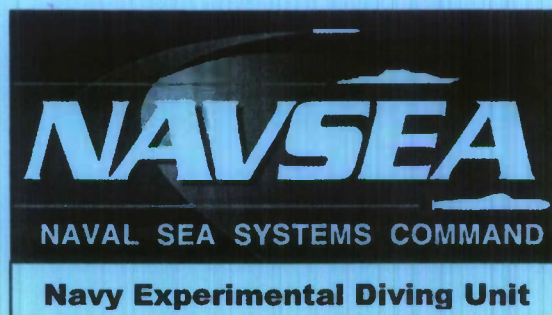


Navy Experimental Diving Unit
321 Bullfinch Rd.
Panama City, FL 32407-7015

TA 04-15
NEDU TR 08-06
July 2008

FIELD EVALUATION OF TOPSIDE DECOMPRESSION MONITOR (TDM) DURING OPERATIONAL DIVING



Authors: L. A. Roy, LT, MC, USN
Principal Investigator

M. J. Lewis, HMC, USN
Associate Investigator

K. A. Gault
Associate Investigator

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

20090203136

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE					
1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS			
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.			
2b. DECLASSIFICATION/DOWNGRADING AUTHORITY					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NEDU Technical Report No. 08-06		5. MONITORING ORGANIZATION REPORT NUMBER(S)			
6a. NAME OF PERFORMING ORGANIZATION Navy Experimental Diving Unit	6b. OFFICE SYMBOL (If Applicable)	7a. NAME OF MONITORING ORGANIZATION			
6c. ADDRESS (City, State, and ZIP Code) 321 Bullfinch Road, Panama City, FL 32407-7015		7b. ADDRESS (City, State, and ZIP Code)			
8a. NAME OF FUNDING SPONSORING ORGANIZATION NAVSEA	8b. OFFICE SYMBOL (If Applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER			
8c. ADDRESS (City, State, and ZIP Code)		10. SOURCE OF FUNDING NUMBERS			
		PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO. 04-15 WORK UNIT ACCESSION NO.	
11. TITLE (Include Security Classification) (U) FIELD EVALUATION OF TOPSIDE DECOMPRESSION MONITOR (TDM) DURING OPERATIONAL DIVING					
12. PERSONAL AUTHOR(S) L. A. ROY, M. J. LEWIS, and K. A. GAULT					
13a. TYPE OF REPORT Technical Report	13b. TIME COVERED FROM AUG 07 to Mar 08	14. DATE OF REPORT (Year, Month, Day) 2008 July		15. PAGE COUNT 29	
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Topside Decompression Monitor, TDM, Next Generation Dive System, NGDS, Oxygen Regulating Control Assembly, ORCA, decompression, VVAL-18, VVAL 18-M.			
FIELD	GROUP				SUB-GROUP
19. ABSTRACT: The TDM was used to record depth-time profiles of dives performed by three Navy diving units during surface-supplied harbor cleanup dives; VVAL-18M decompression tables were used to determine decompression times. The decompression times required by the tables were compared against decompression times prescribed by the TDM running the VVAL-18M real-time algorithm. For 309 dives conducted, there were matching written and uncorrupted TDM records for 17 in-water decompression dives and 142 surface decompression dives. The primary reasons for TDM records being unavailable were failure to charge the batteries and cable connection problems. Decompression required by the TDM would have been a mean of 7.9 min shorter for in-water decompression and a mean of 9.5 minutes shorter for surface decompression dives than the limits required by the tables — reductions of 69% and 26%, respectively. For these near square profiles, the time savings are small for each dive, but over the course of several dives they would have allowed time to dive additional teams each day. Real-time decompression calculations afford operationally relevant savings in decompression times for surface-supplied diving.					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS		21. ABSTRACT SECURITY CLASSIFICATION Unclassified			
22a. NAME OF RESPONSIBLE INDIVIDUAL NEDU Librarian	22b. TELEPHONE (Include Area Code) 850-230-3100		22c. OFFICE SYMBOL		

DD Form 1473

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

CONTENTS

	<u>Page no.</u>
DD Form 1473	i
CONTENTS	ii
INTRODUCTION	1
METHODS	1
EXPERIMENTAL DESIGN AND ANALYSIS	3
INSTRUMENTATION	3
RESULTS	3
SUMMARY	3
Table 1. Summary of SurDO ₂ dives	3
Table 2. Summary of In-water decompression dives	4
DISCUSSION	4
CONCLUSIONS	6
RECOMMENDATIONS	6
REFERENCES	7
APPENDIX A: Topside Decompression Monitor Operating Procedures	A1
APPENDIX B: Individual Dive Site Data	B1
Data from the USS EMORY S. LAND	B1
Table B1. Data Summary	B1
Table B2. SurDO ₂ decompression dives	B1
Table B3. In-water O ₂ decompression dives	B1
Data from MDSU 2 Detachment 2	B2
Table B4. Data Summary	B2
Table B5. SurDO ₂ decompression dives	B3
Table B6. In-water O ₂ decompression dives	B5
Table B7. In-water Air decompression dives	B7
Data from MDSU 2 Detachment 6	B9
Table B8. Data Summary	B9
Table B9. SurDO ₂ decompression dives	B10
Table B10. In-water O ₂ decompression dives	B14

completed. After training was completed, MDSU 2 Det 2 dives were also conducted with the ORCA and VVAL-18M tables.

Comparisons between actual decompression times completed by the divers of the units involved and the tabular decompression times were made to determine decompression time savings. The first nine dives for MDSU 2 Det 2 were conducted with the Standard Air Tables from the *U.S. Navy Diving Manual, Revision 5*;² the remainder were conducted with VVAL-18M tables that have since been published in *Revision 6* of the manual.³

At no time did the diving supervisor use the information obtained from the TDM to determine any diver's decompression schedule. Divers incurred no additional risk from implementation of the test procedures. The pressure transducer for each diver was attached to the preexisting surface-supplied umbilical to avoid interfering with normal diving operations (see Fig. 2). The monitored diver depth/time profiles recorded by the TDM and a backup system (DR200 dive recorder) were logged to data files. The actual dive charts were copied and used to compare decompressions indicated by the TDM to include oxygen stops and surface decompressions.

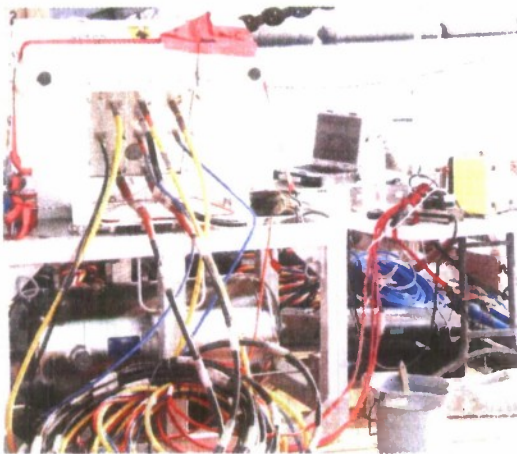


Fig.1



Fig. 2

Before each diving day, the TDM was set up in accordance with the operating procedures listed in Appendix A. The dives then proceeded as scheduled, after the pressure transducer had been securely attached to the umbilical close to the monitored diver's chest level. The secondary data logger was also securely fastened to each diver's umbilical in the same general area. The Associate Investigator trained an appointed designee from each of the three dive sides to train those scheduled to man the charts/logs in operating the TDM throughout the dives. Diver depth/time profiles from the TDM were archived at the end of each week, and copies were made of the

INTRODUCTION

To enhance the deployability, safety, and efficiency of U.S. Navy surface-supplied air diving operations, the U.S. Navy Supervisor of Diving is developing a Next Generation Dive System (NGDS). A principal objective is to enhance the safety and efficiency of surface-supplied air decompression procedures. This will be achieved through use of in-water oxygen decompression supported by a topside decompression monitor (TDM) system that will prescribe diver decompression schedules in real time — according to the actual depth-time profiles experienced by the divers, not according to costly conventions for rounding up required depths and times when such schedules are obtained from conventional decompression tables. The TDM is designed to be used in conjunction with the Oxygen Regulating Console Assembly (ORCA); the VVal-18M air, air with in-water oxygen, and surface decompression with oxygen decompression tables to provide real-time prescriptions of diver decompression obligations. The ORCA, an integral component of the NGDS, has been authorized for Navy use.

Naval Sea Systems Command tasked Navy Experimental Diving Unit (NEDU) to evaluate the prototype version of the TDM during operational dives in La Maddalena, Italy.¹ The purpose of the project was to test the form and function of the TDM as an operational system. The primary objective was to compare the prescribed decompression times of the TDM and those of the conventional tables. A secondary objective was to obtain informal feedback about the system configuration from end users. The TDM was not used to dictate decompression for any dives.

METHODS

Fleet divers from three diving units — the USS EMORY S. LAND (ESL) (AS 39) and Detachments (Det) 2 and 6 of Mobile Diving and Salvage Unit (MDSU) Two — used two TDM systems during diving operations in La Maddalena. The original intent was to use the TDM during dives following the VVAL-18M dive tables and to use the ORCA for in-water decompression with oxygen. An associate investigator deployed one TDM system with the ESL dive locker (see Fig. 1) from a barge moored alongside the ESL and supported by the fly-away recompression chamber (FARC) system deployed from Explosive Ordnance Disposal (EOD) Mobile Unit 8. VVAL-18M dive tables ranging from 90 to 130 feet of seawater (fsw) were used.

The second TDM system was placed with the MDSU 2 Det 2 divers diving from a waste oil barge and using standard air tables while awaiting the arrival of the MDSU 2 Det 6 divers who were embarked on the USNS GRASP (T-ARS 51). The MDSU 2 Det 6 divers were equipped with another ORCA and were certified to use it.

When the USNS GRASP arrived, the first TDM (deployed with the ESL divers) was moved to the MDSU 2 Det 6 dive side. The ORCA previously used by the ESL dive locker was transferred to the MDSU 2 Det 2 divers, and certification training was

paper dive charts. Failure of the TDM at any time did not result in dive termination. The secondary data logger was collected from each umbilical at the conclusion of the operational dive series.

EXPERIMENTAL DESIGN AND ANALYSIS

The primary outcome of the study was a comparison between decompression times prescribed by the TDM and those prescribed by the conventional tables, VVAL-18M and Standard Air.

INSTRUMENTATION

The following equipment was used during the testing:

Two TDM systems running a prototype version of the software and using eight Honeywell model PPTR0300AP5VB pressure and temperature transducers, with one transducer per diver (red/green = two per dive) and two transducers as spares for each dive side; and

Eight DR200 data loggers, two for each dive side's red and green umbilicals and two spares.

RESULTS

SUMMARY

A total of 309 man-dives were completed with the TDM on station. Of these dives, nine had missing smooth logs, 105 had no TDM file, 34 had incomplete or unusable TDM files, and two were repetitive dives. That resulted in 159 dives with both smooth logs and usable TDM records: an overall capture rate of 52%. The smooth logs and TDM records are summarized in the Appendix B tables. One hundred forty-two dives used air with surface decompression with oxygen (SurDO₂) as summarized in Table 1, and 17 were conducted with in-water decompression as summarized in Table 2. Ten of the in-water decompressions used the ORCA system with in-water oxygen decompression. The SurDO₂ dives resulted in average decompression time savings of 9.5 min (26%). The in-water decompression dives had decompression time savings of 7.9 min (69%).

Table 1. Summary of SurDO₂ dives

	N	Average TDT		Savings	
		Tables	TDM	Minutes	Percent
ESL	5	36	21	15	41.7
MDSU2 Det 2	52	36.8	29.7	7.1	19.3
MDSU 2 Det 6	85	36.4	25.7	10.7	29.4
All SurDO ₂ Dives	142	36.5	27.0	9.5	26.0

Table 2. Summary of In-water decompression dives

	N	Average TDT		Savings	
		Tables	TDM	Minutes	Percent
In-water O ₂ ESL	4	20	6.7	13.2	66.2
In-water O ₂ MDSU 2 Det 2	2	10	0	10	100
In-water Air MDSU 2 Det 2	7	6.9	2	3.4	50
MDSU 2 Det 6	4	11.5	2.5	9	78.3
All In Water Decompression Dives	17	11.4	3.6	7.9	68.7

DISCUSSION

The time savings that can be realized from using the TDM are important to recognize, for they offer a potential for improved efficiency throughout surface-supplied Navy diving. Significant time savings from real-time monitoring of dive depth can result in required decompression times that are shorter, or allowable no-decompression bottom times that are longer, than schedules from *Revision 6* of the *Navy Diving Manual* in many operational dives.

Beyond the time savings in this series, a more important point is the low overall data capture rate in the dive series. Many problems resulted in lost data: hardware failure, inadequate training, and inadequate situational awareness.

As a result of these problems, the need for an increasingly robust TDM training program, including instruction in both operating and emergency procedures, is apparent. Such a program will need to include instruction in hardware design and proper setup/deployment, software interface procedures, and backup power options.

In hardware, the most common problem was that of intermittent to continuous loss of sensor data. This resulted from poor connections between the end of the cable and the control box. The current hardware configuration uses a plastic connector that lacks any significant mechanism for strain relief. As a result, when the cable is subjected to any strain (from being stepped on, kicked, etc.), it is transmitted back to the coupling. The current design was incapable of maintaining secure contact throughout the operational conditions seen in this dive series. This connector needs to be made more robust than it now is.

In conjunction with this revision, the pin configuration on both ends of the cable should be made the same to make troubleshooting intermittent losses of data easier than it was between dives. Under the current configuration it is cumbersome to conduct troubleshooting, because the sensor cannot be connected to the control box except

through the umbilical. Because the umbilical is 300 to 600 feet long, to conduct a sensor test with a different umbilical takes unnecessary effort.

Although dive site personnel generally commended the software interface, one problem with the user interface was improper entry of diver data between dives. This causes a carryover of prior dive data and can result in inaccurate calculation of decompression obligations. To correct this improper entry problem, training programs must emphasize proper interdive operational procedures. Also, if possible, software design should be considered to help the operator remember to enter the new diver data.

Some data was lost because of power failure to the control box. The current design of the TDM allows for a wide variety of power supply options, and all TDM power failures could have been corrected with proper training. No situation occurred in which power could not have been restored with a complete set of accessories and completely developed operational procedures.

CONCLUSIONS

Because of limitations in both the TDM's hardware and software capabilities, it cannot adequately perform in its current design. Dive side personnel will require much more extensive training than that provided during this testing to adequately use the TDM as a decompression tool. However, the TDM shows great promise as a means to improve the efficiency of many operational Navy dives through the monitoring of real-time depths and the calculating of decompression obligations. When the TDM can be deployed to the fleet, gains in allowable bottom time will be significant for most multilevel dives.

RECOMMENDATIONS

From the data obtained during this study and the adamant requests for implementation by on-site personnel, we recommend that the TDM be advanced to the next phase of testing. Required next steps include enhancing the software's capability to compute repetitive dive decompression, independently verifying and validating the software/algorithm through a formal independent verification and validation (IV&V) process, and performing additional manned testing with decompressions prescribed by the TDM.

While the software is being enhanced and validated, the hardware should be improved — made rugged to include connectors made of stronger materials with improved designs to relieve strains on each end of the cable. Each end of the cable should use similar pin designs to make cable troubleshooting procedures more intuitive than they currently are.

Operational procedures also need to be updated to include instructions for supplying multiple power sources from 110–240 V ac and 12–48 V dc to the TDM break-out box, including dive side auxiliary generators. Furthermore, procedures must be developed for cases of TDM failures such as those seen during this testing.

REFERENCES

1. Commander, Naval Sea Systems Command, *Task Assignment 04-15: Electronic Collection of Operational Dive Data*, 30 Sep 2004.
2. Commander, Naval Sea Systems Command, *U.S. Navy Diving Manual, Revision 5*, Publication SS521-AG-PRO-010 (Arlington, VA: NAVSEA, 2006).
3. Commander, Naval Sea Systems Command, *U.S. Navy Diving Manual, Revision 6*, Publication SS521-AS-PRO-010 (Arlington, VA: NAVSEA, 2008).

APPENDIX A: Topside Decompression Monitor Operating Procedures

TDM AIR/IN-WATER O₂ DECOMPRESSION PROCEDURES		
	PROCEDURE	INITIAL
1	When divers leave surface and dive time starts, Log (on chart) Left Surface Time as displayed by "Current Time:" in upper right of Decompression Schedules screen.	
2	Conduct dive IAW Dive Plan/Supervisor/USN Diving Manual.	
3	Note Deepest Depth (Max D) during Dive (on chart).	
4	When diver(s) state " <i>left bottom</i> ," select " Leave Bottom " button for the diver(s).	
	NOTE: There is a single button for all divers leaving bottom, or each diver can leave bottom independently by using the button at the bottom of the screen.	
5	When doing "AIR/In-water O ₂ " dive, select " Switch To Oxygen " Button for Red Diver when he/she circulates after O ₂ Shift. Write O ₂ time on chart. Verify Green background "Breathing Oxygen" appears above decompression depth/time area (in place of white background "Breathing Air").	
6	When doing "AIR/In-water O ₂ " dive, select " Switch To Oxygen " Button for Green Diver when he/she circulates after O ₂ Shift. Write O ₂ time on chart. Verify Green background "Breathing Oxygen" appears above decompression depth/time area (in place of white background "Breathing Air").	
7	Write stop time for each in-water stop as each is completed w/ travel time on chart.	
8	Write Reach Surface time on chart (let TDM run).	
9	Select " Switch To Air " for Red when hat comes up.	
10	Select " Stop " when Green diver's hat comes up; push "OK" in dialog box to Stop.	
11	Complete TDM DIVE SETUP FOR NEXT DIVE if continuing w/ diving operations; if not continuing, complete TDM POSTDIVE PROCEDURES.	

	TDM AIR DECOMPRESSION PROCEDURES	
	PROCEDURE	INITIAL
1	When divers leave surface and dive time starts, Log (on chart) Left Surface Time as displayed on "Current Time" in upper right of Decompression Schedules screen.	
2	Conduct dive IAW Dive Plan/Supervisor/USN Diving Manual.	
3	Note Deepest Depth (MAX D) during Dive (on chart).	
4	When diver(s) state " <i>left bottom</i> ," select " Leave Bottom " button for the diver(s).	
	NOTE: There is a single button for all divers leaving bottom, or each diver can leave bottom independently by using the button at the bottom of the screen.	
5	Log bottom time on chart, then ascent time to stop upon arrival at first stop.	
6	Log stop time for each in-water stop as each is completed w/ travel time on chart.	
7	Log Reach Surface time on chart (let TDM run).	
8	Let TDM run while Red is unhatted. Select " Stop " when Green diver's hat comes up.	
9	Complete TDM DIVE SETUP FOR NEXT DIVE if continuing w/ diving operations; if not continuing, complete TDM POSTDIVE PROCEDURES.	

	TDM SURDO₂ DECOMPRESSION PROCEDURES	
	PROCEDURE	INITIAL
1	When divers leave surface and dive time starts, Log (on chart) Left Surface Time as displayed on "Current Time" in upper right of Decompression Schedules screen.	
2	Conduct dive IAW Dive Plan/Supervisor/USN Diving Manual.	
3	Note Deepest Depth (MAX D) during Dive (on chart).	
4	When diver(s) state " <i>left bottom</i> ," select " Leave Bottom " button for the diver(s).	
	NOTE: There is a single button for all divers leaving bottom, or each diver can leave bottom independently by using the button at the bottom of the screen.	
5	Log bottom time on chart, then ascent time to surface (or ascent to 1 st stop, if any).	
6	Log stop time for each in-water stop as each is completed (if stops required).	
7	Log Reach Surface time on chart (let TDM run).	
8	Let TDM run while Red is unhatted; Select " Stop " when Green diver's hat comes up.	
9	Log 40–50 fsw time on chart and chamber stops.	
10	Complete TDM DIVE SETUP FOR NEXT DIVE if continuing w/ diving operations; if not continuing, complete TDM POSTDIVE PROCEDURES.	

	TOPSIDE DECOMPRESSION MONITOR PREDIVE SETUP	
	(Note: the Toughbook has a touch screen; you can touch the screen to select or activate a button or icon.)	
	PROCEDURE	INITIAL
1	Plug Break-out Box (BOB) into ac (110–120 V) outlet (if no outlet, skip to step 3).	
2	Plug Laptop (TB = Panasonic Toughbook) charging cable into BOB GFCI outlet, then into TB ac power port.	
3	Plug Serial Cable connector from BOB to Serial Port on TB; secure with thumbscrews.	
4	Boot Windows XP Pro (power up the Laptop).	
5	Plug Red, Green, and Standby umbilical Cannon Plugs into BOB.	
6	Launch TDM program (double-click icon on desktop); open Configuration Screen (click CONFIGURE button).	
7	Remove electrical protective cap from one transducer and connect to Red Diver Umbilical; ensure connection is finger tight (USE NO PLIERS or WRENCH).	
8	Enter Red Diver's Transducer Serial Number and Diver Name where specified.	
9	Verify zero fsw on configuration screen (click ZERO button as needed).	
10	Repeat steps 7 through 9 for Green Diver's transducer, umbilical, and Diver's Name.	
11	Repeat steps 7 through 9 for Standby Diver's transducer, umbilical, and Diver's Name.	
12	Close the TDM configuration window.	
13	Verify each Diver's name is displayed correctly in the Decompression Schedules Window.	
14	Select Gas Mix/Dive Mode for each Diver.	
15	Touch Start Button (Dive Time will begin when Divers pass 7 fsw).	
16	Follow Dive Procedures as directed by the Diving Supervisor.	

APPENDIX B: Individual Dive Site Data

Data from the USS EMORY S. LAND

Table B1. Data Summary

Number of dives with possible TDM use	16
Number of dives missing smooth Logs	2
Number of dives missing TDM files	5
Number of Profiles for Analysis	9

Table B2. SurDO₂ decompression dives

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
13-Aug-07	15:35 Red ¹	108	44	30				
13-Aug-07	15:35 Green ¹	108	44	30				
15-Aug-07	12:57 Red	115	38	30	112.5	37.3	15	15
15-Aug-07	12:57 Green	115	38	30	109.5	37.3	15	15
17-Aug-07	09:51 Red	117	49	45	113.5	48.3	30	15
17-Aug-07	09:51 Green	117	49	45	109.3	48.3	30	15
17-Aug-07	15:33 Red ¹	112	35	30				
17-Aug-07	15:33 Green	112	35	30	107.3	34.4	15	15
AVERAGE (when both sources exist) N = 5				36			21	15
Percent of TDT								41.7

¹TDM file is missing

Table B3. In-water O₂ decompression dives

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
13-Aug-07	1:17 Red ¹	110	40	23				
13-Aug-07	1:17 Green ¹	110	40	23				
14-Aug-07	10:50 Red ²				109.9	34.5	0	
14-Aug-07	10:50 Green ²				109.9	34.7	0	
15-Aug-07	09:50 Red	116	33	23	109.8	32.0	6	17
15-Aug-07	09:50 Green	116	33	23	108.4	32.1	4	19
17-Aug-07	13:52 Red	110	35	17	108.5	34.6	8	9
17-Aug-07	13:52 Green	110	35	17	108.6	34.6	9	8
AVERAGE (when both sources exist) N = 4				20			6.7	13.2
Percent of TDT								66.2

¹TDM file is missing

²Smooth Log is missing

Data from MDSU 2 Detachment 2

Table B4. Data Summary

Number of dives with possible TDM use	167
Number of dives missing smooth Logs	7
Number of dives missing TDM files	71
Number of incomplete TDM files	28
Number of Profiles for Analysis	61

Table B5. SurDO₂ decompression dives

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
7-Sep-07	09:25 Red	118	27	9 ¹	117.2	26.6	15	-6
7-Sep-07	09:25 Green	118	27	9 ¹	117.2	26.6	15	-6
7-Sep-07	11:34 Red	118	27	9 ¹	117.3	26.7	15	-6
7-Sep-07	14:28 Red	118	30	9 ¹	117.9	29.27	15	-6
7-Sep-07	14:28 Green	118	30	9 ¹	117.2	29.22	15	-6
7-Sep-07	15:29 Red ^{2,3}	118	29		116.7			
7-Sep-07	15:29 Green ²	74	10		73.7	9.52	0	
7-Sep-07	16:32 Red	118	29	9 ¹	117.2	28.8	15	-6
7-Sep-07	16:32 Green	118	29	9 ¹	117.2	28.8	15	-6
7-Sep-07	17:34 Red	120	30	9 ¹	117.6	29.5	15	-6
7-Sep-07	17:34 Green	120	30	9 ¹	117.5	29.5	15	-6
8-Sep-07	8:40 Red	120	48	45	118.3	47.4	45	0
8-Sep-07	8:40 Green	120	48	45	117.3	47.5	45	0
8-Sep-07	10:10 Red	116	49	50	119.3	48.6	45	5
8-Sep-07	10:10 Green	116	49	50	116.8	48.7	45	5
8-Sep-07	11:43 Red	120	49	45	117.8	48.4	45	0
8-Sep-07	11:43 Green	120	49	45	118.1	47.9	45	0
8-Sep-07	13:57 Red	120	49	50	118.5	47.9	45	5
8-Sep-07	13:57 Green	120	49	50	117.1	47.9	45	5
9-Sep-07	8:28 Red	118	50	45	116.5	48.9	45	0
9-Sep-07	8:28 Green	118	50	45	114.7	49	45	0
9-Sep-07	9:51 Red	117	50	45	114.3	48.9	45	0
9-Sep-07	9:51 Green	117	50	45	115.1	48.9	45	0
9-Sep-07	13:17 Red	118	49	45	115.1	48	45	0
9-Sep-07	13:17 Green	118	49	45	112.5	48.1	45	0
9-Sep-07	14:47 Red ^{2,3}	118	49	50	113.2			
9-Sep-07	14:47 Green ^{2,3}	118	49	50				
9-Sep-07	16:09 Red	118	49	50	114.1	48.6	45	5
9-Sep-07	16:09 Green	118	49	50	114.6	48.6	45	5
10-Sep-07	8:10 Red	120	49	50	114.5	48.7	45	5
10-Sep-07	8:10 Green	120	49	50	116.3	48.7	45	5
10-Sep-07	9:45 Red	116	51	60	114.8	50.1	45	15
10-Sep-07	9:45 Green	116	51	60	113.8	50.1	45	15
10-Sep-07	11:20 Red	120	47	45	116	46.2	45	0
10-Sep-07	11:20 Green	120	47	45	116	46.3	45	0
10-Sep-07	14:24 Red ²	115	49	45	116.3	48.7		
10-Sep-07	14:24 Green ²	115	49	45		48.7		

¹ Decompression conducted using Tables from Navy Diving Manual, Revision 5.² TDM file is incomplete or corrupted.³ TDM Recording Terminated at Depth.

Table B5. Cont.

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
11-Sep-07	08:08 Red	89	56	15	89	55.7	15	0
11-Sep-07	08:08 Green	89	56	15	86.8	55.6	15	0
11-Sep-07	9:52 Red ¹	92	50	30	86.1	49.1		
11-Sep-07	9:52 Green ¹	92	50	30				
11-Sep-07	11:14 Red	88	56	30	86.8	55	15	15
11-Sep-07	11:14 Green	88	56	30	86.8	55	15	15
11-Sep-07	16:40 Red	95	48	30	94.6	47	15	15
11-Sep-07	16:40 Green	95	48	30	81.4	47.1	15	15
12-Sep-07	8:15 Red	78	56	45	81.5	55.2	15	30
12-Sep-07	8:15 Green	78	56	45	87.5	55.3	15	30
12-Sep-07	9:48 Red	80	66	30	79.7	65.2	15	15
12-Sep-07	9:48 Green	80	66	30	81.6	65.2	15	15
12-Sep-07	14:00 Red	90	65	45	82.6	64.8	15	30
12-Sep-07	14:00 Green	90	65	45	81	64.8	15	30
12-Sep-07	16:30 Red ¹	79	52	45	77.9	51		
12-Sep-07	16:30 Green ¹	79	65	45	77.4	51		
13-Sep-07	8:12 Red	79	89	45	79.5	88.4	30	15
13-Sep-07	8:12 Green	79	89	45	78.9	88.5	30	15
13-Sep-07	10:20 Red	80	86	38	80.1	85	30	8
13-Sep-07	10:20 Green	80	86	38	78.6	85.1	30	8
13-Sep-07	13:34 Red	83	80	60	85.1	79.7	30	30
13-Sep-07	13:34 Green	83	80	60	80.1	79.6	30	30
13-Sep-07	15:46 Red	88	57	30	87.9	56.5	15	15
13-Sep-07	15:46 Green	88	57	30	76.6	56.5	15	15
14-Sep-07	14:00 Red ²				76.9	56.6	15	
14-Sep-07	14:00 Green ²				80.1	56.6	15	
AVERAGE (when both sources exist) N = 52				36.8			29.7	7.1
Percent of TDT								19.3

¹ TDM file is incomplete or corrupted.² Smooth Log is missing.

Table B6. In-water O₂ decompression dives

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
15-Sep-07	13:16 Red ²	60	90	13	59.3	65.8		
15-Sep-07	13:16 Green ²	60	90	13	60			
19-Sep-07	13:10 Red ¹	69	57	11				
19-Sep-07	13:10 Green ¹	69	57	11				
20-Sep-07	10:10 Red ¹	53	90	8				
20-Sep-07	10:10 Green ¹	53	90	8				
20-Sep-07	12:12 Red ¹	57	84	13				
20-Sep-07	12:12 Green ¹	57	84	13				
21-Sep-07	10:12 Red ¹	56	77	10				
21-Sep-07	10:12 Green ¹	56	77	10				
21-Sep-07	11:58 Red ¹	56	69	7				
21-Sep-07	11:58 Green ¹	56	69	7				
21-Sep-07	13:36 Red ¹	63	68	16				
21-Sep-07	13:36 Green ¹	63	68	16				
21-Sep-07	15:20 Red ¹	61	79	20				
21-Sep-07	15:20 Green ¹	60	54	0				
22-Sep-07	8:30 Red ¹	63	59	11				
22-Sep-07	8:30 Green ¹	63	59	11				
22-Sep-07	10:14 Red ²	58	79	10				
22-Sep-07	10:14 Green	58	79	10	55.2	75.9	0	10
22-Sep-07	12:03 Red ²	57	80	10	57.8	76		
22-Sep-07	12:03 Green	57	80	10	55.8	75.1	0	10
22-Sep-07	14:07 Red ²	59	68	7	53.1			
22-Sep-07	14:07 Green ²	59	68	7	49.2			
22-Sep-07	15:40 Red ¹	61	78	20				
22-Sep-07	15:40 Green ¹	61	78	20				
23-Sep-07	8:20 Red ¹	53	95	11				
23-Sep-07	10:25 Red ¹	61	74	20				
23-Sep-07	12:30 Red ¹	61	68	16				
23-Sep-07	14:11 Red ¹	57	64	7				
23-Sep-07	15:39 Red ¹	59	89	13				
24-Sep-07	8:21 Red ¹	59	100	18				
24-Sep-07	11:23 Red ¹	55	78	5				
24-Sep-07	13:05 Red ¹	57	74	10				
25-Sep-07	9:03 Red ¹	57	90	13				
25-Sep-07	11:03 Red ¹	65	67	16				
25-Sep-07	13:45 Red ¹	59	70	7				
27-Sep-07	8:45 Red ¹	67	74	20				
15-Sep-07	13:16 Red ²	60	90	13	59.3	65.8		

¹TDM file is missing.²TDM file is incomplete or corrupted.

Table B6. Cont.

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
27-Sep-07	10:49 Red ¹	69	67	16				
27-Sep-07	10:49 Green ¹	69	67	16				
27-Sep-07	12:55 Red ¹	67	53	8				
27-Sep-07	12:55 Green ¹	67	53	8				
28-Sep-07	10:46 Red ¹	97	35	11				
28-Sep-07	10:46 Green ¹	97	35	11				
28-Sep-07	13:45 Red ¹	97	33	11				
28-Sep-07	14:56 Red ¹	97	43	23				
28-Sep-07	16:35 Red ¹	97	44	22				
28-Sep-07	18:14 Red ¹	97	40	17				
AVERAGE (when both sources exist) N = 2				10			0	10
Percent of TDT								100

¹TDM file is missing

Table B7. In-water Air decompression dives

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
7-Sep-07	10:26 Red	120	28	14	116.9	27.5	12	2
7-Sep-07	10:26 Green	120	28	14	116.6	27.5	12	2
13-Sep-07	10:34 Red ¹	60	88	13				
13-Sep-07	10:34 Green ¹	60	88	13				
14-Sep-07	8:42 Red ³				60.1	22.1	0	
14-Sep-07	10:15 Red ³				78.6	59.4	0	
14-Sep-07	10:15 Green ³				78.6	59.4	0	
14-Sep-07	15:26 Red ³				78.1	46.4	0	
14-Sep-07	15:26 Green ³				77.1	46.5	0	
15-Sep-07	14:43 Red	59	57	0	57.5	56	0	0
15-Sep-07	14:43 Green	59	57	0	58.9	56.1	0	0
15-Sep-07	17:05 Red ¹	61	48	0				
15-Sep-07	17:05 Green ¹	61	48	0				
16-Sep-07	16:34 Red ¹	63	60	11				
16-Sep-07	16:34 Green ¹	63	60	11				
16-Sep-07	14:38 Red ²	59	88	13	51.6			
16-Sep-07	14:38 Green ²	59	88	13	59.5			
17-Sep-07	8:10 Red ¹	54	88	8				
17-Sep-07	8:10 Green ¹	54	88	8				
17-Sep-07	10:10 Red ²	55	104	15	56.3	45		
17-Sep-07	10:10 Green ²	55	104	15	51.2	98		
17-Sep-07	12:25 Red ²	55	78	4	54.8	75.2		
17-Sep-07	12:25 Green ²	55	78	4	54.6	75.4		
17-Sep-07	14:10 Red ²	57	80	10	56			
17-Sep-07	14:10 Green ²	57	80	10	53.7			
17-Sep-07	15:58 Red ¹	54	68	0				
17-Sep-07	15:58 Green ¹	54	68	0				
18-Sep-07	13:13 Red ¹	56	69	7				
18-Sep-07	13:13 Green ¹	56	69	7				
18-Sep-07	16:33 Red ¹	59	60	0				
18-Sep-07	16:33 Green ¹	59	60	0				
19-Sep-07	8:09 Red	59	77	10	54.9	74.4	0	10
19-Sep-07	8:09 Green ²	59	77	10	55.8			
19-Sep-07	9:57 Red	57	57	0	54.6	54.5	0	0
19-Sep-07	9:57 Green ²	57	57	0	53			
19-Sep-07	11:18 Red	59	78	10	58.1	71.9	0	10
19-Sep-07	11:18 Green ²	59	78	10	57.9			
19-Sep-07	14:39 Red ¹	59	56	0				

¹ TDM file is missing.² TDM file is incomplete or corrupted.³ Smooth Log is missing.

Table B7. Cont.

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
19-Sep-07	14:39 Green ¹	59	56	0				
19-Sep-07	15:59 Red ¹	59	82	13				
19-Sep-07	15:59 Green ¹	59	82	13				
20-Sep-07	8:33 Red ¹	57	68	7				
20-Sep-07	8:33 Green ¹	57	68	7				
20-Sep-07	14:12 Red ¹	59	58	0				
20-Sep-07	14:12 Green ¹	59	58	0				
20-Sep-07	15:27 Red ¹	59	100	18				
20-Sep-07	15:27 Green ¹	59	100	18				
21-Sep-07	8:21 Red ¹	53	73	0				
21-Sep-07	8:21 Green ¹	53	73	0				
24-Sep-07	15:19 Red ¹	57	29	0				
25-Sep-07	12:44 Red ¹	59	25	0				
28-Sep-07	11:56 Red ¹	93	23	0				
28-Sep-07	12:45 Red ¹	97	20	0				
30-Sep-07	10:47 Red ¹	99	43	22				
AVERAGE (when both sources exist) N = 7				6.9			3.5	3.4
Percent of TDT								50.0

¹TDM file is missing.

Data from MDSU 2 Detachment 6

Table B8. Data Summary

Number of dives with possible TDM use	126
Number of dives missing smooth Logs	0
Number of dives missing TDM files	29
Number of incomplete TDM files	6
Number of Repetitive Dives	2
Number of Profiles for Analysis	89

Table B9. SurDO₂ decompression dives

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
30-Aug-07	10:39 Red ²	106	55	45	105.4	54.3		
30-Aug-07	10:39 Green ²	106	55	45	105.8	54.3		
30-Aug-07	13:02 Red	112	48	45	109	48.6	15	30
30-Aug-07	13:02 Green	112	48	45	109.5	48.6	15	30
30-Aug-07	14:27 Red	108	40	30	106.3	39.3	15	15
30-Aug-07	14:27 Green	108	40	30	105.2	39.2	15	15
30-Aug-07	15:43 Red ¹	106	34	26				
30-Aug-07	15:43 Green ¹	106	34	26				
31-Aug-07	12:40 Red	110	54	45	108.4	53.7	30	15
31-Aug-07	12:40 Green	110	54	45	107.2	53.7	30	15
31-Aug-07	14:48 Red	106	74	60	106	74.4	45	15
31-Aug-07	14:48 Green	106	74	60	104.6	73.3	45	15
3-Sep-07	09:25 Red	104	45	30	103.9	44.9	15	15
3-Sep-07	09:25 Green	104	45	30	103.8	44.9	15	15
3-Sep-07	12:28 Red	106	42	30	104.5	41.6	15	15
3-Sep-07	12:28 Green	106	42	30	104.6	41.6	15	15
3-Sep-07	14:00 Red	106	44	30	104.9	43.4	15	15
3-Sep-07	14:00 Green	106	44	30	104.2	43.3	15	15
3-Sep-07	15:14 Red	106	48	45	104.8	47.6	15	30
3-Sep-07	15:14 Green	106	48	45	105.5	47.5	15	30
6-Sep-07	10:15 Red	122	45	45	121.7	44.1	45	0
6-Sep-07	10:15 Green	122	45	45	120.8	44.1	45	0
6-Sep-07	12:46 Red	120	44	45	120.1	43.8	30	15
6-Sep-07	12:46 Green	120	44	45	119.1	43.7	30	15
6-Sep-07	14:15 Red	121	48	60	118.9	47.4	45	15
6-Sep-07	14:15 Green	121	48	60	119	47.3	45	15
6-Sep-07	16:34 Red	121	43	45	120.1	42.1	30	15
6-Sep-07	16:34 Green	121	43	45	123	42.2	30	15
6-Sep-07	17:48 Red	121	34	30	120.8	33.8	30	0
6-Sep-07	17:48 Green	121	34	30	117.9	33.9	30	0
7-Sep-07 ³	08:58 Red	118	15	0	117	14.6	0	
7-Sep-07 ³	08:58 Green	118	15	0	116.9	14.5	0	
Repetitive	10:01 Red	120	37	30	116.9	21.6	15	15
Repetitive	10:01 Green	120	37	30	117.8	21.7	15	15
7-Sep-07	11:10 Red	124	44	45	121.9	43.6	30	15
7-Sep-07	11:10 Green	124	44	45	122	43.6	30	15
7-Sep-07	13:09 Red	122	44	45	117.6	40.2	30	15
7-Sep-07	13:09 Green	122	44	45	119.6	40.2	30	15

¹ TDM file is missing.² TDM file is incomplete or corrupted.³ First dive of a repetitive dive series; savings tabulated only for last dive.

Table B9. Cont.

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
7-Sep-07	14:58 Red	120	44	45	120	43.7	45	0
7-Sep-07	14:58 Green	120	44	45	119.5	43.7	45	0
7-Sep-07	17:48 Green	118	29	15	117.3	28	15	0
8-Sep-07	09:08 Red	120	42	45	117	41.9	30	15
8-Sep-07	09:08 Green	120	42	45	117	41.7	30	15
8-Sep-07	10:25 Red	124	40	45	122.3	40	30	15
8-Sep-07	10:25 Green	124	40	45	122.2	40.1	30	15
8-Sep-07	13:06 Red	124	27	15	122.3	26.2	15	0
8-Sep-07	13:06 Green	124	27	15	120.8	26.2	15	0
8-Sep-07	16:45 Red	120	39	30	117.2	39.2	30	0
8-Sep-07	16:45 Green	120	39	30	117.4	39.2	30	0
9-Sep-07	08:46 Red	119	45	45	120.5	44.5	45	0
9-Sep-07	08:46 Green	119	45	45	117.9	44.5	30	0 ¹
9-Sep-07	10:34 Red ²	118	39	45				
9-Sep-07	10:34 Green ²	118	39	45				
9-Sep-07	12:54 Red	117	46	45	116.1	45.1	30	15
9-Sep-07	12:54 Green	117	46	45	116.9	45	30	15
9-Sep-07	14:30 Red	118	45	45	117	44.8	45	0
9-Sep-07	14:30 Green	118	45	45	115.2	44.8	30	0 ¹
9-Sep-07	15:50 Red	116	43	45	115.9	42.8	30	15
9-Sep-07	15:50 Green	116	43	45	115.9	42.8	30	15
9-Sep-07	17:29 Green	119	30	15	118.9	29.7	15	0
10-Sep-07	08:45 Red	120	45	45	118.8	44.3	45	0
10-Sep-07	08:45 Green	120	45	45	118.6	44.2	30	0 ¹
10-Sep-07	10:00 Red	119	37	30	115.9	36.2	30	0
10-Sep-07	10:00 Green	119	37	30	117.8	36.2	30	0
10-Sep-07	12:30 Red	121	37	45	117.6	36.4	30	15
10-Sep-07	12:30 Green	121	37	45	118	36.5	30	15
11-Sep-07	09:10 Red ⁴	112	50	30	105.6	49.3	0	30
11-Sep-07	09:10 Green ⁴	112	50	30	112.1	49.4	0	30
11-Sep-07	11:23 Red ²	116	46	45				
11-Sep-07	11:23 Green ²	116	46	45				
11-Sep-07	13:03 Red ³	116	41	45				
11-Sep-07	13:03 Green	116	41	45	114.8	40.7	45	0
11-Sep-07	17:20 Red ³	104	29	15				
11-Sep-07	17:20 Green	104	29	15	103.1	27.9	15	0
12-Sep-07	08:25 Red ²	114	37	30				
12-Sep-07	08:25 Green ³	114	37	30				

¹ Divers would decompress on stage in pairs.² TDM file is missing.³ TDM file is incomplete or corrupted.⁴ Dives were conducted with some in-water decompression prior to SurDO².

Table B9. Cont.

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
12-Sep-07	09:43 Red ¹	105	43	30				
12-Sep-07	09:43 Green ²	105	43	30				
12-Sep-07	11:10 Red ¹	104	38	30				
12-Sep-07	11:10 Green ¹	104	38	30				
12-Sep-07	13:40 Red ¹	100	43	30				
12-Sep-07	13:40 Green ¹	100	43	30				
12-Sep-07	15:30 Red ¹	106	43	30				
12-Sep-07	15:30 Green ¹	106	43	30				
13-Sep-07	08:30 Red ¹	114	49	45				
13-Sep-07	08:30 Green ¹	114	49	45				
13-Sep-07	10:10 Red	118	45	45	103.6	44.7	45	0
13-Sep-07	10:10 Green ¹	118	45	45				
13-Sep-07	12:17 Red ¹	120	47	45				
13-Sep-07	12:17 Green ¹	120	47	45				
13-Sep-07	13:43 Red ¹	106	45	30				
13-Sep-07	13:43 Green ¹	106	45	30				
13-Sep-07	15:14 Red ¹	106	40	30				
13-Sep-07	15:14 Green ¹	106	40	30				
14-Sep-07	08:30 Red	96	48	30	98	47.4	30	0
14-Sep-07	08:30 Green	96	48	30	98.8	47.4	30	0
14-Sep-07	10:08 Red	104	40	30	101.6	39.3	15	15
14-Sep-07	10:08 Green	104	40	30	103.5	39.2	15	15
14-Sep-07	14:45 Red ¹	118	49	45				
14-Sep-07	14:45 Green ¹	118	49	45				
14-Sep-07	16:11 Red	98	47	30	98	56.9	15	0 ³
14-Sep-07	16:11 Green	98	47	30	97.9	46.8	30	0
15-Sep-07	09:59 Red	100	47	30	97.7	46.1	15	15
15-Sep-07	09:59 Green	100	47	30	100.8	46.1	15	15
15-Sep-07	12:20 Red	102	41	30	101.3	40.1	15	15
15-Sep-07	12:20 Green	102	41	30	105.8	40.1	15	15
15-Sep-07	13:39 Red	118	39	30	99.6	38.1	0	30
15-Sep-07	13:39 Green	118	39	30	117.9	38	0	30
15-Sep-07	15:40 Red	102	47	45	99.7	46.7	15	15 ³
15-Sep-07	15:40 Green	102	47	45	102.1	46.8	30	15
15-Sep-07	17:40 Red	97	39	30	96.7	38.8	15	15
15-Sep-07	17:40 Green	97	39	30	98.7	38.8	15	15
16-Sep-07	14:26 Red	102	28	15	100	27.8	0	15
16-Sep-07	14:26 Green	102	28	15	102	27.8	0	15

¹ TDM file is missing.² TDM file is incomplete or corrupted.³ Divers would decompress on stage in pairs; savings is to the longer required deco time for the pair according to the TDM.

Table B9. Cont.

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
17-Sep-07	11:20 Red	99	43	30	99.1	42.5	15	0 ¹
17-Sep-07	11:20 Green	99	43	30	99.1	42.5	30	0
17-Sep-07	13:06 Red	99	48	30	100.5	47.7	30	0
17-Sep-07	13:06 Green	99	48	30	99.5	47.8	30	0
AVERAGE (when both sources exist) N = 85				36.4			25.7	10.7
Percent of TDT								29.4

¹ Divers would decompress on stage in pairs; savings is to the longer required deco time for the pair according to the TDM.

Table B10. In-water O₂ decompression dives

dive date	Identifier	Smooth Log			TDM			Savings
		Max Depth	Bottom Time	TDT	Max Depth	Bottom Time	TDT	
31-Aug-07	08:49 Red	104	40	23	104	39.6	0	18 ¹
31-Aug-07	08:49 Green	104	40	23	104.8	39.5	5	18
12-Sep-07	17:40 Red ²	103	15	0				
12-Sep-07	17:40 Green ²	103	15	0				
14-Sep-07	12:20 Red	97	19	0	96.7	18.9	0	0
14-Sep-07	12:20 Green	97	19	0	97.3	18.9	0	0
16-Sep-07	15:30 Red ²	102	19	0				
16-Sep-07	15:30 Green ²	102	19	0				
AVERAGE (when both sources exist) N = 4				11.5			2.5	9
Percent of TDT								78.3

¹ Divers would decompress on stage in pairs; savings is to the longer required deco time for the pair according to the TDM.

² TDM file is missing.