement decisions. The activities associated with this assessment were based on recommendations from a focus group of public safety divers with experience using handheld underwater metal detectors.

1.1 Evaluator Information

Eight public safety divers from various jurisdictions and with at least 2 years of experience using handheld underwater metal detectors were selected to be evaluators for the assessment. Evaluator information is listed in Table 1-1. Prior to the assessment, evaluators signed a nondisclosure agreement, conflict of interest statement, and photo release form.

Table 1-1. Evaluator Information

Evaluator	Years of Experience	State
Police Department—Diver, Dive Team	20+	NC
Sheriff's Office—Diver, Dive Team	20+	NY
Police Department—Diver, Search and Recovery Team	20+	PA
Fire Department—Diver, Marine Unit	20+	TN
Sheriff's Department—Diver, Dive Rescue/Swift Water Team	16-20	WA
Police Department—Diver, Search and Dive Team	11-15	AL
Police Department—Diver, Search and Rescue Team	11-15	OH
Fire Department—Captain, Dive Team	11-15	TX

1.2 Assessment Products

Eight products were selected and purchased for the assessment based on market research and the focus group's recommendations. Final selection was based on how well each product met the product selection criteria identified by the focus group and listed in Table 1-2.

Table 1-2. Product Selection Criteria

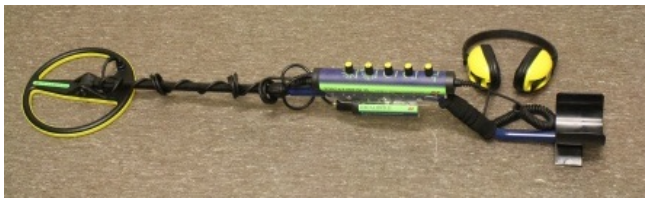
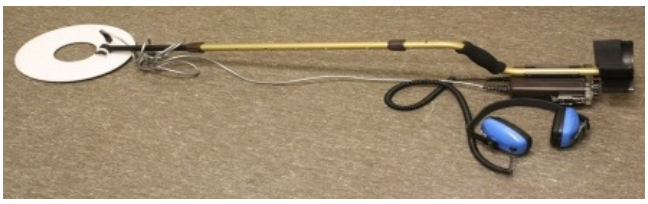
Product Selection Criteria	Description
Fully Submersible	Submersible to a depth of 60 feet
Audible Alerts	Audible alerts
Headphone	Headphone
Modular	Modular design
Interchangeable Coil	Interchangeable coil
Operating Temperature	Operating temperature range of 32° to 90°F
Chemical Resistance	Resistant to chemicals, fuels, and oils
Warranty	2-year warranty
Technical Support	8 hours a day, Monday through Friday
User Manual	Hard copy user manual

Handheld underwater metal detectors with a variety of technologies—broadband spectrum (BBS), pulse induction (PI), and very low frequency (VLF)—were selected for assessment. These products met at least the top three product selection criteria, and no more than one product from each vendor was selected for assessment. Where multiple coil sizes were available or included with purchase, the coil closest to 10 inches was purchased and used in the assessment. There were no metal detectors identified that provided vibration alerts and also met these criteria.

Table 1-3 presents the products that were assessed.

Table 1-3. Assessed Products

Vendor	Product	Product Image
Aquascan International Ltd.	Aquapulse 1B (PI)	
Fisher® Research Labs	CZ-21 QuickSilver (VLF)	

Vendor	Product	Product Image
Garrett Electronics Inc.	Sea Hunter™ Mark II (PI)	
JW Fishers Mfg. Inc.	Pulse 8X (PI)	
Kellyco Metal Detectors	Viper Hybrid Trident (VLF)	
Minelab Americas Inc.	Excalibur II (BBS)	
Tesoro Electronics Inc.	Tiger Shark (VLF)	
White's Electronics Inc.	Surf PI Dual Field (PI)	

2. EVALUATION CRITERIA

The SAVER Program assesses products based on criteria in five established categories:

- **Affordability** groups criteria related to life-cycle costs of a piece of equipment or system;
- **Capability** groups criteria related to the power, capacity, or features available for a piece of equipment or system to perform or assist the responder in performing one or more relevant tasks;
- **Deployability** groups criteria related to the movement, installation, or implementation of a piece of equipment or system by responders at the site of its intended use;
- **Maintainability** groups criteria related to the maintenance and restoration of a piece of equipment or system to operational condition by responders; and
- **Usability** groups criteria related to the quality of the responders' experience with the operational employment of a piece of equipment or system. This includes the relative ease of use, efficiency, and overall satisfaction of the responders with the equipment or system.

The focus group of public safety divers met in January 2013 and identified 20 evaluation criteria within four SAVER categories: Capability, Deployability, Maintainability, and Usability. The focus group discussed the Affordability category but did not identify any evaluation criteria for that category. They assigned a weight for each criterion's level of importance on a scale of 1 to 5, with 1 being somewhat important and 5 being of utmost importance. The SAVER categories were assigned a percentage to represent each category's importance relative to the other categories.

Products were assessed against 18 evaluation criteria. Discrimination was not assessed because after follow-up discussions with the focus group participants, it was determined that this feature is not typically used by public safety divers as it may hinder detection of target objects. In addition, buoyancy was not assessed since evaluators agreed that buoyancy is a matter of user preference and can be easily adjusted if necessary. Table 2-1 presents the evaluation criteria and their associated weights as well as the percentages assigned to the SAVER categories. Refer to Appendix A for evaluation criteria considerations.

Table 2-1. Evaluation Criteria

SAVER CATEGORIES			
Usability	**Capability**	**Deployability**	**Maintainability**
Overall Weight 45%	Overall Weight 40%	Overall Weight 10%	Overall Weight 5%
Evaluation Criteria			
Ease of Operation Weight: 4	**Durability** Weight: 5	**Setup** Weight: 4	**Maintenance** Weight: 4
Alerts Weight: 4	**Depth Rating** Weight: 4	**Modular** Weight: 3	**Battery Accessibility** Weight: 3
Maintain Settings Weight: 4	**Accessories** Weight: 4		**Technical Support** Weight: 2
Headphone Weight: 4	**Sensitivity** Weight: 4		
Battery Runtime Weight: 3	**Penetration** Weight: 4		
Radio Frequency Interference Weight: 2	**Discrimination** Not Assessed		
Buoyancy Not Assessed	**Operating Temperature** Weight: 3		
User Manual Weight: 2			

3. ASSESSMENT METHODOLOGY

The products were assessed over 5 days. On the first day of the assessment, a subject matter expert (SME) and facilitators presented a safety briefing and an overview of the assessment process, procedures, and schedule to the evaluators. Each product was then assessed in two phases: (1) specification assessment and (2) operational assessment.

3.1 Phase I/Specification Assessment

During the specification assessment, evaluators assessed each product based on vendor-provided information and specifications. Product information was confirmed by vendors prior to the assessment.

3.2 Phase II/Operational Assessment

During the operational assessment, evaluators assessed each product based on their hands-on experience using the product after becoming familiar with its proper use, capabilities, and features. The SME and facilitators assisted the evaluators with product familiarization, and evaluators had access to the reference material included with each product. The handheld underwater metal detectors were assessed in four scenarios: (1) pre-dive, (2) object detection in the Wando River, (3) dive operation in the Wando River, and (4) object detection in Lake Moultrie. After completing the object detection and dive operation scenarios in the Wando River, evaluators inspected the detectors for ruggedness and then worked as a group to perform vendor-recommended, post-dive maintenance (Figure 3-1). Evaluators completed the assessment worksheets for each product before assessing the next.

Figure 3-1. Post-Dive Maintenance

3.2.1 Pre-Dive Scenario

During the pre-dive scenario, evaluators reviewed the reference material provided by the vendor and familiarized themselves with the location and operation of the controls on each detector. Evaluators inspected the controls to determine if there were features to prevent unintentional adjustments while operating the detectors. Evaluators observed whether the headphones were permanently attached to the detectors or could be disconnected. If detachable, evaluators detached the coil and control module from the shaft, and then reattached them to assess ease of setup and modularity (Figure 3-2). Evaluators also inspected and assessed the ruggedness of the detectors. Lastly, evaluators swept the detectors over metal objects lying on the ground to become familiar with each detector's controls, settings, and alerts.

Figure 3-2. Assessing Modularity

3.2.2 Object Detection Scenario – Wando River

During the object detection scenario in the Wando River, evaluators used the detectors to locate objects previously buried by assessment team members. These objects were buried at various depths so evaluators could assess each detector's sensitivity and penetration capabilities, alerts, ease of operation, and ability to maintain settings. The objects were secured to markers and grouped by station, as outlined in Table 3-1.

Table 3-1. Object Detection Stations

Station	Object	Marker	Depth (Approximate)
1	Inoperable Handgun	A	12 inches
		B	6 inches
		C	3 inches
		D	½ inch
2	Galvanized Steel Pipe	A	12 inches
		B	6 inches
		C	3 inches
		D	½ inch
3	9mm Shell Casing	A	12 inches
		B	6 inches
		C	3 inches
		D	½ inch

Working independently and prior to approaching the first station, evaluators configured the detectors for use based on instructions in the reference material and used the detectors in the area to establish baseline settings. Next, standing in the water with the coil submersed, each evaluator approached a station, adjusted the detector's coil angle, and swept the coil over the markers at the station, adjusting the controls as necessary (Figure 3-3). Evaluators repeated this process until each detector was assessed at all three stations. Evaluators also assessed radio frequency interference by using the detectors in close proximity to each other on land to determine if interference occurred. At the end of this scenario, evaluators worked as a group and detached the control module and coil on each detector to further assess the modularity of the detectors.

Figure 3-3. Object Detection in the Wando River

3.2.3 Dive Operation Scenario – Wando River

In the dive operation scenario (Figure 3-4), evaluators conducted shallow-water dives in the Wando River while wearing an exposure suit, dive hood, and standard SCUBA diving equipment. The dives did not exceed 15 feet, and each dive lasted 3 to 5 minutes. A safety diver recorded the dive times and tank levels.

Figure 3-4. Dive Operation in the Wando River

Wearing cold-water dive gloves, evaluators configured the detectors for use based on instructions provided by the vendor and then dove with their underwater light, following a line course that consisted of two designated stations. At each station, evaluators used the detectors to locate a galvanized steel pipe buried approximately ½ inch beneath the river bottom, adjusting the coil angle and controls as necessary. During the dive, evaluators assessed alerts, ease of operation, ability to maintain settings, and how well the detector's headphone worked with a full-face mask and dive hood as well as if the headphone remained in place during the dive.

3.2.4 Object Detection Scenario – Lake Moultrie

During the object detection scenario in Lake Moultrie, evaluators used the detectors to locate objects previously buried by assessment team members. These objects were buried at various depths so evaluators could assess each detector's sensitivity and penetration capabilities, alerts, ease of operation, and ability to maintain settings. The objects were secured to markers and grouped by station, as outlined in Table 3-1. Working independently and prior to approaching the first station, evaluators configured the detectors for use based on instructions in the reference material and used the detector in the area to establish baseline settings. Next, standing in the water with the coil submersed, each evaluator approached a station, adjusted the detector's coil angle, and swept the coil over the markers at the station, adjusting the controls as necessary (Figure 3-5). Evaluators repeated this process until each detector was assessed at all three stations. After completing all stations, evaluators assessed radio frequency interference by using one detector at a time in close proximity to a depth finder to determine if interference occurred. After completing all stations with all detectors, evaluators removed and reinstalled the batteries in the detectors and inspected the battery compartment seals. Next, evaluators checked the electronic compartment seals and visually inspected the detectors, noting any damage or issues.

Figure 3-5. Object Detection in Lake Moultrie

3.3 Data Gathering and Analysis

Each evaluator was issued an assessment workbook that contained vendor-provided information and specifications, assessment procedures, and worksheets for recording criteria ratings and comments. Evaluators used the following 1 to 5 scale to rate each product:

1. *Meets none* of my expectations for this criterion;
2. *Meets some* of my expectations for this criterion;
3. *Meets most* of my expectations for this criterion;
4. *Meets all* of my expectations for this criterion; and
5. *Exceeds* my expectations for this criterion.

Criteria that were rated multiple times throughout the assessment were assigned final overall ratings by the evaluators. Facilitators captured advantages and disadvantages for the assessed products as well as general comments on the handheld underwater metal detectors assessment and the assessment process. Once assessment activities were completed, evaluators had an opportunity to review their criteria ratings and comments for all products and make adjustments as necessary.

At the conclusion of the assessment activities, an overall assessment score, as well as category scores and criteria scores, were calculated for each product using the formulas referenced in Appendix B. In addition, evaluator comments for each product were reviewed and summarized for this assessment report.

4. ASSESSMENT RESULTS

Overall scores for the assessed products ranged from 3.1 to 4.3. Table 4-1 presents the overall assessment score and category scores for each product. Products are listed in order from highest to lowest overall assessment score throughout this section. Calculation of the overall score uses the raw scores for each category, prior to rounding; products with the same rounded overall score are in order based on the raw data.

Table 4-1. Assessment Results

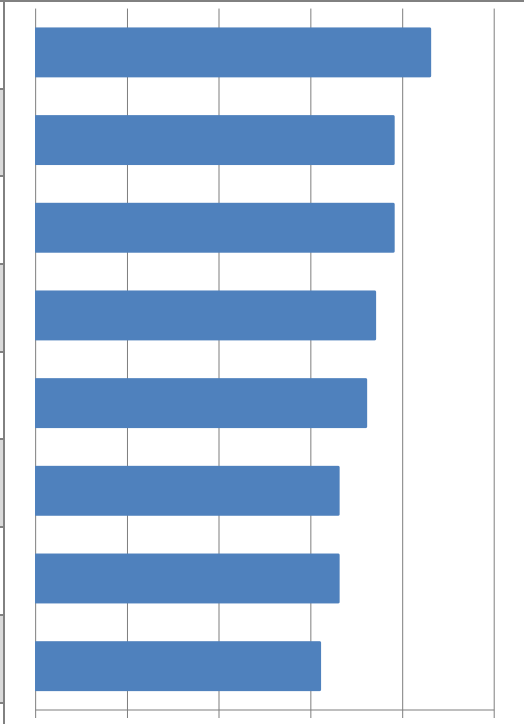
Product	Overall Score	Overall	Usability	Capability	Deployability	Maintainability
JW Fishers Mfg. Inc. Pulse 8X		**4.3**	4.3	4.3	4.3	4.4
Garrett Electronics Inc. Sea Hunter™ Mark II		**3.9**	3.8	4.1	3.3	4.0
Fisher® Research Labs CZ-21 QuickSilver		**3.9**	3.9	3.9	4.1	3.6
Aquascan International Ltd. Aquapulse 1B		**3.7**	3.9	3.5	3.8	3.5
Minelab Americas Inc. Excalibur II		**3.6**	3.7	3.7	3.3	3.6
Tesoro Electronics Inc. Tiger Shark		**3.3**	3.1	3.7	2.9	3.3
White's Electronics Inc. Surf PI Dual Field		**3.3**	3.2	3.5	2.9	3.7
Kellyco Metal Detectors Viper Hybrid Trident		**3.1**	3.1	3.1	3.1	3.4

Table 4-2 presents the criteria ratings for each product. The ratings are graphically represented by colored and shaded circles. A green, fully shaded circle represents the highest rating. Refer to Appendix A for evaluation criteria considerations. Evaluators noted all of the assessed detectors featured coils that were easy to adjust. In addition, all of the detectors alerted on the steel pipe and handgun at all depths assessed. Table 4-3 presents vendor-provided key specifications for the assessed products. All of the detectors feature audible alerts. A user manual is included with purchase and is available online for all detectors. In addition, technical support for all products can be reached by phone and e-mail.

Table 4-2. Criteria Ratings

KEY Lowest Rating → Highest Rating									
Category	**Evaluation Criteria**	**Pulse 8X**	**Sea Hunter™ Mark II**	**CZ-21 QuickSilver**	**Aquapulse 1B**	**Excalibur II**	**Tiger Shark**	**Surf PI Dual Field**	**Viper Hybrid Trident**
Usability	Ease of Operation	●	◕	◕	◕	◕	◔	◑	◑
	Alerts	●	◕	◕	◕	◕	◕	◕	◕
	Maintain Settings	◕	◕	◕	◕	◕	◑	◑	◕
	Headphone	●	◕	◑	◕	◑	◑	◔	◔
	Battery Runtime	◕	◕	●	◕	◕	◕	●	◑
	Radio Frequency Interference	◕	◕	◕	●	◕	◕	◕	◕
	User Manual	◕	◑	◕	◑	◕	◑	◕	◑
Capability	Durability	●	◕	◕	◕	◕	◕	◕	◕
	Depth Rating	●	●	●	●	●	●	◕	◕
	Accessories	◕	◕	◕	◕	◕	◕	◑	◔
	Sensitivity	◕	◕	◕	◕	◑	◑	◕	◑
	Penetration	◕	◕	◕	◑	◑	◑	◕	◑
	Operating Temperature	◑	◕	◑	◑	◑	◑	◑	◑

KEY Lowest Rating → Highest Rating									
Category	**Evaluation Criteria**	**Pulse 8X**	**Sea Hunter™ Mark II**	**CZ-21 QuickSilver**	**Aquapulse 1B**	**Excalibur II**	**Tiger Shark**	**Surf PI Dual Field**	**Viper Hybrid Trident**
Deployability	Setup	◕	◕	◕	◕	◕	◑	◑	◕
	Modular	◕	◑	◕	◕	◑	◑	◑	◔
Maintainability	Maintenance	●	◕	◕	◕	◑	◕	◕	◕
	Battery Accessibility	◕	◕	◕	◔	●	◑	◕	◕
	Technical Support	●	◑	◑	●	◑	◑	◑	◑

Table 4-3. Key Specifications

Key Specification	Pulse 8X	Sea Hunter™ Mark II	CZ-21 QuickSilver	Aquapulse 1B	Excalibur II	Tiger Shark	Surf PI Dual Field	Viper Hybrid Trident
MSRP	$2,495	$880	$1,349	$1,955	$1,949	$779	$895	$1,000
Warranty Duration	2 years	1 year	2 years	2 years	1 year	Lifetime	2 years	5 years
Search Technology	PI	PI	VLF	PI	BBS	VLF	PI	VLF
Visual Alert	✓							✓
Weight (pounds)	6.2	5.1	6.1	9.0	4.6	4.5	4.6	4.2
Coil Size(s) (inches)[1]	7.5 and 10[2]	8 and 10x14[3]	10.5	10	10	10.5	12	10
Interchangeable Coil	✓	✓		✓				
Detachable Headphone	✓	✓		✓				
Depth Rating (feet)	200	200	250	328	200	200	100	132
Operating Temperature	32° to 120°F	-4° to 140°F	32° to 110°F	32° to 120°F	32° to 113°F	30° to 100°F	32° to 158°F	32° to 120°F
Storage Temperature	20° to 150°F	-40° to 158°F	32° to 110°F	32° to 120°F	-4° to 140°F	30° to 100°F	0° to 158°F	32° to 120°F
Low-Battery Indicator	Needle-style indicator	Single audible alert at startup	Faint audible alert when battery check is performed	None	Continuous audible alert	Single audible alert when battery check is performed	Faint audible alert when battery check is performed	Continuous audible alert
Battery	Proprietary battery pack[4]	AA (8)	9 Volt (4)	Proprietary battery pack	Proprietary battery pack[4]	AA (8)	AA (8)	9 Volt (1)
Battery Runtime (hours)	10 to 12	18 to 22	35 to 55	10 to 12	14 to 19	10 to 20	25 to 35	6 to 10

Key Specification	Pulse 8X	Sea Hunter™ Mark II	CZ-21 QuickSilver	Aquapulse 1B	Excalibur II	Tiger Shark	Surf PI Dual Field	Viper Hybrid Trident
Training	Not provided by vendor	Instructional DVD and online videos	Not provided by vendor	Not provided by vendor	Not provided by vendor	Not provided by vendor	Online videos	Not provided by vendor
Technical Support Availability	24/7	Central Time 8:00 a.m. to 4:30 p.m. Monday through Friday	Mountain Time 8:00 a.m. to 5:00 p.m. Monday through Friday	24/7	Eastern Time 8:00 a.m. to 5:00 p.m. Monday through Friday	Mountain Standard Time 10:00 a.m. to 4:00 p.m. Monday through Friday	Pacific Time 8:00 a.m. to 4:30 p.m. Monday through Friday	Eastern Time 8:00 a.m. to 5:00 p.m. Monday through Friday

Notes:
[1]The diameter is provided for round coils; the length and width are provided for oval coils.
[2]The 10-inch coil was used in the assessment.
[3]The 10x14-inch coil was used in the assessment.
[4]The proprietary battery pack is user replaceable with purchase of a second battery pack.
✓—detector is equipped with corresponding feature
Blank cell—detector is not equipped with corresponding feature
°F—degrees Fahrenheit
Search Technology: Broadband Spectrum (BBS); Pulse Induction (PI); Very Low Frequency (VLF)

4.1 JW Fishers Mfg. Inc. – Pulse 8X

The Pulse 8X (Figure 4-1) received an overall assessment score of 4.3 and costs $2,495 as assessed. The as assessed cost includes both the standard 7.5-inch coil and the optional 10.0-inch coil ($195), as well as the coil-connector option ($150). Additionally, a control module with leak indicator light (Figure 4-2); a removable, submersible earphone; land-use headphones; a proprietary, rechargeable battery pack; AC and DC battery chargers; a land-use shaft that extends from 32 to 54 inches; a 19-inch dive shaft; a belt; additional hardware; a carrying case; an accessories bag; a user manual; and a 2-year warranty were included with purchase.

Figure 4-1. Pulse 8X

Figure 4-2. Pulse 8X Control Module

Accessories available for an additional cost include a 5-inch coil; an 8x48-inch coil, skids and a 100-foot cable (for deployment from a boat); a 16-inch coil with dive handle; an 18-inch coil with a 100-foot cable; a 22-inch hand probe; a coil connector; and submersible headphones.

The following sections, broken out by SAVER category, summarize the assessment results.

Usability

The Pulse 8X received a Usability score of 4.3. The following information is based on evaluator comments:

- The detector was easy to operate, even while wearing cold-water gloves, since the two controls were intuitive, spaced sufficiently apart, and easily adjusted. In addition, the coil angle adjusted easily;
- The detector's alerts were easy to hear and see. The visual indicator meter was helpful in determining the strength of the signal;
- The selection control clicked into place, and the zero adjustment control was firm enough to avoid unintentional adjustments;
- The earphone was versatile and easily interchanged, and it stayed in place during the dive operation scenario;
- The battery runtime met expectations;
- No radio frequency interference occurred when operating the detector in proximity to a depth finder. Interference occurred when using the detector approximately 1 to 4 feet away from another operating detector on land; and

- The user manual was well organized with adequate information on setup and use. However, evaluators would have preferred additional setup illustrations, as well as a quick-start guide.

Capability

The Pulse 8X received a Capability score of 4.3. The following information is based on evaluator comments:

- The detector seemed very rugged with well-sealed electronic compartments;
- The detector's depth rating of 200 feet is deeper than most dive teams will be permitted to dive;
- Purchase of the detector included all accessories necessary for use on land and underwater. In addition, the DC battery charger featured alligator clips. The accessories available for an additional cost, including a variety of coil and cabling options, permit expandability;
- The sensitivity and penetration capabilities of the detector enabled it to detect all objects at most depths, although detecting the shell casing at the 6- and 12-inch depths was difficult at times; and
- A minimum operating temperature lower than 32°F may be required for operation in icy conditions.

Deployability

The Pulse 8X received a Deployability score of 4.3. The following information is based on evaluator comments:

- With only two controls, setup of the detector was very quick and easy; and
- The detector was simple to configure for use both on land and underwater. It was easy to remove the coil from the shaft and reattach it. In addition, the control module could be easily removed from and reattached to either the shaft or dive belt.

Maintainability

The Pulse 8X received a Maintainability score of 4.4. The following information is based on evaluator comments:

- The vendor-recommended post-dive maintenance was completed quickly and easily and only required rinsing the detector with fresh water and storing it in a cool, dry place;
- The rechargeable battery means a user will rarely have to access the battery. However, battery access was not user friendly since the O-ring was difficult to set in place and a Philips head screwdriver was required to access the battery compartment; and
- Technical support is available 24 hours a day, 7 days a week.

4.2 Garrett Electronics Inc. – Sea Hunter™ Mark II

The Sea Hunter Mark II (Figure 4-3) received an overall assessment score of 3.9 and costs $880. Both an 8-inch and 10x14-inch coil; a control module with flood indicator window (Figure 4-4); removable, submersible headphones; eight size AA batteries; a modular shaft that adjusts from 28 to 52 inches; a belt; a control module pouch; control module mounting hardware; a user manual; an instructional DVD; and a 1-year warranty were included with purchase.

Figure 4-3. Sea Hunter Mark II

Accessories available for an additional cost include a ¼-inch headphone adapter; a 10x14-inch coil cover; and additional submersible headphones that may provide better performance and volume control.

Figure 4-4. Sea Hunter Mark II Control Module

The following sections, broken out by SAVER category, summarize the assessment results.

Usability

The Sea Hunter Mark II received a Usability score of 3.8. The following information is based on evaluator comments:

- In general, the detector was easy to operate. The controls were intuitive and separated enough to make adjustments easy, even while wearing cold-water gloves. In addition, the coil angle adjusted easily;
- The detector's alert was easy to hear;
- The controls were firm and separated enough to prevent unintentional adjustments;
- The headphones were easily interchanged and stayed in place during the dive operation scenario;
- The battery runtime met expectations;
- Overall, no radio frequency interference occurred when operating the detector in proximity to a depth finder. Interference occurred when using the detector approximately 6 feet away from another operating detector on land; and
- The user manual was easy to understand, but it was not comprehensive since detailed instructions for attaching the control module to the shaft were not provided. In addition, evaluators would have preferred the inclusion of a quick-start guide.

Capability

The Sea Hunter Mark II received a Capability score of 4.1. The following information is based on evaluator comments:

- The detector seemed rugged with well-sealed battery and electronic compartments; however, it was easy to over tighten the battery compartment cover, and the headphone connector pins could be easily damaged;
- The detector's depth rating of 200 feet is deeper than most dive teams will be permitted to dive;
- Purchase of the detector included all accessories necessary for use on land and underwater. The accessories available for an additional cost add some versatility;
- The sensitivity and penetration capabilities of the detector enabled it to detect all objects at all depths; however, the shell casing buried at 12 inches was somewhat difficult to detect; and
- A minimum operating temperature of -4°F should permit operation in icy conditions.

Deployability

The Sea Hunter Mark II received a Deployability score of 3.3. The following information is based on evaluator comments:

- With only three controls, setup of the detector was easy; and
- The coil was very easy to remove and reattach to the shaft; however, changing between land and dive configuration was difficult due to the number of small plastic screws and the two-piece metal bracket (Figure 4-5) that mounts the control module to the modular pieces of the shaft.

Figure 4-5. Two-Piece Metal Bracket

Maintainability

The Sea Hunter Mark II received a Maintainability score of 4.0. The following information is based on evaluator comments:

- The vendor-recommended post-dive maintenance was completed quickly and easily and only required rinsing the detector with fresh water and removing the batteries prior to storing it in a cool, dry place;
- The batteries were easily accessed without tools by turning a cap; however, the battery compartment cover was easily over tightened, resulting in it being difficult to remove; and
- The hours of availability for technical support are during the standard workday; however, the evaluators noted a preference for the availability of support at night and on weekends.

4.3 Fisher® Research Labs – CZ-21 QuickSilver

The CZ-21 QuickSilver (Figure 4-6) received an overall assessment score of 3.9 and costs $1,349. A 10.5-inch coil; a control module (Figure 4-7); hardwired, submersible headphones; a shaft that extends from 33 to 50 inches; a belt clip; cable straps; a user manual; and a 2-year warranty were included with purchase. The four 9-volt batteries required to operate the detector were not included with purchase.

Figure 4-6. CZ-21 QuickSilver

Accessories available for an additional cost include an 8-inch coil; an arm cuff strap; a battery recharge kit; a chest harness; and a coil scuff plate.

The following sections, broken out by SAVER category, summarize the assessment results.

Figure 4-7. CZ-21 QuickSilver Control Module

Usability

The CZ-21 QuickSilver received a Usability score of 3.9. The following information is based on evaluator comments:

- The detector was easy to operate. The large size and separation of the four controls allowed for easy manipulation with cold-water gloves. The controls were clearly marked; however, there were too many controls. The coil angle adjusted easily, and this detector had a pinpoint feature that was very helpful in detecting targets without having to sweep the detector;
- The detector's alert was easy to hear. In addition, the detector provided different tones for different types of metals;
- The controls were firm enough to prevent unintentional adjustments; however, most controls did not click in place;
- The headphones stayed in place during the dive operation scenario and had ports for equalizing pressure and draining water; however, evaluators noted a preference for user-replaceable headphones;
- The battery runtime exceeded expectations;
- No radio frequency interference occurred when operating the detector in proximity to a depth finder. Interference occurred when using the detector approximately 6 feet away from another operating detector on land; and

- The user manual was very comprehensive and easy to follow. The illustrations were helpful, although additional illustrations for removing the coil would be useful. The condensed operating instructions provided in the user manual were very useful; however, the evaluators would have preferred a quick-start guide.

Capability

The CZ-21 QuickSilver received a Capability score of 3.9. The following information is based on evaluator comments:

- The detector seemed to be a rugged, well-built unit and had a sealed battery compartment; however, the thin wiring on the headphones could easily break;
- The detector's depth rating of 250 feet is deeper than most dive teams will be permitted to dive;
- Purchase of the detector included all accessories necessary for use on land and underwater. The accessories available for an additional cost add versatility;
- The sensitivity and penetration capabilities of the detector enabled it to detect all objects at most depths, although detecting the shell casing at the 3-, 6-, and 12-inch depths was difficult at times; and
- A minimum operating temperature lower than 32°F may be required for operation in icy conditions.

Deployability

The CZ-21 QuickSilver received a Deployability score of 4.1. The following information is based on evaluator comments:

- The four controls had clearly marked default settings, which made setup of the detector quick and easy; and
- It was simple to configure the detector for use both on land and underwater since the control module slid easily on and off the shaft and attached easily to the included belt clip. In addition, the coil was easily removed and reattached to the shaft.

Maintainability

The CZ-21 QuickSilver received a Maintainability score of 3.6. The following information is based on evaluator comments:

- The vendor-recommended post-dive maintenance was completed quickly and easily and only required rinsing the detector with fresh water and removing the battery prior to storage;
- The battery compartment was easily accessed by removing two screws with a coin or screwdriver; and
- The hours of availability for technical support are during the standard workday; however, the evaluators noted a preference for the availability of support at night and on weekends.

4.4 Aquascan International Ltd. – Aquapulse 1B

The Aquapulse 1B (Figure 4-8) received an overall assessment score of 3.7 and costs $1,955. A 10-inch coil; a control module (Figure 4-9); a removable, submersible earphone; a sealed, proprietary rechargeable battery; an AC battery charger; a shaft that extends from 24 to 40 inches; a control module harness; a user manual; and a 2-year warranty were included with purchase.

Figure 4-8. Aquapulse 1B

Accessories available for an additional cost include a 15-inch coil; a 15-inch coil with a 65-foot cable; an 8-inch coil with stem; an arm saver support shaft; an extending handle; 12- and 36-inch ferrite probes; land-use headphones; and submersible headphones.

The following sections, broken out by SAVER category, summarize the assessment results.

Figure 4-9. Aquapulse 1B Control Module

Usability

The Aquapulse 1B received a Usability score of 3.9. The following information is based on evaluator comments:

- The detector was easy to operate, even while wearing cold-water gloves, since it had only two controls that were spaced sufficiently apart and easily adjusted. The coil angle adjusted easily. The cables from the coil to the control box were an entanglement hazard that the evaluators secured during the assessment;
- The detector's alert was easy to hear;
- The sensitivity control clicked in place, and the threshold control was firm enough to prevent unintentional adjustments; however, the control module was not attached to the shaft, which could make it prone to unintentional adjustments;
- The earphone stayed in place during the dive operation scenario, and it was versatile and easily interchanged; however, the earphone was more difficult to use on land because a head mount was not included with purchase;
- The battery runtime met expectations;
- No radio frequency interference occurred when operating the detector in proximity to a depth finder. Interference occurred when using the detector approximately 3 feet away from another operating detector on land; and

- The user manual was comprehensive, but the illustrations were not easy to understand, and the instructions were lengthy and confusing. In addition, evaluators would have preferred the inclusion of a quick-start guide.

Capability

The Aquapulse 1B received a Capability score of 3.5. The following information is based on evaluator comments:

- The detector seemed to be a very rugged and well-sealed unit; however, it had metal pins on the coil and earphone connectors (Figure 4-10) that could be damaged during assembly or disassembly. In addition, the ports for the earphone and coil connectors could easily be confused, and the unit could be damaged if the connectors are inserted into the wrong ports;
- The detector's depth rating of 328 feet is deeper than most dive teams will be permitted to dive;

Figure 4-10. Metal Pins on Coil and Earphone Connectors

- Purchase of the detector included all accessories necessary for use underwater. The accessories available for an additional cost, including a variety of coils and a Pelican case, add versatility;
- The steel pipe and handgun were detectable at all depths; however, the shell casing was not detected at the 3-, 6-, or 12-inch depths; and
- A minimum operating temperature lower than 32°F may be required for operation in icy conditions.

Deployability

The Aquapulse 1B received a Deployability score of 3.8. The following information is based on evaluator comments:

- With only two controls, setup of the detector was easy; and
- The coil was easily removed from and reattached to the shaft. The control module did not attach to the shaft; instead, the control module must be worn on a belt, which was not included with purchase.

Maintainability

The Aquapulse 1B received a Maintainability score of 3.5. The following information is based on evaluator comments:

- The vendor-recommended post-dive maintenance was completed quickly and easily and only required rinsing the detector with fresh water and cleaning the connections with cotton swabs prior to storage;

- The rechargeable battery was sealed and not user replaceable. A failed battery would require the entire control module to be shipped to the manufacturer located in England; and
- Technical support is available 24 hours a day, 7 days a week.

4.5 Minelab Americas Inc. – Excalibur II

Figure 4-11. Excalibur II

The Excalibur II (Figure 4-11) received an overall assessment score of 3.6 and costs $1,949 as assessed. A 10-inch coil; a control module (Figure 4-12); hardwired, submersible headphones; a proprietary, rechargeable battery pack; an AC battery charger; a modular shaft that adjusts from 32 to 36 inches when in dive configuration and from 45 to 48 inches when in land configuration; a hardware pack; a tool pouch; a carrying case; a trash pouch; a skid plate to protect the coil and assist with visibility in the water; a user manual; and a 1-year warranty were included with purchase.

Figure 4-12. Excalibur II Control Module

Accessories available for an additional cost include an 8-inch coil; 8- and 10-inch skid plates; a DC battery charger; an adaptor charger; a battery holder kit; a hip-mount kit; a side-mount shaft; an upper 90-degree shaft; and a battery pack that accepts size AA alkaline batteries.

The following sections, broken out by SAVER category, summarize the assessment results.

Usability

The Excalibur II received a Usability score of 3.7. The following information is based on evaluator comments:

- The detector was easy to operate, even while wearing cold-water gloves. The coil and five controls adjusted easily; however, there were too many controls, and operating the detector was not intuitive as a result;
- The detector's alert was easy to hear;
- The controls were firm enough to prevent unintentional adjustments;
- The headphones stayed in place during the dive operation scenario; however, evaluators noted a preference for user-replaceable headphones;
- The battery runtime met expectations;
- No radio frequency interference occurred when operating the detector in proximity to a depth finder. Interference occurred when using the detector approximately 4 feet away from another operating detector on land; and

- The user manual was neatly organized, user friendly, and easy to understand. The quick-start guide had useful illustrations and was easy to understand.

Capability

The Excalibur II received a Capability score of 3.7. The following information is based on evaluator comments:

- The detector seemed to be a rugged and well-sealed unit, although the battery pack connector (Figure 4-13) loosened at times after multiple dives;
- The detector's depth rating of 200 feet is deeper than most dive teams will be permitted to dive;
- Purchase of the detector included all accessories necessary for use on land and underwater. The accessories available for an additional cost, including an optional battery pack that accepts eight size AA batteries, add versatility;

Figure 4-13. Battery Pack Connector

- The sensitivity and penetration capabilities of the detector enabled it to locate the handgun and steel pipe at all depths. The shell casing was not detected at the 6- or 12-inch depths and was difficult to locate at shallower depths; and
- A minimum operating temperature lower than 32°F may be required for operation in icy conditions.

Deployability

The Excalibur II received a Deployability score of 3.3. The following information is based on evaluator comments:

- The five controls had clearly marked default settings, which made setup of the detector quick and easy; and
- The control module and coil were easily removed from and reattached to the shaft. However, use without the shaft required a hip mount kit, which was not available during the assessment since it was not included with purchase of the detector.

Maintainability

The Excalibur II received a Maintainability score of 3.6. The following information is based on evaluator comments:

- The vendor-recommended post-dive maintenance was time consuming. There were many steps involved, and the entire detector had to be taken apart so it could be thoroughly rinsed with fresh water;
- The rechargeable battery pack was easily accessed, removed, and replaced without tools; and

- The hours of availability for technical support are during the standard workday; however, the evaluators noted a preference for the availability of support at night and on weekends.

4.6 Tesoro Electronics Inc. – Tiger Shark

The Tiger Shark (Figure 4-14) received an overall assessment score of 3.3 and costs $779. A 10.5-inch coil; a control module (Figure 4-15); hardwired, submersible headphones; eight size AA batteries; a modular shaft that adjusts from 45 to 52 inches; extra O-rings and silicone grease; cable straps; a user manual; and a lifetime warranty were included with purchase.

Figure 4-14. Tiger Shark

Figure 4-15. Tiger Shark Control Module

Accessories available for an additional cost include a body-mount pouch; small and large carrying cases; a lower ABS pole; and a treasure pouch.

The following sections, broken out by SAVER category, summarize the assessment results.

Usability

The Tiger Shark received a Usability score of 3.1. The following information is based on evaluator comments:

- Although the coil was easy to adjust, it was difficult to navigate through the water and control in the current due to drag caused by its large surface area. The control module was crowded with four controls that were not easily accessible since the control module was located under the shaft, making the detector difficult to operate. The size of the lettering on the controls was small, making it difficult to read;
- The detector's alert was easy to hear;
- The controls were firm and held their position without accidental adjustment. Two of the four controls clicked in place; however, they were too close to each other and could be inadvertently changed when making adjustments;
- The headphones stayed in place during the dive operation scenario; however, the cables on the headphones were long and somewhat cumbersome. The evaluators noted a preference for user-replaceable headphones;
- The battery runtime met expectations;
- No radio frequency interference occurred when operating the detector in proximity to a depth finder. Interference occurred when using the detector approximately 1 to 6 feet away from another operating detector on land; and

- The user manual was comprehensive and easy to understand, although it was almost too detailed. The quick-start guide was easy to understand but long.

Capability

The Tiger Shark received a Capability score of 3.7. The following information is based on evaluator comments:

- The detector seemed to be a rugged and well-sealed unit; however, the thin wires on the headphones could be easily damaged. In addition, the electronic components were exposed during battery replacement, making them prone to damage;
- The detector's depth rating of 200 feet is deeper than most dive teams will be permitted to dive;
- Purchase of the detector included all accessories necessary for use on land and underwater as well as items for maintenance, such as extra O-rings and silicone. The accessories available for an additional cost add versatility;
- The sensitivity and penetration capabilities of the detector enabled it to locate the handgun and steel pipe at all depths without adjusting the sensitivity control; however, detecting the shell casing at the 6- and 12-inch depths was somewhat difficult and required adjustments to the sensitivity control; and
- A minimum operating temperature lower than 30°F may be required for operation in icy conditions.

Deployability

The Tiger Shark received a Deployability score of 2.9. The following information is based on evaluator comments:

- With four controls placed close together, setup was somewhat difficult, and the user manual had to be referenced. Setup would likely become easier with practice; and
- Overall, the control module was easy to remove from the shaft and attach to the included dive belt; however, the bracket on the back of the control module (Figure 4-16) pushed into the user's side when worn on a belt, causing discomfort.

Figure 4-16. Control Module Bracket

Maintainability

The Tiger Shark received a Maintainability score of 3.3. The following information is based on evaluator comments:

- The only vendor-recommended post-dive maintenance was to rinse the submersible headphones. Rinsing the detector after use in salt water was not addressed in the manual;
- The batteries were user replaceable and easily accessed without tools. However, the batteries were in the same compartment as the electronics, and the door was tethered

to the control board; therefore, battery replacement could damage the exposed electronics; and

- The hours of availability for technical support are during the standard workday; however, the evaluators noted a preference for the availability of support at night and on weekends.

4.7 White's Electronics Inc. – Surf PI Dual Field

The Surf PI Dual Field (Figure 4-17) received an overall assessment score of 3.3 and costs $895. A 12-inch coil; a control module (Figure 4-18); hardwired, submersible headphones; eight size AA batteries; a shaft that extends from 45 to 50 inches; cable straps; a user manual; and a 2-year warranty were included with purchase.

Figure 4-17. Surf PI Dual Field

Accessories available for an additional cost include a battery pack; a battery holder; a deluxe backpack case; a carrying case; an extension center shaft; a fiber lower shaft; a fiber, lower, tall-man shaft; and a steady search coil bracket.

The following sections, broken out by SAVER category, summarize the assessment results.

Figure 4-18. Surf PI Dual Field Control Module

Usability

The Surf PI Dual Field received a Usability score of 3.2. The following information is based on evaluator comments:

- Although the coil was easy to adjust, operating the detector was awkward because the control module was located under the shaft and upside down. In addition, the controls were small and close together, making adjustments difficult, especially while wearing cold-water gloves;
- Overall, the detector's alert was easy to hear;
- The controls had little resistance to movement and were close together, making unintentional adjustments more likely;
- The headphones were not user replaceable and were sometimes difficult to keep in place during the dive operation scenario; however, evaluators noted a preference for user-replaceable headphones;
- The battery runtime exceeded expectations;

- No radio frequency interference occurred when operating the detector in proximity to a depth finder. Interference occurred when using the detector approximately 4 to 5 feet away from another operating detector on land; and
- The user manual was easy to read and understand. However, evaluators would have preferred additional illustrations, as well as a quick-start guide.

Capability

The Surf PI Dual Field received a Capability score of 3.5. The following information is based on evaluator comments:

- The detector seemed to be a rugged and well-sealed unit; however, the electronic components were exposed during battery replacement, which may result in damage;
- The detector's depth rating of 100 feet met expectations; however, some agencies may require a detector that can go deeper;
- Purchase of the detector included all accessories necessary for use on land and underwater. Accessories available for an additional cost are very basic and include mostly replacement parts, not allowing for much versatility;
- The sensitivity and penetration capabilities of the detector enabled it to detect all objects at most depths; however, it was difficult to detect the shell casing at the 3-, 6-, and 12-inch depths; and
- A minimum operating temperature lower than 32°F may be required for operation in icy conditions.

Deployability

The Surf PI Dual Field received a Deployability score of 2.9. The following information is based on evaluator comments:

- The three controls had default settings, which made setup of the detector easy; however, placement of the control module on the underside of the shaft made it awkward to configure for use; and
- The control module easily detached from the shaft and slid onto the included dive belt; however, when worn in the dive configuration, the controls faced away from the user.

Maintainability

The Surf PI Dual Field received a Maintainability score of 3.7. The following information is based on evaluator comments:

- Vendor-recommended post-dive maintenance was easy to perform, and the instructions provided were very comprehensive. The detector was rinsed with soap and water, and the O-rings were cleaned and inspected. Batteries require removal for long term storage;
- The batteries were user replaceable and easily accessed without tools. However, the batteries were in the same compartment as the electronics so battery replacement could potentially damage the detector; and

- The hours of availability for technical support are during the standard workday; however, the evaluators noted a preference for the availability of support at night and on weekends.

4.8 Kellyco Metal Detectors – Viper Hybrid Trident

The Viper Hybrid Trident (Figure 4-19) received an overall assessment score of 3.1 and costs $1,000. A 10-inch coil; a control module (Figure 4-20); hardwired, submersible headphones; a 9-volt battery; a shaft that extends from 40 to 46 inches; a carrying case; a user manual; and a 5-year warranty were included with purchase.

Figure 4-19. Viper Hybrid Trident

Accessories available for an additional cost primarily include replacement parts such as an arm rest; a cam lock; a cam lock assembly; a coil loop support; a headphone pad; a metal battery door; and a plastic battery door.

Figure 4-20. Viper Hybrid Trident Control Module

The following sections, broken out by SAVER category, summarize the assessment results.

Usability

The Viper Hybrid Trident received a Usability score of 3.1. The following information is based on evaluator comments:

- The detector was easy to operate with only two controls that were clearly marked and separated enough to allow manipulation with cold-water gloves. However, the controls were somewhat difficult to turn and, although the coil angle adjusted easily, it was difficult to tighten in place once adjusted;
- The detector featured both visual and audible alerts; however, it was difficult to hear the audible alert at times. The visual alert was a light that illuminated when an object was detected;
- The controls were very firm, making unintentional adjustments less likely;
- The headphones were not user replaceable and were sometimes difficult to keep in place during the dive operation scenario;
- The battery runtime may not be sufficient for some dive operations;
- No radio frequency interference occurred when operating the detector in proximity to a depth finder. Interference occurred when using the detector approximately 4 feet away from another operating detector on land; and

- The user manual was comprehensive and easy to read. However, evaluators would have preferred instructions for removing the control module from the shaft and inclusion of a quick-start guide.

Capability

The Viper Hybrid Trident received a Capability score of 3.1. The following information is based on evaluator comments:

- The detector seemed to be a rugged and well-sealed unit; however, the headphones seemed to be poorly constructed and made of low-quality materials that became loose-fitting during the assessment;
- The detector's depth rating of 132 feet met expectations; however, some agencies may require a detector that can go deeper;
- Purchase of the detector included all accessories necessary for use on land and underwater. Accessories available for an additional cost are replacement parts, which do not allow for expandability;
- The detector was able to detect the steel pipe and handgun at all depths, although the alerts were very faint at the 12-inch depth. The shell casings could not be detected at any depth; and
- A minimum operating temperature lower than 32°F may be required for operation in icy conditions.

Deployability

The Viper Hybrid Trident received a Deployability score of 3.1. The following information is based on evaluator comments:

- The two controls had default settings, which made setup of the detector quick and easy; and
- The control module detached from the shaft by removing two screws; however, it was not intended to be removed for modular use.

Maintainability

The Viper Hybrid Trident received a Maintainability score of 3.4. The following information is based on evaluator comments:

- Vendor-recommended post-dive maintenance was not addressed in the manual so the detector was rinsed with fresh water after use, which was easy;
- The battery was easily accessed without tools; however, the battery wires that connect to the 9-volt battery were short, making replacement somewhat difficult due to not having much room to work; and
- The hours of availability for technical support are during the standard workday; however, the evaluators noted a preference for the availability of support at night and on weekends.

5. SUMMARY

According to evaluators, detectors with a minimal amount of controls are preferred, and batteries, headphones, and coils should be user replaceable and rugged enough to endure public safety use. Metal detectors that can be easily reconfigured (i.e., modular) are preferred. Coil size is important, and coils with a large surface area may create drag underwater, making use difficult during a dive. Evaluators agreed that technical support should be available 24 hours a day, 7 days a week and reference material should be printed on water-resistant paper. Evaluators noted all of the assessed detectors featured coils that were easy to adjust. In addition, all of the detectors alerted on the steel pipe and handgun at all depths assessed. The advantages and disadvantages for the assessed products are highlighted in Table 5-1.

Table 5-1. Product Advantages and Disadvantages

Vendor/Products		Advantages	Disadvantages
 MSRP: $2,495	JW Fishers Mfg. Inc. Pulse 8X Overall Score: 4.3	• Only two controls • Visual indicator displays signal strength • Easily changed into modular configuration • Includes user-replaceable land-use headphone and submersible earphone • Very rugged • Many accessories available • Includes both AC and DC battery chargers • DC battery charger features alligator clips • 24/7 technical support	• O-ring on battery compartment is difficult to set in place • Heavy for land use
 MSRP: $880	Garrett Electronics Inc. Sea Hunter™ Mark II Overall Score: 3.9	• Includes user-replaceable submersible headphones • Low minimum operating temperature • Short dive shaft	• Many small parts make removal of the control module difficult

Vendor/Products	Advantages	Disadvantages
 Fisher® Research Labs CZ-21 QuickSilver MSRP: $1,349 Overall Score: 3.9	• Control module and controls are easy to reach and adjust • High contrast lettering on control labels with clearly marked default settings • Provides different tones for different metals • Easily changed into modular configuration • Ports on headphones for equalizing pressure and draining water • Pinpoint feature • Long battery runtime	• Too many controls • Headphones are not user replaceable • Thin wiring on headphones could break • Heavy for land use
 Aquascan International Ltd. Aquapulse 1B MSRP: $1,955 Overall Score: 3.7	• Only two controls • Includes user-replaceable submersible earphone • Very rugged • Many accessories available • Comes standard in a modular configuration • 24/7 technical support	• No included accessories to mount control module to shaft • Free flowing cables may be entanglement hazard • Control module not attached to shaft makes it prone to unintentional adjustments • Battery is not user replaceable • Coil and earphone ports easy to confuse • Heavy for land use
 Minelab Americas Inc. Excalibur II MSRP: $1,949 Overall Score: 3.6	• Bright green color easy to see underwater • Easily replaced rechargeable battery pack • Optional battery pack that accepts eight size AA batteries	• Too many controls • Headphones are not user replaceable
 Tesoro Electronics Inc. Tiger Shark MSRP: $779 Overall Score: 3.3	• Warning on control module and headphones noting headphones are not removable	• Control module is located under the arm and controls are too close together • Headphones are not user replaceable • Battery compartment is shared with other electronics • Large surface area of coil causes drag in the current • Control labels are difficult to read due to small font • Difficult to adjust shaft length

Vendor/Products		Advantages	Disadvantages
 MSRP: $895	White's Electronics Inc. Surf PI Dual Field Overall Score: 3.3	• Large, bright coil is easily seen underwater • Lightweight on land • Control module setup and maintenance is basic	• Control module on shaft is upside down and backwards • Controls settings are too easy to change and controls are too close together • Headphones are not user replaceable • Coil floats
 MSRP: $1,000	Kellyco Metal Detectors Viper Hybrid Trident Overall Score: 3.1	• Only two controls • Visual indicator (LED) signals detection • Powered by a single 9-volt battery • Battery compartment is easily accessible	• No accessory included that allows for hands-free (modular) use • Controls are difficult to turn • Headphones are not user replaceable • Short battery runtime • Headphones are too flexible and fit loose during the dive • Difficulty detecting small objects at deeper depths

Emergency responder agencies that consider purchasing handheld underwater metal detectors should carefully research each product's overall capabilities and limitations in relation to their agency's operational needs.

APPENDIX A. EVALUATION CRITERIA CONSIDERATIONS

Criterion	Specification Assessment	Pre-Dive Scenario	Object Detection Scenario (Wando River)	Dive Operation Scenario	Object Detection Scenario (Lake Moultrie)	Consideration
Usability						
Ease of Operation		✓	✓	✓	✓	How easy is it to adjust the detector's controls? Do the number, location, and size of the controls meet expectations?
			✓	✓	✓	How easy is it to adjust the coil angle?
Alerts		✓	✓	✓	✓	When an object is detected, do the types of alerts meet expectations? How easy is it to hear and/or see the alerts?
Maintain Settings		✓		✓		Do the features that prevent unintentional adjustments of the detector's settings meet expectations?
Headphone		✓				Does the ability to replace the headphone meet expectations?
				✓		Does the ability to use the headphone with other dive equipment meet expectations? How well does the headphone stay in place throughout the dive?
Battery Runtime	✓					Does the length of time the detector can operate before replacing or charging the batteries meet expectations?
Radio Frequency Interference			✓	✓	✓	How much radio frequency interference occurs between the detector and electronics?
User Manual	✓					Does the format and availability of the user manual and/or quick-start guide meet expectations?
		✓	✓	✓	✓	How useful is the information provided in the user manual and/or quick-start guide?

Criterion	Specification Assessment	Pre-Dive Scenario	Object Detection Scenario (Wando River)	Dive Operation Scenario	Object Detection Scenario (Lake Moultrie)	Consideration
Capability						
Durability		✓			✓	Are the detector's battery and electronic compartments sealed?
		✓	✓	✓	✓	Does the overall ruggedness of the detector and all included components meet expectations?
Depth Rating	✓					Does the detector's depth rating meet expectations?
Accessories	✓					Do the items included with purchase meet expectations? Do the accessories available for an additional cost meet expectations?
Sensitivity			✓		✓	Does the size of the objects the detector can detect meet expectations?
Penetration			✓		✓	Does the detector's ability to penetrate bottom sediment meet expectations?
Operating Temperature	✓					Do the minimum and maximum operating temperatures of the detector meet expectations?
Deployability						
Setup		✓	✓	✓	✓	How easy is it to prepare and configure the detector for use?
Modular		✓				How easy is it to detach and reattach the coil and control box?
				✓		How easy is it to use the detached coil and control box to detect objects?
Maintainability						
Maintenance			✓	✓		How easy is it to perform vendor-recommended maintenance?
Battery Accessibility					✓	Does the detector feature user-replaceable batteries? How easy is it to replace the detector's batteries?
Technical Support	✓					Does the availability of and contact methods for technical support meet expectations?

APPENDIX B. ASSESSMENT SCORING FORMULAS

The overall score for each product was calculated using the product's averaged criterion ratings and category scores. An average rating for each criterion was calculated by summing the evaluators' ratings and dividing the sum by the number of responses. Category scores for each product were calculated by multiplying the average criterion rating by the weight assigned to the criterion by the focus group, resulting in a weighted criterion score. The sum of the weighted criterion scores was then divided by the sum of the weights for each criterion in the category as seen in the formula and example below.

Category Score Formula

$$\frac{\sum\left(Average\,Criterion\,Rating \times Criterion\,Weight\right)}{\sum\left(Criterion\,Weights\right)} = Category\ Score$$

Category Score Example[1]

$$\frac{\left(4.3\times 4\right)+\left(5\times 4\right)+\left(4\times 3\right)+\left(4.5\times 3\right)+\left(4.5\times 3\right)}{4+4+3+3+3} = 4.5$$

To determine the overall assessment score for each product, each category score was multiplied by the percentage assigned to the category by the focus group. The resulting weighted category scores were summed to determine an overall assessment score as seen in the formula and example below.

Overall Score Formula

$$\sum\left(Category\ Score \times Category\ Percentage\right) = Overall\ Assessment\ Score$$

Overall Score Example[1]

Capability		*Usability*		*Affordability*		*Maintainability*		*Deployability*		
$\left(4.0\times 33\%\right)$	+	$\left(4.2\times 27\%\right)$	+	$\left(4.2\times 20\%\right)$	+	$\left(3.8\times 10\%\right)$	+	$\left(4.5\times 10\%\right)$	=	4.1

[1]Examples are for illustration purposes only. Formulas will vary depending on the number of criteria and categories assessed and the criteria and category weights.