## **Modeling Tunnel Magazine QD Arcs Using GIS**

Ed Falconer, GISP Tyler Ross, PhD, PE NAVFAC ESC, 1100 23rd Ave, Port Hueneme, CA 93043-4370

#### Abstract

The Naval Facilities Command (NAVFAC) Engineering Service Center (ESC), located in Port Hueneme, CA, has developed tools to quickly provide map displays of the Quantity-Distance (QD) arcs for tunnel magazines using both DoD and NATO criteria. The development of the maps of possible NEW storage scenarios included a 3D analysis of the tunnels and the surrounding topography to assess available soil cover and the surface breach that could result if insufficient soil cover were available. The explosive hazard criteria intelligent tables linked with GIS map displays provided a means to rapidly model the QD arcs generated by alternative storage scenarios in underground explosive storage facilities. The 3D modeling and visualization of the expanding shock and pressure hazards for a range of NEW quantities compared to the soil surface allowed detailed examination of the potential surface breach crater characteristics.

#### Introduction

The Naval Facilities Command (NAVFAC) Engineering Service Center (ESC), located in Port Hueneme, CA, has developed tools to quickly provide map displays of the Quantity-Distance (QD) arcs for tunnel magazines using both DoD and NATO criteria.

ESC has integrated Geographic Information System (GIS) map display tools and intelligent tables containing QD arc calculations for tunnel magazines in order to rapidly examine alternative explosives storage scenarios. The tools were developed, tested, and used to delineate on planning maps the incremental increases in size of the QD arcs which would be derived from possible increases in Net Explosives Weight (NEW) of stored munitions. The goal of the effort was to quickly and inexpensively provide a series of planning QD arc maps to Asset Managers to permit better decision making on optimizing the balance between the need for increased NEW storage within operational constraints.

The development of the maps of possible NEW storage scenarios included a 3D analysis of the tunnels and the surrounding topography to assess available soil cover and the surface breach that could result if insufficient soil cover were available. The 3D analysis compared the tunnel geometry to a LIDAR model of the topography of the mountain in which the tunnels were constructed. Using the 3D analysis tools permitted a detailed examination of the interaction between the tunnel and the available soil cover.

	Report Docume	entation Page		I OM	Form Approved IB No. 0704-0188				
Public reporting burden for the col maintaining the data needed, and c including suggestions for reducing VA 22202-4302. Respondents sho does not display a currently valid C	lection of information is estimated t ompleting and reviewing the collect this burden, to Washington Headqu uld be aware that notwithstanding an DMB control number.	o average 1 hour per response, inclu ion of information. Send comments arters Services, Directorate for Info ny other provision of law, no person	ding the time for reviewing insi regarding this burden estimate rmation Operations and Reports shall be subject to a penalty for	tructions, searching exis or any other aspect of th s, 1215 Jefferson Davis r failing to comply with	ting data sources, gathering and is collection of information, Highway, Suite 1204, Arlington a collection of information if it				
Report Documentation Page   Set Or Approved Out BNA contractions     while exponing builds for the collection of information is assimated to wange I hour per exponse, including the time for reviewing intractions, such the collection of information of informations. Set Outperformance, and comments and and appendix the collection of information of the collection of information. Set Outperformance, and comments and and appendix the collection of information. Set Outperformance, and appendix the collection of information. The completing and workers and the collection of information. Set Outperformance, and appendix the collection of information of the collection of information. The collection of information of the collection of information. The collection of information of the collection of information. The collection of information of the collection of information. The collection of information of the collection of information. The collection of information of information. The collection of information of information of information of information. The collection of information of information of information. The collection of information of information of information of information. The collection of information of information of information of information of information of information of information. The collection of information of informati					RED				
4. TITLE AND SUBTITLE				5a. CONTRACT	NUMBER				
Modeling Tunnel N	Aagazine QD Arcs U	Using GIS		5b. GRANT NUM	IBER				
				5c. PROGRAM E	LEMENT NUMBER				
6. AUTHOR(S)				5d. PROJECT NU	JMBER				
				5e. TASK NUMBER					
				5f. WORK UNIT NUMBER					
7. PERFORMING ORGANI NAVFAC ESC, 110	ZATION NAME(S) AND AI 00 23rd Ave, Port H	DDRESS(ES) Iueneme, CA 93043	-4370	8. PERFORMING REPORT NUMB	G ORGANIZATION ER				
9. SPONSORING/MONITO	RING AGENCY NAME(S) A	AND ADDRESS(ES)		10. SPONSOR/M	ONITOR'S ACRONYM(S)				
				11. SPONSOR/M NUMBER(S)	ONITOR'S REPORT				
12. DISTRIBUTION/AVAII Approved for publ	LABILITY STATEMENT ic release, distributi	on unlimited							
13. SUPPLEMENTARY NO See also ADM0023 Oregon on 13-15 Ju	otes 13. Department of I uly 2010, The origin	Defense Explosives S al document contai	Safety Board Sem ns color images.	inar (34th) h	eld in Portland,				
14. ABSTRACT The Naval Facilitie CA, has developed magazines using bo scenarios included cover and the surfa criteria intelligent generated by altern and visualization o the soil surface allo	es Command (NAVI tools to quickly pro oth DoD and NATO a 3D analysis of the ace breach that coul tables linked with G native storage scena f the expanding sho owed detailed exami	FAC) Engineering S vide map displays of criteria. The develo tunnels and the sur d result if insufficie FIS map displays pr rios in underground ck and pressure haz nation of the potent	ervice Center (ES of the Quantity-D opment of the ma crounding topogr nt soil cover were ovided a means to a explosive storag cards for a range ial surface breac	SC), located i istance (QD) ps of possible aphy to asses available. The prapidly moo ge facilities. T of NEW quar h crater char	n Port Hueneme, arcs for tunnel e NEW storage s available soil he explosive hazard lel the QD arcs he 3D modeling ntities compared to acteristics.				
15. SUBJECT TERMS					1				
16. SECURITY CLASSIFIC	ATION OF:		17. LIMITATION OF	18. NUMBER	19a. NAME OF				
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified	SAR	27	ALSI UNSIDLE FERSUN				

The analysis tools were applied to the tunnel storage magazines at a US DoD installation. A sampling of the maps developed for that study is provided in this report. The maps and NEW storage amounts developed in that analysis do not represent the actual storage parameters of the magazines. The maps merely represent the QD arcs resulting from a range of possible storage amounts and are provided for example purposes only.

#### **Tunnel Magazines**

Tunnel magazines are a type of underground storage facility which can consist of a single explosives storage chamber or multiple connected chambers with protective features. According to DoD 6055.09-STD (Feb. 29, 2008, p50), "To qualify as an underground facility, the minimum distance from the perimeter of a storage area to an exterior surface shall be great than  $0.25 \text{ W}^{1/3}$  ( $0.10 \text{ Q}^{1/3}$ )". Normally the minimum distance requirement is met by the existing soil cover, which would be sufficient to contain most blast and fragment effects.

The calculated QD arc for a tunnel is dependent upon local geology and site-specific parameters such as the tunnel dimensions. Special protective features may be built for the structure to reduce the Inhabited Building Distance (IBD) for both the fragment debris and overpressure airblast (e.g. debris traps, expansion chambers, portal barricades, high pressure closures, and facility design/construction)

Overpressure and fragments are channeled out through openings such as doors and vents. The channeling of the airblast and debris fragments through openings, especially the front portal, can act like a shotgun. The QD criteria for overpressure and fragment hazards are therefore typically more severe than for standard earth covered magazines.

#### **Tunnel Magazine QD Arc Criteria**

The intelligent table tools developed by ESC determine the QD arcs for tunnel magazines using the DoD and NATO criteria for airblast overpressure, adit (portal) fragment debris, and surface breach debris. The two sets of criteria provide different QD arc patterns on the resultant maps. For the analysis, DoD and NATO criteria were examined for each tunnel magazine. The application of the different sets of criteria, either DoD or NATO, would have to be applied to all of the storage tunnels in the area.

The DoD explosive storage QD arc criteria are defined in DoD Standard 6055.09-STD. The NATO explosive QD arc criteria are defined in the NATO Allied Ammunition Storage and Transportation Publication 1 (AASTP-1). The DoD Standard and NATO Publication define underground storage facilities and describe the criteria for the QD safety arcs for tunnel magazines. One of the main differences between the two sets of criteria is that the QD arc criteria for tunnel magazines defined in the DoD Standard 6055.09-STD have generally remained unchanged for 20 years. The NATO AASTP-1 criteria have progressed with continued development through the NATO working group.

The QD arc for adit debris using the DoD criteria requires an 1800 ft safety distance regardless of the HD 1.1 or 1.3 NEW quantities. The adit debris QD arc for NATO criteria is dependent upon the HD 1.1 and 1.3 quantities. The NATO criteria describe a minimum of approximately 750 ft safety arc, which progresses with increases in NEW. The safety distance surpasses DoD criteria above approximately 9,000 lbs NEW.

The overpressure QD arc defined by the DoD criteria describes an oval-shaped area. The overpressure DoD criteria for IB distance is 1.2 psi. The overpressure QD arc defined by NATO criteria describes a heart-shaped area with the point angled in the direction of the tunnel, i.e. in the direction of the "shotgun" blast. NATO criteria require the overpressure to be reduced to 0.725 psi to define IB distance. This is more conservative than the DoD criteria. The shape of the NATO arc provides a larger safety area along the forward centerline than the oval-shaped area defined by the DoD criteria. The back-side area provides a small safety arc than the DoD oval-shaped area.

The surface rupture debris QD arc described by the DoD criteria is a circular-shaped area centered on the probable rupture location at the point of least soil cover over the underground storage tunnel. The surface rupture debris QD arc described by the NATO criteria includes directional effects in the same way as the NATO adit debris arc, making it non-circular. The NATO surface rupture debris arc angle is determined by the slope azimuth at the probable rupture location at the point of least soil cover.

The different sizes and shapes of the QD arcs created to comply with the DoD and NATO criteria provided a wide variety of possible footprint areas depending on the specific NEW storage and the criteria which were used. The intelligent table and GIS tools created by ESC provide a means to rapidly develop maps for a range of NEW values and criteria to allow planners to compare and contrast the areas of impact versus the operational requirements in the area

### Methods

Spreadsheets were used in Microsoft Office Excel to calculate coordinate points for the various arcs. Coordinates were calculated at 5 degree intervals to create a 360 degree arc of 72 points. Site-specific factors considered in the calculations include: magazine volume, loading density, hydraulic diameter, geology type, soil cover, and surface slope angle (for NATO criteria). The various arcs calculated include: overpressure, adit (portal) debris, surface breach (if applicable), ground shock, chamber separation, required soil cover, and PTRD (Public Transportation Route Distance) for various hazards. (See Figure 1)

#### Intelligent QD Hazard Arc Tables



#### Figure 1

The hazard arcs for each magazine calculated by the intelligent tables were integrated into an ArcGIS Map Document for interactive display. It was essential to maintain an interactive connection between the intelligent tables and the GIS map display in order to rapidly develop a series of maps to evaluate a range of NEW storage scenarios. By maintaining the interactive connection between the intelligent tables and the GIS changes made to the NEW or changing from the DoD criteria to the NATO criteria could be immediately displayed when the map was refreshed.

To maintain the interactive connection between the intelligent tables and the ArcGIS map document required a three step process. First, the hazard arc distances were determined by the intelligence built into the tables based on the chosen NEW and the DoD or NATO criteria. The intelligent tables then used the QD arc distances to calculate the location of a series of points spread throughout the perimeter of the hazard area, with a point calculated every five degrees (5°) from the origin point of the hazard arc. The location of these five-degree arc points were brought into the ArcGIS map document as an Event Theme point dataset. In this way changes to the NEW or to the criteria, e.g. by switching from DoD to NATO criteria, would cause the intelligent tables to calculate new hazard arc distances that would feed into new recalculations of the five-degree point locations. The ArcGIS map display would have to be refreshed to prompt the Event Themes to reacquire the five-degree arc point locations. Once the map redrew it would show the new hazard arc as a series of points along the perimeter. (See Figure 2)

# 10 <t

#### Intelligent QD Hazard Arc Tables Integrated with GIS Maps

Figure 2

The hazard arc perimeter point locations are calculated based on the Quantity-Distances determined by the intelligent tables from the NEW and the chosen criteria, DoD or NATO. The distances are determined for each 5 degree arc from the given center point of the entry portal or of the surface breach location. The location of the origin point, and therefore also the derived five-degree arc points, were calculated using coordinates from projection NAD83 HARN State Plane Hawaii3 FIPS5103. This is the projection system used by the base. By calculating the positions using a known coordinate system, the ArcGIS event theme could readily display the calculated hazard arc points with other data such as buildings, roads, the base boundary, etc.

To adjust to an alternate tunnel location, or an alternate projection system, the origin point of the hazard arcs at the entry portal or the surface breach of the new X, Y coordinates need only be entered into the intelligent tables. The intelligent tables and integration with GIS were designed to facilitate adaptation of the process to other locations.

To determine the accurate location of the surface breach point, 3D analysis was performed with GIS comparing the soil cover available throughout the length of the storage chamber to the actual topographic landforms as determined by data available from a LIDAR survey of installation elevation. To perform the 3D analysis, contour line models were developed of the increasing shock and pressure hazard as the NEW quantities were increased. The contour line models were converted to 3D shapes that were then compared to 3D features derived from the existing elevation data. (See Figure 3)



Expanding 3D Surface for the Shock and Pressure Hazard for a Range of Soil Cover

Figure 3

The comparison between the expanding surface for the shock and pressure hazard for a range of NEW quantities and the static elevation surface permitted the accurate determination of the location of least soil cover. The 3D model of the elevation surface was derived from one-foot contour line data. Therefore models were created of the expanding shock and pressure hazard surface at one-foot intervals. Comparison of the two models allowed the derivation of an estimate of soil cover accurate to within one foot of the actual distance to nearest surface breach. The calculated available soil cover permitted the reverse calculation of the NEW value that would not result in a surface breach for each underground storage facility. (See Figure 4)



Modeling Surface Breach Crater at One-Foot Increments

Figure 4

The models of the expanding shock and pressure hazards for a range of NEW quantities when compared to the soil surface allowed visualization of the size and shape of the surface breach. In the visualizations, the expanding area of potential surface breach could be observed wrapping around the mountain landforms. In some instances the expanding shock and pressure hazard would have a potential to cause two surface breaches, one on each side of the spur landform in which the underground storage facility was constructed. The models of the potential surface breach crater were used to derive the average centroid of the crater for each incremental increase in NEW so as to provide the best estimate of the origin point for the surface debris hazard arcs. (See Figure 5)



### 3D Modeling of Surface Breach Crater and Landform Surface

Figure 5

The accurate determination of the surface breach origin point permitted the identification of the topographic characteristics of slope and azimuth at the surface breach location. The NATO criteria have directional effects in their QD arcs for surface breach debris fragments. The direction is determined by the azimuth of the breach point. The 3D models thus provided a more accurate estimate of the surface breach point characteristics vital for development of the NATO QD arcs.

### Results

The integration of intelligent QD hazard arc tables with GIS for display and analysis permitted rapid development of planning maps for a range of NEW quantities using both the DoD and NATO criteria. For the analysis of some of the underground storage facilities, the capabilities of the integrated tools were used to examine hundreds of

storage scenarios in order to visualize the effects of alternate storage scenarios and to develop an understanding of the area. For the final analysis, 77 planning maps and their concomitant GIS datasets were created for the base in order to provide them with the same type of understanding one could develop through using the tools interactively. (See Figure 6)



Rapidly Developed QD Arc Planning Maps

Figure 6

The analysis of the expanding shock and pressure hazards for a range of NEW quantities compared to the soil surface indicated that for some of the tunnels at high NEW quantities a second surface breach would be possible on the reverse side of the mountain ridge in which the tunnels were constructed. This result was unexpected and would probably not have been identified without the use of the GIS map visualization and modeling effort. The QD arcs for surface breach debris were extended from both the front and the back side of mountain when those high NEW values were considered. (See Figure 7)



3D Surface for the Shock and Pressure Hazard Reveals Potential

Figure 7

#### Conclusions

The explosive hazard criteria intelligent tables linked with GIS map displays provided a means to rapidly model the QD arcs generated by alternative storage scenarios in underground explosive storage facilities. The tools allowed the examination of a QD arcs for a range of NEW quantities and for switching between DoD and NATO criteria. The GIS map display allowed for immediate validation of the QD arcs compared to planning features such as buildings, roads, etc. The resultant QD planning maps acted as a decision support system for optimizing explosives storage within operational constraints of the site.

The 3D modeling and visualization of the expanding shock and pressure hazards for a range of NEW quantities compared to the soil surface allowed detailed examination of the potential surface breach crater characteristics. Accurate estimates of available soil cover were developed for the full extent of the underground explosives storage chamber. The size and shape of the potential surface breach was determined at a range of NEW quantities to examine the breach crater as it conformed to the landscape. The results of the analysis were used to determine the crater centroid for a range of NEW quantities. The revised centroid values were used to determine the slope and azimuth of the landscape at that centroid for inclusion in development of the QD arcs when using NATO criteria.

The intelligent tools integrated with GIS were developed so as to be readily transferable to other locations. In this way they can provide planners with a means to rapidly visualize the QD arcs resulting from a range of alternative storage scenarios in tunnel magazines.

### **Bibliography**

DoD 6055.09-STD, "DoD Ammunition and Explosives Safety Standards," February 29, 2008, Incorporating Change 2, August 21, 2009

NATO AASTP-1 (ED 1), "Allied Ammunition Storage and Transportation Publication 1: Manual of NATO Safety Principles for the Storage of Military Ammunition and Explosives." May 2006



## Modeling Tunnel Magazine QD Arcs Using GIS

Ed Falconer, GISP Tyler Ross, PhD, PE 13 July 2010

## Modeling Tunnel Magazine QD Arcs Using GIS



- Introduction
  - Tunnel Magazines
  - DoD and NATO QD Arc Criteria
- Methods
  - QD Criteria Intelligent Tables Creation
  - QD Hazard Tables Connected to GIS
  - 3D Analysis of Required Soil Cover and Mountain Landform
- Results
  - Possible Surface Breach on Reverse Side of Mountain Ridge
  - Rapid Development of Numerous Storage Scenarios
- Demonstration
- •Summary
- Questions







- •Tunnel magazines have sufficient soil cover to contain most blast and fragment effects
- •Overpressure and fragments are channeled out through openings such as doors and vents
- •Quantity-Distance (QD) criteria for overpressure and fragment hazards differ from those of standard magazines and are typically more severe
- •QD is dependent upon local geology and site-specific parameters such as tunnel dimensions

## **DoD and NATO QD Arc Criteria**



## •DoD 6055.09-STD

- -Generally remained unchanged for more than 20 years
- -1800 ft adit debris arc regardless of HD 1.1 or 1.3 quantity
- -IBD overpressure criteria = 1.2 psi
  - Oval shape arc
- -Surface rupture debris arc assumed to be circular

## •NATO AASTP-1

- -Continued development through NATO working group
- -Adit debris arc dependent upon HD 1.1 or 1.3 quantity
  - Minimum of 750 ft and surpasses DoD criteria above 9,000 lbs NEW
- -IBD overpressure criteria = 0.725 psi (more conservative)
  - "Heart" shaped arc
  - More conservative along the forward centerline
- -Surface rupture debris arc includes directional effects

## **QD Criteria Intelligent Tables Creation**



- Automated spreadsheet considers
  - -Magazine volume
  - -Loading density
  - -Hydraulic diameter
  - -Geology type
  - -Soil cover
  - -Surface slope angle (NATO)

## Hazard Arcs calculated

- -Overpressure
- -Adit (Portal) debris
- -Surface breach (if applicable)
- -Ground shock
- -Chamber separation
- -Required soil cover
- -PTRD for various hazards

NPU <sup>-</sup>	Γ		
Magazine	NEW	Criteria	
#	(lbs)		
1514	5000	NATO	
1515	10000	NATO	•
1516	10000	DoD	
1517	10000	NATO	
1518	10000	NATO	



## **QD Hazard Tables Connected to GIS**



• Calculated Hazard Arcs for each magazine integrated into ArcGIS Map Document for interactive display

 Hazard Arc points calculated in Excel table using coordinates from projection NAD83 HARN State Plane Hawaii3 FIPS5103

- Table of calculated hazard arc point values converted to ArcGIS Event Themes for map display with roads, buildings, etc.
- ArcGIS Event Theme maintains connection to source table – Changes in Hazard Arcs table immediately reflected on map



# 3D Analysis of Required Soil Cover and Mountain Landform



- •Created models of the extent of the soil cover required to mitigate shock & pressure hazards for a given NEW
- Compared models against the detailed mountain landform



## **3D Analysis of Soil Cover**



- Modeled surface breach crater at 1 foot intervals of chamber to surface distance
- Derived accurate estimates of available soil cover at all points along full length of tunnels
- Allowed reverse calculation of allowable NEW to avoid surface breach







- •Modeled Surface Breach craters for range of NEW for each tunnel
  - -Determined location, size, and shape of Surface Breach craters
- •Changed Surface Breach Debris arcs to reflect breach crater center location (and azimuth of the hill slope for NATO criteria)



## 3D Analysis and QD Hazard Tables Linked to GIS



- •3D analysis results combined with maps linking QD hazard tables and GIS
- Provided rapid development of QD arc planning maps





# Possible Surface Breach on Reverse Side of Mountain Ridge

- 3D analysis revealed that at high NEW shock & pressure hazards for some tunnels could extend from rear of magazine out to opposite side of mountain ridge in which they are located
- The QD Arcs for Surface Breach Debris were thus extended from both front and back side of mountain







Rapid Development of Numerous Storage Scenarios



• ESC examined a wide range of NEW storage scenarios using both DoD and NATO criteria for tunnels



 Goal to achieve optimum balance of storage within operational constraints



## **Demonstration**



Microso	ft Excel - Kane	oheArcCa	lculator_0	91029.xls																	
Eile	Edit ⊻iew Inse	ert Forma	t <u>I</u> ools <u>D</u>	jata <u>W</u> indo	w <u>H</u> elp	Adobe PDF			-										Type a que	stion for he	lp ∙.
		2 1 2 1	1 2 3	2 - 🥩	- P -	👷 Σ 🝷	<b>2↓ X↓   ₩</b> 4	🚯 100% 👱 🤇													
ial	✓ 10	- B	<i>Ι</i> <u>υ</u>   <u>≡</u>	<b>= = •</b>	\$ %	• •.0 .00 •.€ 00. •	律律 Ⅲ、	· 👌 • 🛕 •													
D10	-	& DoD																			
A	В	С	D	E	F	G	н	L.	J	K	L	M	N	0	P	Q	R	S	T	U	V
												_									-
												-									-
<u> </u>		-																			
	INPU	I.																			
							Allowable	Allowable	Magazine	Magazine	W/V	W/V	Hydr	Hydr	DOD	NATO	Soil	Scaled			
	Magazine	NEW	Criteria				Pso @ IBD	Pso @ IBD	Volume	Volume			Dia, D	Dia. D		_	Cover	cover	Breach?		
	#	(lbs)					psi (DoD)	psi (NATO)	ft <sup>3</sup>	m <sup>3</sup>	pcf	ka/m3	ft	m	0 = IBC	0 = IBD	ft	m/(kg^(1/3))	ves/no	fv	NAT
	1514	3600	DoD	-			1.20	0.725	54 609	1.546	TI OPI	1.03	17.45	178	612	880	32	0.836	VES	0.07631	ii 7
	1515	2000	DoD				1.20	0.725	57 372				12.10	3 74	484		32	1.008			
	1516	2000	DoD	-			1.20	0.725	52 013				12.20	3 72	500		23	0.774			
	1517	20000	DoD				1.20	0.725	55 474				12.50	3.81	1.780		36	0.347			
	1518	60000	NATO	_			120	0.725	51 830				12.75	3 88	1761		31	0.314			
														-							
-		User supp	olied info																		-
-		Colculato	data.				DO NOT CHA	NICE			Assun	nptions									-
		Calculater	Juala				1614				loadin	a density	r < 3 lbs	(ft3)							-
							1615				map o	utput is	in meter	3		-					-
							1516				soil co	ver > 0.7	75w^(1/3	1							
							1617														
							1618														
-																					-
-																					-
																					-
																					-
																					-
															-						

Ready









	research (	cel - Annocember	General Party	12.00								
21		the past of	test Jose One	Shops ibs walls an								N 113 P 111 13 140
	2 M L)	1427	10 X 10 20	(1)内·代门选正	- 31 TI 38	10,004 9 40 2						
-				# (#) # . to (# . to (# .	1100.0010	A Decker						
-		1										
	1			A 100				ALC: NO.			1000	1000 B 1000
150		THEM OF BE X	TIGLA OP 80 Y	THEM OF STR & THE	OF PHP Y	TIDIA Cana	THE OF MON	TRISCE DO V	TREAS OF IPTE V	THESE OF PER Y	TIGIC Cana	THE OF BO Y
100	1.1	and as in	2007.0	selfe is all	30327	Wite Matthew full	COPIE IN	112210	tofent w	51104.75	with training full	CPA4 3
31	- 6	627054 30	213318	527797-53	31013	1014, XEDbs DvD	117757 24	24303.94	L1700.00	107174	1016, 2000an DiO	627562.3
4	10	42%44.10	21303.00	1. E27932.0x	31/25/01	X14. 252034 \$40	\$27751.22	21303.07	627796.16	21206.41	1016, 206084 DeD	\$25143.07
8	15	627643.75	21299-43	\$17536.58	21405111	1614, 3500bs \$e0	\$27746.52	3130230	11779353	3129179	1016, 2080bs, DeD	S70K 0
2	20	427039-20	2445.00	12704.06	31140.07	1014, 308094 BHD	127714.10	24275.22	127730.24	21404 (51	1016, 20800a Doll	\$2701.2
7	25	127128.27	21432.0	127680 16	21408.03	W14, MEDES DED	527744.98	31,803,10	127790-36	31409.28	1010, 20808s DeD	£19246. W
6	- X)	42/540.66	3847.9	GP106-G2	31466.23	HITE, JOEDBA, DHD	\$2756.34	21403.72	127733.40	21216.04	1516, 2080 to a Del-	52126.0
91	X	127544 52	21623	\$17732.08	31477.25	1514, 3550 bs. DeO	\$27750.33	2949271	12796-54	31424.09	1016, 30KOBN, DED	\$2727.2
18	AQ.	- C2163-60	31175.9	627726.54	31105.63	VE14, XEEDEA, DED.	- SITM 7	344373	12779626	31436.41	1016, 20000a, DeD	621220.07
	- 45	\$27927.98	21025	527726-02	31803.17	1514, 2560bs, DvD	\$27790.24	2812.72	5270P-52	2176.02	1016, 2000ba, BuD	\$29282.0
12	- 40	127965.22	3490373	12/714.26	31406.12	1614, 356054, BHD	627790-34	18442.92	12790616	31849 (9	1918, 20009-A END	52/06.2
13	- 35	12772.0	31(4)(6	521712.18	31936.05	"E14, 25800m \$00	10/1727	3113.43	127(8) 3	1106.25	1111, 2003th	6790.5
14	60	101W196		127724.28	311.8.18	1014, 255084, BAD	52(77) #	2447.25	12791207	318672	7576, 20000a, DeC	5/1/6.4
16		427W0.Q	2108.90	12/728.08	21476.29	W14, 26031, D4D	\$27786.28	2143.00	1278/214	21464.28	WH, 2808a Dr0	\$27250.75
18.	- 2	47.464.90	19562.74	527794.91	3161813	W14, MEDRA END	547742.28	1147.00	16/10/21	3126718	1918, 2080/84, \$MC	5,296.5
	- 3	60.014	2112/14	1. 12/78187	31422.17	W14, 286031, BND	- MORES	10/200	10/05/21	2184.82	11%, 28084, DO	- N/W18
18	- 89	4,27719.62	19929	907744 81	31421.08	WIA, MADES, END	527636-24	1015.20	16792913	11281 54	2818, 228099, 840	5,0167.00
2-	- 20	627238	211/6.2	54770.20	2768.02	W14, 28LDEL, EVD	104020	2007/20	10110.00	1101.0	1116, 20008a, Dec	10000
0-	- 2			100750	- 124 14	WILL MADE AND	10000				State States and	10000
100		400000	31503.0	1007768.00	315,25 13	WIN, PRODUCED	10100	10001.27	100000	31886.13	7476, 200000, DOD	10000
4-	- 20	410342.00	100017	617764 87		Mid Million Sec.	41704.14	The second	417641.44	11400.00	NAME OFFICER AND	10004
- 12		411114.8.21	1001	AVTITAL INC.	1100.00	Table Marries Fach	1100.00	1101100	avrile al de	1 mm	will there and	1000
8-	116	6778453	1216.2.1	SUTTING.	31436.04	with Million Real	12764.0	11407.07	ACTING 10	11445.78	with Dilling Fail.	107344
9.	120	401778.00	104431	6377727 16	31428.68	W14 WEDS- Dell	CNO W	11411.75	101165-01	1100.47	1616 (2000a Del)	4273612
	126	62275 3	11142.0	STITUE N	114.08.08	WHAT WELDER DATE	\$17(5) #	1141105	10007 40	11454.00	with their fail.	60701114
26	182	407788315	194274	427795158	91428.02	WILL WEDNI ELC.	4076218	18479.70	\$2,7950 N	TLUG TR	with Disting Indi	42797 8
3	100	6,7784 63	11146.0	CITH IS	314.8.02	WIA WALLS AND	627662.03	14474.00	107491-07	21463.37	WH DECKA DAD	6,790H 6
201	141	400088.80	inizi w	427746-18	\$14,36,93	Wig Wallion End	42746412	11474.75	427665-02	91.000 AL	1916 20808-s Dell	6000K V
	146	4,5752 M	28541.78	CUTE-M	31424.61	Wid, Million, Bull	62962 23	14476-06	627848-66	11461.41	WH, 2003a Oct.	627/H W
10	191	6,77.996.76	31004	617781.66	31428.11	WIA WEDS: END	427989 72	347624	401987.24	1 26.11	1918, 208104, Doll	4270H X
28	196	4,0736-00	111164	107794-42	31425.04	W14, WEDDO END	40787216	16475.29	127947-18	11455 14	"HM, DECRA DEC.	C724.6
14	160	407401345	1 3HINA	5079 K (pr	3162010	W14, 96091 810	827874.93	1140125	9.57880 H	11497-02	1616, 20000 a. Doll	4/27/102 28
78	145	1,7411	38621/4	6,077R*A2	316 10 10	W14, WEDRI, END	\$27678.35	11407.14	10107111	11/100 110	1010, 200004, END	1,01000 /1
16	00	4,7163.00	1012315	417796-78	215.8.76	W14, PEDIn Ehd	\$J7877 H	1144.0	80787211	01498.98	Wife, 208004, Ebdl.	627041 N
2.		5/1827 X	21526.2	127789.077	316 (6.21	WIA MEDRI, BOD	\$27879.34	11402.00	10/17/2/06	21454.08	W15, 200081, \$401	679010
	- 183	42745942	101234	COLN	318/12/54	W14, WEIRs, Bell	CETING SA	3140540	127971.N	140.79	With Dillion Dell.	C7(4).18
78	18	107112.30	34122.8	1. 12/11/21 14	31612.05	VE14, METRIE, END.	\$27062.00	21408.71	12797111	21452.19	1015, 20800-4, Doll.	107545.2

## **Demonstration**







icrosoft	Dicel - Mine	obeArcCa	iculater_0	91029.XB																		14
St Di	t See but	et Fgma	i jook g	ata Windo	- 64	digeren													7194 + 614	tion for being	1 = 4	•
8.4	10.01	121	1 4 24	3.1	0.000	19.2.	+ 21 31 44 4	1 100% ·	a													
and and an	+ 10	HIR!			5.16	. 12.75	1 (Re (Re) (D))	. A . A .														
010		6 NATO				144 4 14	the second second															
A		C	E .		F	G	н	1	1	к	L	M	N	0	P	0	*	s.	Ť	U	V	13
-	-			-		-			-		-	114		-	-							
- 1	NDI I	т																				
	NFU								-			-		-								
							Allowable	Allowable	Magazine	Magazine	WIV	WW	Hydr	Hydr	DOD	NATO	Sell	Scaled				
	Magazire	NEW	Criteria				Pto @ IBD	Pto @ IBD	Volume	Volume			Dia, D	Dia, D			Cover	cover	Breach?			
		(bu)					psi (DoD)	DSI ENATOI	R <sup>2</sup>	m <sup>2</sup>	pcf	kalm3		-	D = 18C	0 = IBD		milkg*(1/3))	vesino	t.	NATO .	4
	1514	3900	Diff				1.20	0.725	64.000	1000	1000		1000	-		100	33	0.035	180	or other	i mu	e
	1515	200					1.23	0.725									82					
	1616	10,000	NATO	1			1.20	0.726									23					
	1617		240				1.20	0.755	6.6 4 7.4				19.60				30					
	1518	-	sato.				1.20	0.725	61.000				12.75				31					
	1.910			-			t-mit-		a caree		_	_					-	A REAL PROPERTY AND A REAL	1000	and the second second		t
	-		-	-																		
		User supp	lied info																			
	_						_	_	_		Assun	ptons										
		Calculated	data				DO NOT CHARLES				Hard n	ick.	- 9.0-1									5
							1610				man	dentally	n maters									1
							1010				salco	ver > 0.7	54113									1
							1017															1
							1612															1
																						1
																						ļ.
	-																					
-	in a man of		The second of the	Daniel Diver	1 m	A		Inter to the						-								11





## Summary

- QD Criteria Intelligent Tables linked with GIS map displays
  - Rapid development of alternative storage scenarios
  - Immediate validation of QD Safety Arcs compared to map features, e.g. roads, housing area, etc.
- 3D visualization of the ground shock
  - Detailed examination of Surface Breach Crater creation
  - More accurate estimation of available ground cover







## **Questions?**

Ed Falconer, GISP Tyler Ross, PhD, PE 13 July 2010