

TEST AND EVALUATION

REPORT

VOLVO L90 ARMOURED FRONT END LOADER **& ALLU SCH 4-25 CRUSHING AND SCREENING BUCKET**



SRSA/SWEDEC NOVEMBER 2006

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1.0 EXECUTIVE SUMMARY

The Swedish Rescue Services Agency (SRSA) evaluated the option of equipping their armoured front end loaders with specialist working tools so that they can be used typically classed as difficult conditions for standard clearance methodologies. These conditions are contaminated areas where the threat is below the standard clearance depths of 20cm and where soil conditions and mine types may render standard detection methods ineffective.

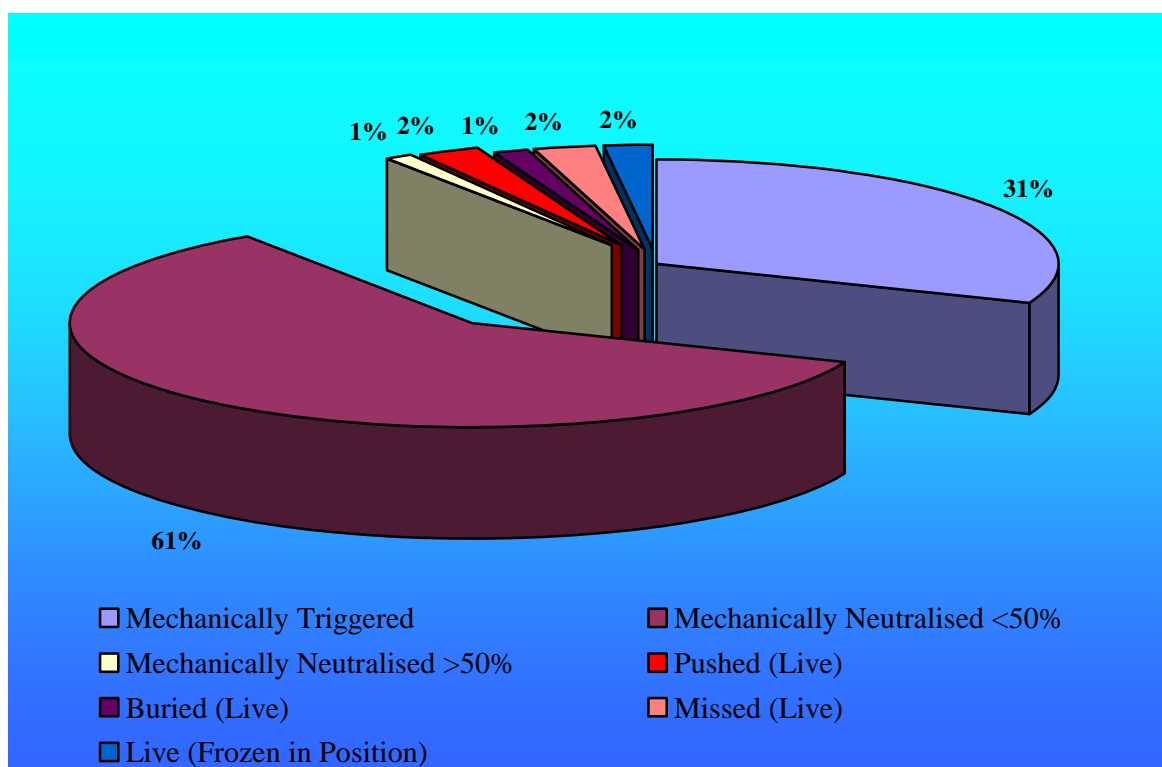
Excavation methods and concepts, using standard bucket configurations, were identified as a potential methodology for this type of work in discussions with GICHD. However, it was also firmly believed that a suitable system could also be used, at the same time, to process the excavated soil.

The trials, in conjunction with SWEDEC, were held in Eksjö Sweden and focused on this concept, where a standard front end loader was fitted with a Crushing and Screening bucket.

Overall, the tests and evaluations conducted during the trials were comprehensive. The trails provided testing staff a clear insight to the performance of the L90 AFEL and the ALLU SCH 4-25 Crushing and Screening bucket.

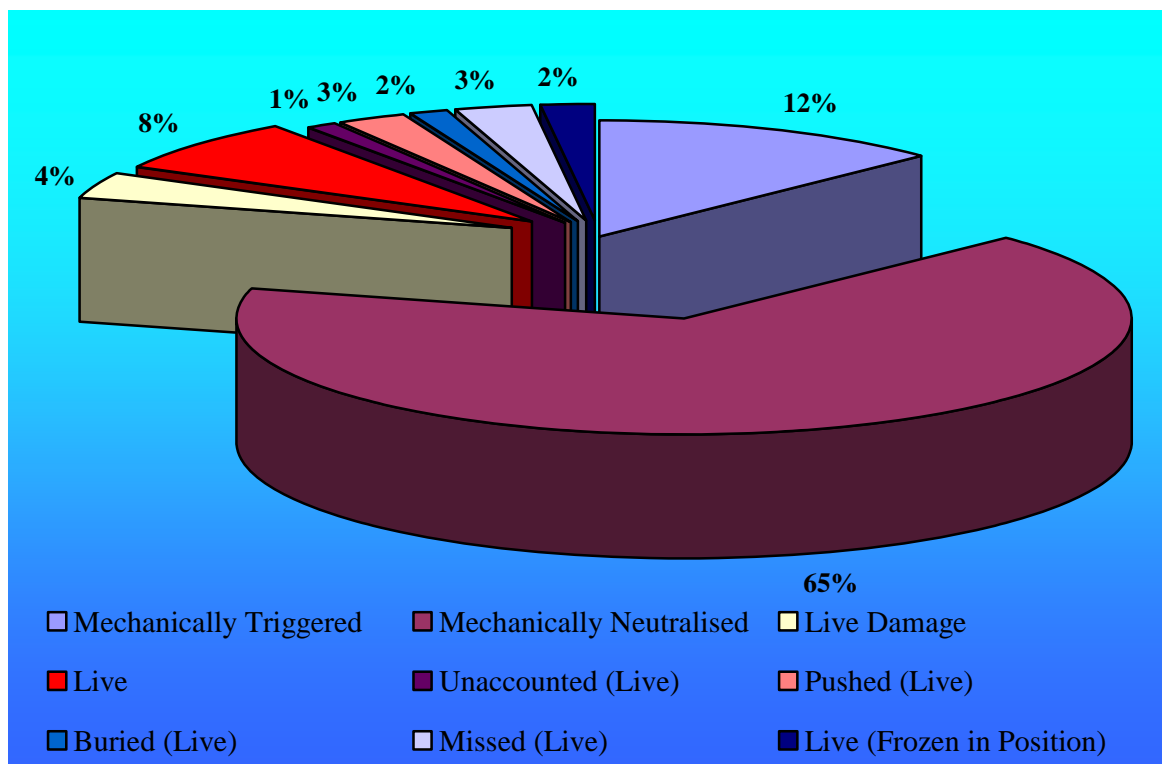
In summary, the following points were achieved:

- a. The results clearly indicate that all anti personnel mines within the bucket are either activated (triggered) or mechanically neutralised. It is physically not possible for any object greater than 23mm x 48mm to pass through the system.



Overall Statistical Summary of Soil Processing of Contaminated Land – AP MINES

- b. Cases where mines were not activated or neutralised are not attributed to machine or tool failure, rather to correct application and employment. All points identified can be corrected through various modifications to machinery and adjustment to training and operational practices.
- c. A residual threat from fuses exists, as fuses were able to pass through the crushing and screening drums during soil processing activities. The option to reduce the screening size is not feasible as it would have a detrimental effect on the performance of the ALLU bucket, severely restricting soil flow and subsequent production rates. However, this residual threat can be countered in any follow-up procedures integrated with the mechanical system. This could involve manual verification of processed soil, or through the application of additional mechanical units such as sifters and magnets, or a combination of the methodologies mentioned.



Overall Statistical Summary of Soil Processing of Contaminated Land - FUSES

Although less test targets were used, only 202, than that recommended in the CWA 15044, the tests provided clear indications that the Volvo L90 AFEL can perform as a platform and the ALLU SCH 4-25 Crushing and Screening bucket has good capabilities to deal with anti-personnel blast mines.

Weather certainly played an important role during the evaluations, hampering the flow of the tests and may have had an influence on some of the results. Due to the weather, Top Soil evaluations for bucket function, and Volvo L90 and bucket excavation evaluations are incomplete. On the other hand, weather conditions did provide valuable insight into how the

system and in particular the bucket performs under extreme conditions, highlighting some of the restrictions that will be faced in such conditions.

Durability tests showed that the specially designed drums are able to withstand multiple detonations, sustaining relatively minor damage. The bucket frame also withstood blast forces, although the final “Live” test certainly showed a major weakness within the chain drive walls. With some modifications, this major issue should be reduced considerably, although not removed completely. In discussions with the manufacturer, repair periods for these cases are in the vicinity of 2-3 days, if the necessary tools and spares are available.

Based on the fact that repeated blast damage from mines containing 200gms of explosives over time may considerably reduce the productive time in relation to cost effectiveness, it is advisable to employ the system in the smaller range of mine contaminated areas, where explosive quantities are in the range of 100 – 150gms.

Preceding survey is therefore critical to effective employment of the system, to identify suitable areas in which the system can be applied to maximise efficiency.

Given correct ground and terrain conditions, the system has the ability to perform well within anti-personnel contaminated areas. The system would prove extremely useful, and versatile, in cases where standard clearance methodologies would be rendered ineffective due to high metal contamination, extensive use of minimum metal mine types, deeply buried mines and shifting soil conditions.

This system is highly capable in the activation and neutralisation of anti personnel landmines, if the points raised during the trials are carefully addressed, recommendations incorporated and strict guidelines for the employment of the system are implemented. This coupled with thorough internal and external quality assurance methods, will ensure the system is capable of providing “clear ground”.

John Morrissey
SRSA Project Manager

07 March 2007

2.0 INTRODUCTION

Over the period 29 October – 10 November 2006, SRSA and SWEDEC conducted testing and evaluation on the Volvo L90 Armoured Front End Loader (AFEL) and the ALLU SCH 4-25 Crushing and Screening Bucket.

The tests were conducted using the CWA 15044 Standards as a guideline, with advice and guidance provided by SWEDEC staff on the conduct of the tests implemented.

2.1 SYSTEM DESCRIPTION

2.1.1 Volvo L90 Armoured Front End Loader (AFEL)



The prime mover is based on the standard Volvo L90 front end loader, model BM0000 employed in commercial horizontal construction and earthmoving projects. The Volvo L90 is widely used as a medium lift wheeled unit for the excavation and loading of material.

The Volvo L90 was incorporated into Swedish military service with the Air force, appropriately armoured and employed in a rapid airfield clearance role. Now redundant due to reductions in military forces, the units have now been allocated to SRSA for humanitarian assistance projects globally.

The cabin is fully enclosed, using 15mm armour plate and 44mm laminated protective glass offering the operator maximum protection against the smaller range of explosive ordnance and fragmentation. Additional armour has been placed on the engine bay, undercarriage and hydraulic cylinders. The tyres are foam filled and resistance to small explosive blasts. Total machine weight is 18 tonnes.

The Volvo L90 is a versatile platform on which a variety of accessories and tools can be mounted.

2.1.2 ALLU SCH 4-25 Crushing and Screening Bucket

The ALLU SCH 4-25 crushing and screening bucket is specifically designed to process materials by physically crushing then screening material to pre set sizes.

Earlier variants of this system have been widely used in the commercial sector, particularly on waste management sites for the mulching and separation of waste material. The buckets are required to excavate stockpiled material, and physically process the material crushing larger items and screening material to a set size. Material that cannot be physically crushed remains inside the bucket and is then piled separately to the screened material.



In contrast to previous variants, the ALLU SCH 4-25 bucket employs a specially designed drum configuration, where the spacing interval has been considerably reduced to a set size of 23mm x 48mm. This was based on recommendations made to the manufacturer, explaining some of the likely difficulties experienced when working landmine and UXO contaminated areas.

The ALLU SCH 4-25 bucket uses four specially modified drums, seated in a standard SCH 4 series bucket. The drums are hydraulically powered by the prime mover, to a single hydraulic pump fitted in the top centre of the bucket. The hydraulic motor then drives a set of chains mounted on each side of the bucket which are linked to each drum respectively.



The screening set size is based on a unique drum design, where hardened discs are placed on a solid steel shaft, at intervals of 35mm. Blades and blade holders are then welded into position between each set of discs. The combination of disc spacing and blade position prevent any object greater than the set size of 28mm x 48mm passing through.

The bucket weighs a total of 3.4 tonnes and has a maximum capacity of 3.6m³.

2.2 **SYSTEM CONCEPT and SCOPE**

Ideally suited to excavation tasks, the Volvo L90 fitted with specific tool arrangements, can be employed in landmine clearance activities, effectively reducing the landmine threat and increasing manual production rates.

The original concept of loaders is designed around a suitably armoured unit, fitted with standard buckets. This system is then required to excavate ground, physically lifting and moving it to another cordoned area for inspection by deminers. Deminers would then thoroughly search the spoil for any landmine or UXO threats, disposing of them accordingly. Once the ground was declared free of contaminants, the soil would then be repositioned in its original state.

This concept of excavating ground is still very viable, and plays an important role in cases of deep buried mines, or in conditions that effectively render electronic detection systems redundant. However, this concept could be enhanced by the introduction of specially designed tools that could process the soil and possible threats, effectively reducing risk and considerably reducing the time for manual follow up.

This test and evaluation report investigates effectiveness of a system, where a specially designed bucket, manufactured for the purpose of processing soil, is fitted to a standard armoured front end loader.

The tests are designed to assess the performance of the bucket, the front end loader, and the system as a whole. Full excavation processes are a proven work methodology, but the concept can be enhanced effectively by increasing productivity while reducing the threat to searching deminers.

The main target is to reduce the manual follow up time, by using a suitable working tool to process ground, and activate or neutralise anti personnel landmines. This could be conducted at any stage during the operation, either within the contaminated area immediately, or through the accepted practice of moving soil to a processing/inspection area.

The trials do not cover a concept of application, but instead study the viability of enhancing an already employed method.

2.3 **TEST and EVALUATION OBJECTIVES**

1. To assess the ability of the ALLU SCH 4-25 Crushing and Screening bucket to process soil and anti-personnel blast mines,
 2. To determine the effectiveness of the ALLU SCH bucket to trigger (activate) or mechanically neutralise anti-personnel landmines,
 3. To assess the ability of the ALLU SCH bucket fitted to the L90 AFEL, in the excavation process,
-

4. To identify durability levels of the ALLU SCH bucket through the detonation of live explosive charges, and
5. To assess the Volvo L90 AFEL as an operating platform.

2.4 TEST CONDUCT

The Tests and Evaluations were conducted at the Norra Kul testing grounds, SWEDEC, in Eksjö, Sweden.

To achieve the objectives, which are expansive in their nature, it was decided to conduct the trials in stages, by focusing on various aspects of the Volvo L90 and the ALLU SCH 4-25 bucket separately. The original trials plan identified a need for four (4) Stages in total, divided into the following categories:

a. Stage 1 – Function Test

The function test was orientated solely towards assessment of the ALLU SCH 4-25 bucket, to determine its ability to process soil and anti-personnel landmines.

Stage 1 consisted of 32 separate serials in total, divided over the three soil conditions specified in CWA 15044. The first 3 serials provided details on soil processing performance only, followed by the remaining serials which all involved surrogate anti-personnel mines.

Secondary assessments include the monitoring of Volvo L90 performance related issues such as:

- i) Operator Perspectives
- ii) Stability
- iii) Balance
- iv) Power

b. Stage 2 – Excavation Assessments

This stage focused on the L90 AFEL fitted with the ALLU SCH 4-25 bucket in an actual excavation role, in the three soil conditions mentioned above. This stage has been divided into two separate components, Phase 1 consisting of excavation assessments in controlled soil lanes, followed by Phase 2 which was excavation in a more natural environment, containing anti-personnel surrogates and light vegetation.

The Phase 1 lanes were established using surrogate anti personnel mine as test targets. The L90 AFEL will be required to excavate the lane, removing the excavated soil to a processing area parallel with the lane, and process the soil and anti-personnel surrogates.

Each lane was 7m in length, containing 10 surrogate anti-personnel mines, using a 2m approach, and a 1m end zone, making total lane length 10m.

Five (5) evaluations were conducted in each of the three soil conditions.



Completion of lane setup for Serial 1B Sand

All positions and depths of laid surrogate mines were recorded

Phase 2 involved an area of natural ground containing 25 surrogate anti-personnel mines. The AFEL with ALLU bucket was required to excavate the area, set at 20m by 20m, remove the soil to a processing area, and process the soil.

Test target depth settings for all serials have been restricted to 20cm maximum, positioned randomly. Phase 1 surrogate mines were laid in a ratio of 3 mines at 0cm, 3 mines at 10cm and 4 mines at 20 cm. Phase 2 surrogate mines were laid in a ratio of 10 mines at 0cm, 10 mines at 10cm and 5 mines at 20cm.

c. Stage 3 Live Mine Excavation Assessment and Bucket Survivability

This stage focused on the ALLU Bucket and its ability to excavate and process live anti-personnel mines, assessing the damage sustained from any detonations.

This stage was divided into two phases. Phase 1 consisted of 12 live individual anti-personnel mines, placed in a cordoned area at ground level. The L90 AFEL, with ALLU bucket was required to firstly excavate, and then process the soil.

A total of four serials were planned for each soil category.



Setup photos for the conduct of live mines excavation and processing.

Phase 2 was a deliberate exercise to determine if the drums could withstand an anti-personnel mine blast directly. Three serials were planned for this phase, using an M49 anti personnel mine as the main charge. The first charge was placed centrally on the centre drum, the second charge on the bearing seat, right side, and the third charge on the bearing seat, left side.

d. Stage 4 Natural Ground Excavation Assessment

This stage involved the L90 AFEL fitted with a standard bucket in an excavation role. The objective was to assess the L90 in a standard working environment to assess performance criteria of the L90 AFEL.

The area allocated was to be a minimum of 1600m² of natural ground covered with light to medium vegetation levels, free of any test targets. The L90 was required to treat the area as if “suspected”, employing the standard concept of operations for large scale excavation tasks.

The exercise would have permitted assessment of the performance of the Volvo L90, providing an insight to the application of the machine, employment methods and performance data related to productivity, limitations, restrictions, fuel consumption etc.

The test and evaluation period allocated proved to be untimely, with the weather conditions proving to be the biggest obstacle to completion. Unfortunately, weather and time constraints forced various reviews of the planned trial content. On completion of the trials, a total of 9 serials from stages 1 and 2 had been cancelled, all involving Top Soil ground conditions.

Live mines testing in Top Soil ground conditions was reviewed, and for safety reasons, the Top Soil serials were cancelled and additional serials were added to Sand and Gravel ground conditions.

Stage 4 was removed completely, so efforts could be focused on the performance of the ALLU bucket and L90 AFEL.

2.4.1 Testing Staff

Maj Göran Danielsson	SWEDEC
Kn Patrik Blomander	Göta Engineers
Lt Tommy Karlsson	Göta Engineers
Kn Lars Andersson	Göta Engineers
John Morrissey	SRSA Project Manager
Jörgen Jarälv	SRSA Assistant/Operator
Anders Johansson	SRSA Assistant/Operator

2.4.2 Weather Conditions

Heavy rain the week prior to the trials left the ground soaked. Drainage in the sand and gravel lanes was reasonably good, although large standing pools of water had formed in a number of areas. The Top Soil lane was completely saturated, and doubts increased as to the viability of conducting Top Soil evaluations.

SWEDEC staff attempted to drain the lanes using a plough to redirect surface water. However this was not as effective as hoped. Overnight temperatures on 31 October and 01 November dropped below zero, reaching -12°C , freezing saturated ground, creating a 10 – 15cm layer of thermo frost.

A summary of daily weather conditions is specified in the table below.

Day	Serials Conducted	Temperature	Weather	Comments
Stage 1 – Function Test Evaluations				
30 Oct 06	Serials 1A – F	4°C	Overcast, dry	
31 Oct 06	Serials 1G – I, 2A, 2B, 3A – 3F	4°C to 10°C	Overcast, dry in morning, turning to rain midday.	Serials 2C and 3G – I were postponed.
01 Nov 06	Serials 4A and B	-6°C	Snow, very windy	Ground conditions frozen. All Serials postponed.
02 Nov 06	Serials 4D – H	-2°C to -3°C	Clear	Used Top Soil pile
03 Nov 06	Serials 4C, 4I – K	-1°C	Clear	
Stage 2 Phase 1 – Excavation Evaluations				
06 Nov 06	Serial 1A			
07 Nov 06	Serials 1B – E	9°C to 10°C	Overcast	
08 Nov 06	Serials 2A and B	8°C to 9°C	Overcast	
09 Nov 06	Serials 2C – E	8°C to 9°C	Clear	
Stage 3 Phase 1 – Live Mine Testing				
08 Nov 06	Serials 1A – F, 2A – F	9°C	Overcast	
Stage 3 Phase 2 – Live Mine Testing				
10 Nov 06	Serials 1A and B	-2°C	Clear	

On 31 October, very wet ground conditions during the conduct of Top Soil serials 1G - 1I forced postponement of the remaining Top Soil evaluations, serials 2C, 3G to I. The machine was very unstable, sinking heavily and risked being bogged. Additionally, the hydraulic pressure within the system struggled to deal with the dense, wet material. Sudden drops in hydraulic pressure stalled the drum rotation, halting soil processing and flow.

Alternative Top Soil options were investigated, and it was decided to use a pile of Top Soil, consistently similar in composition to that placed in the testing lane, instead of using the lane directly due to safety issues mentioned above. It was also agreed that the pile would suit the function tests as only the performance of the bucket was being assessed, and not the action of excavation. Serials 4G – I were completed using this Top Soil pile

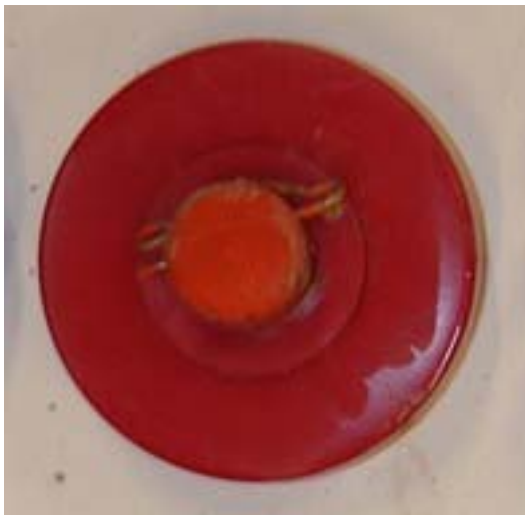
Unfortunately due to other climatic extremes, delays in conducting serials, and time constraints, Top Soil serials 2C, 3G – I were eventually cancelled, as were all Top Soil serials plotted in Stage 2 Phase 1 and Stage 3 Phase 1. It was agreed, for safety reasons, that it was not advisable to search for possible damaged fuses in wet, saturated Top Soil conditions.

Time constraints also prevented completion of Stage 2 Phase 2, and Stage 4 in its entirety.

2.4.3 Test Targets

Test targets used comprised of both surrogate anti-personnel mines and live anti-personnel blast mines.

The surrogate anti personnel mines were representative of small anti-personnel blast mines, very similar in size, shape and weight to the FYR PMA2. The surrogate mine consisted of a plastic circular body, filled with plaster, and contained a fuse well sized to house the M49 anti-personnel mine pressure fuse. The M49 fuse operates with a spring actuated ignitor principle, with a pressure plate area of 21mm diameter.



Top view of a surrogate anti-personnel mine armed with a M49 anti-personnel mine fuse.

Dimensions:	Diameter	68mm
	Height (no fuse)	32mm
	Height (with fuse)	52mm
	Weight (with fuse)	140gms

Live mines used during Stage 3 of the tests and evaluations were restricted to anti-personnel blast categories only, using the Swedish M49 Anti-personnel blast and Swedish #10 Anti-personnel blast mines.

Both mine types were selected due to slight differences in actuation and explosive charge weight. The M49 uses an external pressure fuse described in the surrogate mines section, offering a very small surface area on which the ALLU drums will be required to initiate.

Whereas the #10 anti-personnel blast mine uses an integral pressure fuse, with a much larger pressure plate area. Very similar to Type 72 AP or the larger PMN range.

It was felt that anti-personnel blast mines with different surface areas would react differently during the soil processing phases.



Anti- personnel Mine M49 Blast
 Diameter 75mm
 Height (no fuse) 33mm
 Height (with fuse) 53mm
 Explosives 180gms



Anti-personnel Mine #10 Blast
 Diameter 81mm
 Height 34mm
 Explosives 120gms

Due to the larger explosive weight of the M49, only these test targets were used during Stage 3 Phase 2, where explosives were detonated in pre-determined positions on the drums.

TEST DATA, RESULTS and FINDINGS

3.1 ALLU SCH 4-25 Function Testing MINES Data

Detailed below are the results from tests conducted during Stages 1, 2 and 3. This section covers specific information related to the processing of surrogate and live anti-personnel mines.

Information relating to performance issues are specified in the relevant section.

The tables in this section are summaries only, for all serials within a given soil category. Details for each serial conducted can be found in Annexes A, B and C.

During the initial stages of the trials, it was rapidly realised that AP mine fuses would still pose a possible threat. As a result, fuse data was recorded separately to the mines data. Refer to the relevant section for results identified during the recording of data for fuses.

3.1.1 Stage 1 Function Test SAND

Ser.	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
9	Simulation AP	42	8	30	0	4

RESULTS	42	8	30	0	4
		19%	71%	0%	10%

The serials conducted in sand soil conditions resulted in a 90% mine destruction rate. Offset by 10% of the total mines being confirmed as “live”. No examples of damaged live mines were recorded.



An example of surrogate AP mines after processing through the bucket. All targets have either been triggered or mechanically neutralised. Fuse states can also be identified.

Photo of surrogate mine results from Stage 1 Function Test Serial 4/C Sand

The “live” mines found during serials 4/A and 4/B were the result of some extraordinary circumstances. Overnight temperatures dropped to below -12°C , with day temperatures recorded as -6°C for each serial. On completion of serial 4/A, surrogate AP mines #1 and 2 were found in the bucket, approximately in the same position as laid. Note that these two

targets were placed on the base of the bucket prior to filling. When this point was identified, it was decided to run the bucket processing time in serial 4/B longer, in total 1:13:45, as opposed to the 12.5 seconds in serial 4/A, in the hope that a longer processing time would eventually shift and process the test targets. Interestingly enough, targets #1 and 2 were found in the same state.

View of fused surrogate AP mine frozen in place on the bucket base. In total 4 mines were found frozen inside the bucket during serials 4/A and 4/B.



When excluding extreme weather conditions, the only other possible cause identified for “resting” mines was the counter blade, where mines are shifted through the action of the rotating drum. Items which are caught in this area of the drum may be held there through the sharp angles. As no further cases of “resting” mines were found, this particular idea could not be credited or discredited.

Due to the extreme weather conditions encountered during Serials 4/A and 4/B, an additional two Serials, 4/J and 4/K, were conducted in sand soil conditions, totalling 9 serials in all for this condition.

Further evaluations were postponed pending more favourable conditions. Testing recommenced the next day using gravel soil conditions, and continued evaluations in sand soil conditions did not recommence until two full days had passed.

3.1.2 Stage 1 Function Test GRAVEL

Ser.	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
7	Simulation AP	30	10	20	0	0

RESULTS	30	33%	67%	0%	0%
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Photo of surrogate mine results from Stage 1 Function Test Serial 4/D Gravel

Compared to sand soil conditions, the quantity of surrogate AP mines mechanically triggered was significantly higher. All mines actually processed were mechanically triggered or mechanically neutralised. One surrogate mine was found to still contain a large quantity of simulation explosives and has been recorded as containing over 50% explosive, and mechanically neutralised.

Total number of test targets was 40% less than sand conditions. Reasons are unclear why the mechanically triggered results were vastly improved compared to sand soil conditions. One possibility could be that the coarser material in the bucket leads to a higher detonation rate

It is also noted that no cases of “frozen mines” were recorded during the conduct of serials 4/D, E and F were only slightly warmer and still below zero degrees, recorded between -2°C and -3°C . The bucket processing time was not increased, maintaining an average of 24 seconds per bucket load. However, the bucket was shaken, by tilting forward slightly then sharply back, during the processing action to hopefully free any potential surrogate mines that may have frozen into position. Bucket tilting was combined with a more frequent alternation of drum rotation, which proved quite helpful in assisting soil flow and reduced soil build up above the drums.

Differences in the processing efficiency between sand and gravel conditions cannot be unambiguously assigned to either the difference in soil texture or the effects of the enhanced shaking action.

3.1.3 Stage 1 Function Test TOP SOIL

Ser.	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
3	Simulation AP	18	3	15	0	0

RESULTS	18	17%	83%	0%	0%
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Unfortunately weather prevented completion of all serials planned for Top Soil evaluations, and the evaluations that were completed only managed to covered 3 serials using fused surrogate anti-personnel mines.

The results proved to be very positive, with all mines either mechanically triggered or mechanically neutralised. This clearly indicates that all items did not survive the crushing action of the drums.

3.1.4 General Summary – Function Testing

The results clearly show that any anti-personnel mine processed by the drums was either mechanically triggered or mechanically neutralised.

No records were made of Live or Live Damage mines passing through the system. Four mines were, however, recorded as Live, frozen in position on the base of the bucket due to harsh

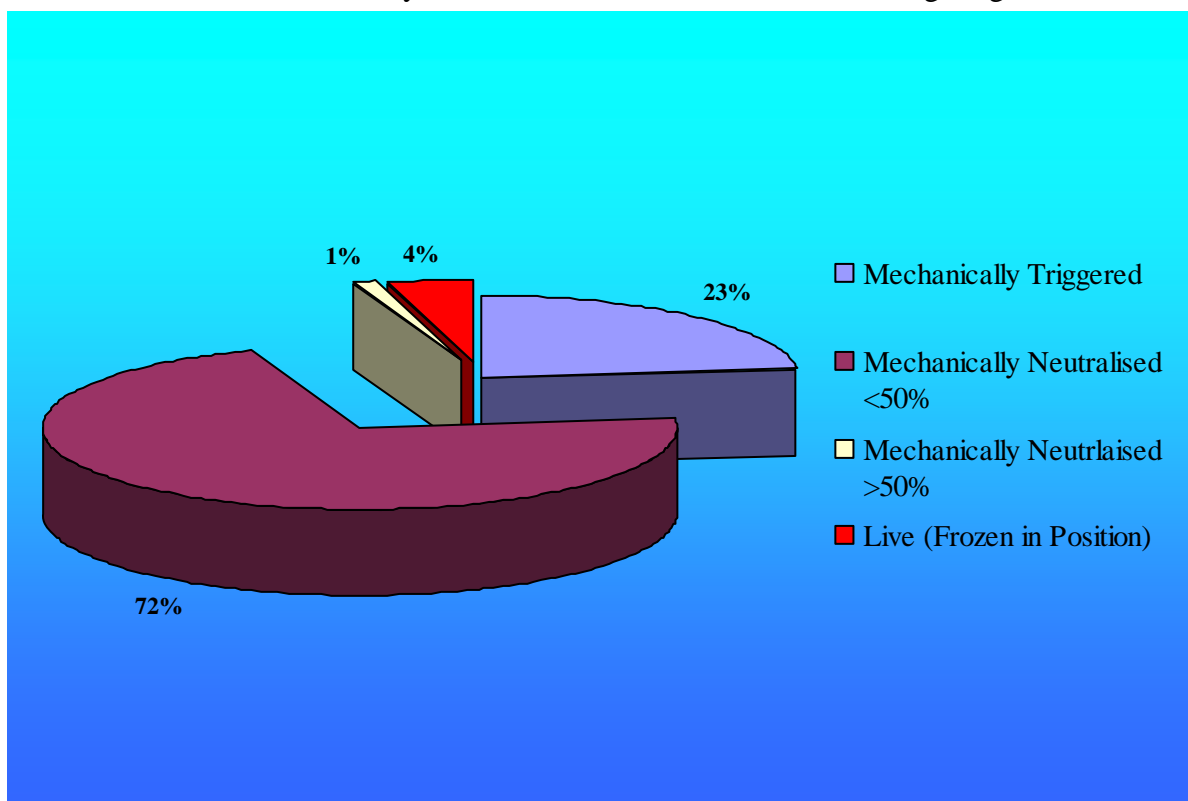
weather conditions. An additional two serials were conducted to counter this occurrence, and on both occasions all mines were mechanically triggered or mechanically neutralised.

The case of mines frozen in position in the bucket is exceptional. However, in an operational sense these items would have either been processed at some stage during the working period, or would have been found during any inspection process when the machine was required to exit the contaminated area.

An increase in mechanical triggered items in gravel soil was noted. It is assumed that coarser material creates a higher detonation rate. However, this assumption needs to be verified with further tests in higher aggregate soils.

Overall the results show a high efficiency and reliability in mine elimination, although not all serials in Top Soil ground conditions could be conducted. Therefore these positive results primarily reflect Sand and Gravel soil conditions and only provide an indication of how the system could perform in top soil ground conditions.

Statistical Summary of Mines Results from Function Testing Stage 1



Although the residual threat of fuses remains, the action of the bucket lowers the risk factor dramatically. Demining staff can be confident in the fact that complete, intact anti personnel blast mines will not be found in processed soil.

Test Data for fuses are covered separately within this test report

3.1.5 Stage 2 Phase 1 Excavation Test SAND

Ser.	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
5	Simulation AP	50	8	34	0	8

RESULTS	50	16%	68%	0%	16%
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3.1.6 Stage 2 Phase 1 Excavation Test GRAVEL

Ser.	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
5	Simulation AP	50	24	21	0	5

RESULTS	50	48%	42%	0%	10%
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View of lane excavation nearing completion

Various difficulties were identified during the conduct of the trials, mainly related to excavation techniques. These points are explained in the ALLU SCH 4-25 performance section of this report, whereas this section focuses on the results of the mines data.

Complying with the results noted in Stage 1 testing, all mines that were physically collected during the excavation were processed through the drums and recorded as mechanically triggered or mechanically neutralised. However, this formed only 87% of the total test targets used.

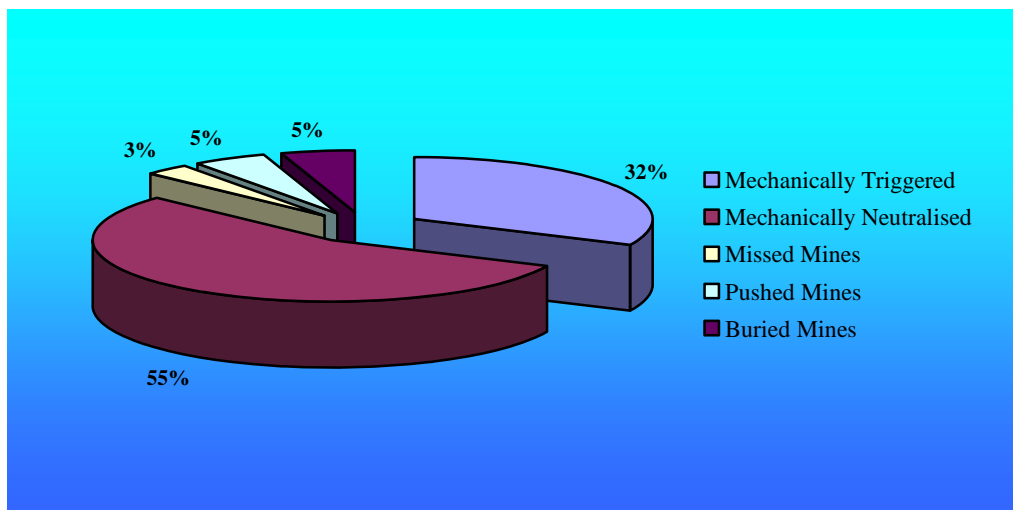
The remaining items, accounting for 13% of the total test targets, were mines that were missed, buried or pushed through the action of excavation. Therefore, from these results we can conclude that the bucket functioned correctly, achieving an excellent activation rate and it's the action of excavating that causes shortfalls in the overall results. Key points for correction of future work methods were identified and are described in sections 6.1 and 7.1.

As observed in Stage 1 testing, a marked increase in triggered items was recorded in gravel soil conditions. This is again attributed to a coarser material increasing the efficiency of the bucket.

Only one item was recorded as thrown from the bucket during soil processing actions, being a top plate which had visual signs of detonation.

As explained earlier in this report, all serials – 5 in total – in Top Soil conditions were removed from the program due to weather conditions and safety reasons.

Statistical Summary of Mines Results from Stage 2 Phase 1



Various test targets during Stage 2 testing were recorded as either missed, buried or pushed during excavation evaluations (refer to above graph). These cases are related to performance data and details on these test targets are described in section 6.1 ALLU SCH 4-25 Performance Results.

3.1.7 Stage 3 Phase 1 Live Mines Testing SAND

Ser.	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
3	Live – Fused M49 AP	3	2	1	0	0
3	Live – Fused #10 AP	3	3	0	0	0

RESULTS	6	83%	17%	0%	0%
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3.1.8 Stage 3 Phase 1 Live Mines Testing GRAVEL

Ser.	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
3	Live – Fused M49 AP	3	2	1	0	0
3	Live – Fused #10 AP	3	3	0	0	0

RESULTS	6	83%	17%	0%	0%
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Although a very low number of targets were used, the overall results were extremely positive, with the bucket achieving 83% in activating the mines. The remaining two items were mechanically neutralised during processing.

This view shows the mechanically neutralised M49 Anti Personnel mine. The fuse, still intact, can be identified next to the large piece of explosives.

Photo from Stage 3 Phase 1 Serial 1B

As expected, mines offering a larger pressure plate area, the #10s, were all detonated. The M49, which has a very small fuse pressure plate area were more difficult to detonate, accordingly registering two items as mechanically neutralised.

The third set of tests, involving Top Soil ground conditions, was removed from the program. Due to weather and ground conditions it was decided, for safety reasons, not to complete Live Mine testing using Top Soil ground conditions.

4.1 ALLU SCH 4-25 Function Testing FUSE Data

As explained earlier, mine fuses have proven to be a residual threat. A relatively high number of fuses managed to pass through the drum screening size of 23mm by 48mm during the trials. The fuses are found in various states, including full live units completely untouched, and a high number of units are damaged by the rotating drums, but are still functional.

As for mines, the fuses were divided into four categories:

- | | | |
|----|--------------------------|--|
| a. | Mechanically Triggered | Activated Fuses |
| b. | Mechanically Neutralised | Detonator separated from Fuse Assembly |
| c. | Live Damage | Fuse intact, but impacted by the drums |
| d. | Live | Complete fuses, untouched |

Fuses recorded as “Live Damage” were individually tested on completion of the trials. All these fuses functioned correctly.

Detailed below are the results from tests conducted during Stages 1, 2 and 3. This section covers specific information related to the processing of fuses for surrogate and live anti-personnel mines.

Information relating to performance issues is specified in the relevant section.

The tables in this section are summaries only, for all serials within a given soil category. Details for each serial conducted can be found in Annex D

4.1.1 Stage 1 Function Test SAND

Ser.	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
8	Simulation AP – Fused	39	21	9	1	8
RESULTS		39	54%	23%	3%	20%

4.1.2 Stage 1 Function Test GRAVEL

Ser	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
6	Simulation AP – Fused	27	19	5	0	3
RESULTS		27	70%	19%	0%	11%

4.1.3 Stage 1 Function Test TOP SOIL

Ser.	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
3	Simulation AP – Fused	18	11	3	0	4
RESULTS		18	61%	17%	0%	22%

Initial evaluations during stage 1 proved to be quite positive, where records show that the crushing effects of the drums managed to activate or neutralise slightly less 81% of all fuses, indicating a residual threat of 19% remaining.

One fuse during Serials 4/G and 4/I respectively could not be found. This accounts for the 11% discrepancy in the results for Top Soil conditions. We have therefore assumed that they are live items and recorded them as such.

4.1.4 Stage 2 Phase 1 SAND

Ser.	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
5	Simulation AP – Fused	50	33	3	6	8

RESULTS	50	66%	6%	12%	16%
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4.1.5 Stage 2 Phase 1 GRAVEL

Ser.	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
5	Simulation AP – Fused	50	36	5	0	9

RESULTS	50	72%	10%	0%	18%
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4.1.6 Stage 3 Phase 1 Live Mine Testing SAND

Ser.	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
3	Live – Fused M49 AP	3	2	0	0	1
3	Live – Fused #10 AP	3	3	0	0	0

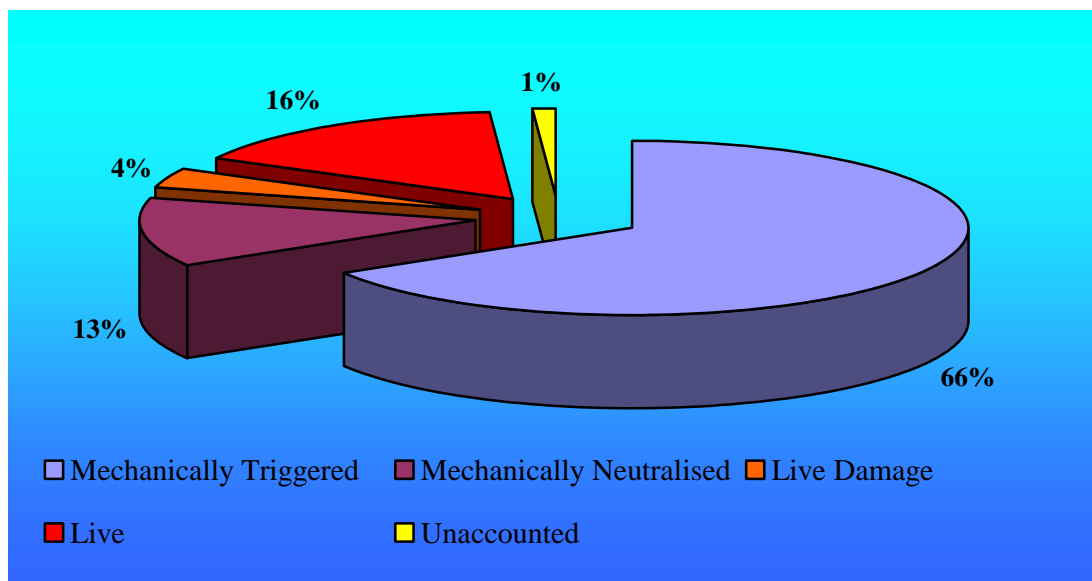
RESULTS	6	83%	0%	0%	17%
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4.1.7 Stage 3 Phase 1 Live Mine Testing GRAVEL

Ser.	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
3	Live – Fused M49 AP	3	2	0	0	1
3	Live – Fused #10 AP	3	3	0	0	0

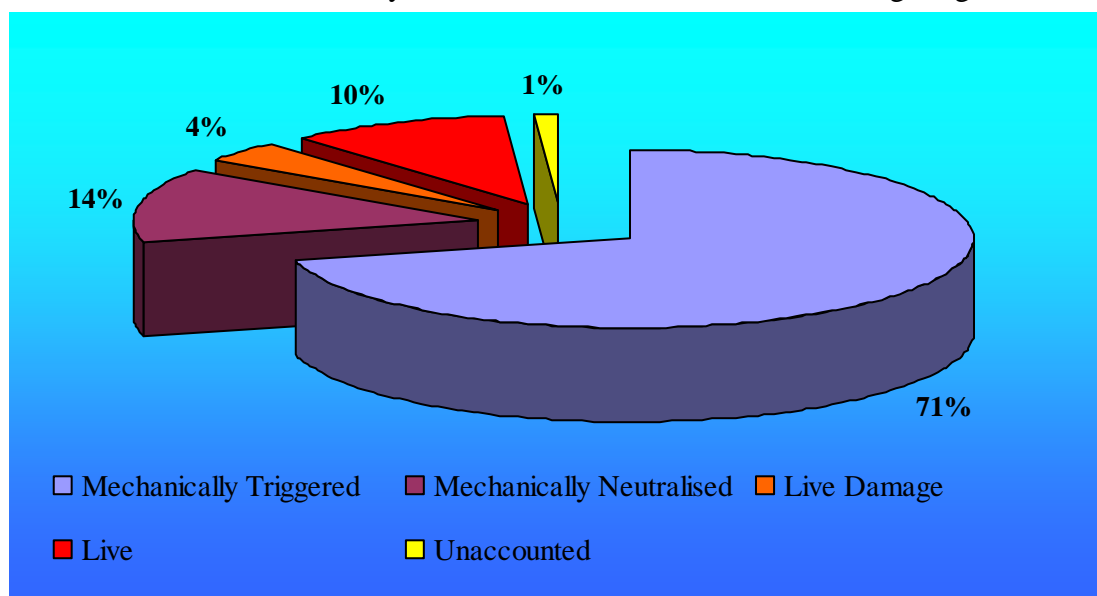
RESULTS	6	83%	0%	0%	17%
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Statistical Summary of Fuse Results from Function Testing Stages 1, 2 and 3



Note: If we were to remove the missed, pushed or buried mines, which actually account for 6.5% of all fuses, from the calculations and assume that excavations were completed correctly. By only focusing on processed fuses, then the percentage of activated fuses rises dramatically.

Theoretical Statistical Summary of Fuse Results from Function Testing Stages 1, 2 and 3



Therefore, we could safely assume that 71% of all fuses processed through the system will be activated, and 14% will be mechanically neutralised, achieving an overall rate of 85%.

The results overall were quite positive, and yes it is understood that insufficient test targets were used to compile solid statistical values, however, the system has indicated a solid ability to activate and neutralise a high percentage of anti-personnel mines and fuses.

Again, the highest percentage of fuses activated or neutralised was registered in gravel soil conditions.

RECOMMENDATIONS

Due to evidence obtained during the trials for fuses passing through the drums, a measure to counter this action would be to reduce the screening set size of 23mm x 28mm. However, this is not an as it would affect soil flow rates Fuses passing through the system are therefore unavoidable and will need to be addressed correctly in enhanced follow up procedures.

Therefore the following recommendations are made:

- a. Follow up methods will need to form an integral component of any standard operating procedure,*
- b. Manual follow up teams can be integrated with the mechanical system to conduct visual, with rakes or hand shovels, or through electronic detection search of processed soils,*
- c. Should ground conditions prevent effective electronic detector follow up, then manual methods can be considered, however it may be more efficient to incorporate additional mechanical systems such as magnets or sifters using a finer screening size.*

5.1 ALLU SCH 4-25 Survivability Testing

Stage 3 focused on using the ALLU SCH 4-25 bucket in more realistic excavation conditions, with the implementation of live test targets. Additional to data recorded in previous stages 1 and 2; these tests were performed to evaluate the effects of detonating anti-personnel mines.

The first phase involved singular anti-personnel blast mines, laid at surface level in sand and gravel soil conditions. Phase two comprised of the deliberate placement of explosive charges on the drums.

These tests by no means cover all possibilities, however, they do investigate the action of the system when an anti-personnel mine is detonated inside the bucket during soil processing activities, identifying potential damages that could be sustained, the nature of the damages and possible repair periods.

5.1.1 Stage 3 Phase 1 Live Mine Testing

A total of 12 individual test targets were used during this stage. Results from these tests are detailed in Section 2.1

A total of 10 detonations were recorded, four with the M49 and 6 with #10 anti-personnel mines. This section examines the effects of those detonations.



This photo shows the detonation of an M49 on the top drum. Damage to the drum was negligible. A gouge in the bucket frame was noted, yet evidence of cracked or chipped discs could be found. It was assumed that the metal washer fitted to the mine as a safe guard was the cause.

Photo of Serial 1A – M49

The photos below show the effects of a M49 detonation on the bucket base, initiated most likely through the action of the rotating lower drum. The detonation removed a section of the lower counter blade, and caused slight deformation of the bucket base. No damage to the drum was noted.



Photo of Serial 2A – M49





These photos show minor damages sustained when a M49 was wedged between two discs. The detonation forced the discs apart slightly, increasing the interval too 42mm, 7mm greater than the norm.



The drums have proven to be manufactured in such a way to withstand multiple blasts, sustaining very minor damage overall. The slight separation of the discs during serial 1C highlighted the possibility that a mine could end up sideways, wedged between discs. The fact that it detonated is positive and underlines the reliability of the drum crushing action.

The damage caused by the detonation can be rapidly repaired by heating and bending the discs back in position. Even if not repaired immediately the discs naturally adjusted their position to accommodate the blade rotation, although not to the 35mm standard. This was observed as tests were continued.

Damages sustained to the counter blade are more concerning, as the gap created can be sufficient to allow a full mine to pass unheeded. Although no cases were recorded, should the system continue operation, mines can pass through the system. If such damage is found during a standard inspection period, it would cast doubts on the processed soil done previously.

Most notable was the fact that M49 created the most serious forms of damage, due to the explosive charge weight, as opposed to the #10s where no physical damages were recorded. Although the difference in charge weight between the two mines is minimal, the difference in damages is substantial.

In all cases, the cause for detonation has been attributed to the action of the rotating drums, and not caused through the action of soil compression or movement. This would indicate that during operational works, the drums will be subjected to a high rate of detonations.

5.1.2 Stage 3 Phase 2 Live Blast Testing

In addition to live testing conducted during Stage 3 Phase 1, M49 anti-personnel mine targets were used as explosive charges. The charges were placed in strategic locations to determine the amount of damage the drums, and bucket, could withstand.



Damage from the blast directly on the discs was minimal, causing slight deformation of the disc edges and cracking a hardened blade.



Serial 1A complied directly with previous test conducted during Stage 3 Phase 1, where the damage from a detonation directly on the drum centre caused minor deformation to the discs and fractured a blade

No evidence of damage could be found in the shaft bearings, bearing housings or bearing seats. The bucket was still operational.

In the second serial the charge was placed deliberately on the bearing, housing and seat, with the express intention to damage the bearing, and quite possibly the bearing seat and housing.

Surprisingly, the bearing, the bearing seat, mount and housing all survived the blast. In fact no physical damage to the bearing assembly could be identified. The hardened discs sustained minor damage consistent with previous tests, losing a blade and holder.

However, quite unexpectedly the blast destroyed the chain drive wall housing, cutting through the plate exposing the internal chain cavity and lubricant.



The blast physically cut through the housing wall, exposing the inner chain drive mechanism and lubricant.

This serial clearly uncovered a major weakness within the system, the chain drive wall, while at the same time the bearing, bearing seat and housing withstood the blast reasonably well.

The damage done during Serial 1B was substantial. The situation of a bearing seat detonation can be considered as worst case with a very low possibility to occur. When considering the physical action of the drum rotation, which is designed to push or pull collected material towards the centre of the bucket during soil processing, the possibility of such a detonation is relatively low.

Due to the damage sustained in Serial 1B, it was decided to cancel the third test, as it was agreed Serial 1B had shown sufficient evidence as to what level of damage would be caused from a bearing seat detonation.

The limited number of mines used during the trial, totalling 14 in all, does not quantify the full success of the drums to withstand a full day of operations. However, the tests show the drums

ability to withstand 200gm detonations and suffer relatively lightly. Damages from detonations are of a kind that the majority of repairs overall are minor, and can be conducted in the field.

RECOMMENDATIONS

- a. *Any operational deployment should consider a comprehensive spares package to support the system. As a minimum it is recommended that at least one spare drum and a suitable quantity of blades, blade holders and discs are held in reserve.*
- b. *During the initial stages of an operational deployment, a qualified mechanic who has received training on the ALLU buckets construction should also form part of the team structure.*
- c. *The system should be supported by a comprehensive support and maintenance unit. This should include welders, generators, gas torches and the necessary hand tools to conduct “in the field” repairs and maintenance.*
- d. *The manufacturer should consider the following modifications:*
 - i) *Reinforcement of the chain drive internal housing wall. The material was identified as mild steel plate, 6mm in thickness. By reinforcing the wall, firstly by increasing plate thickness, or through the addition of hardened steel plate.*
 - ii) *If reinforcement of the chain drive wall is not practical, then options including placement of angled hardened plate needs to be investigated. This angled plate, positioned correctly will direct mines away from the wall into the drums, or in the case of a detonation, actually receive the blast effectively reducing damage sustained.*
 - iii) *Modification to the existing counter blade design. An angled durable steel insert, either placed in front of the existing counter blade, or redesigned to this configuration, would effectively guide items into the drums and subsequent crushing action. This may also reinforce the bucket base and reduce the amount of deformation caused. Reinforcement of the counter blade mount and counter blade bolting points is also recommended.*

Note: Modification of the counter blade to incorporate an angle, say 45[°], may also remove the problem of mines “sitting”, where the soil and blade possibly hold the mines in this position. This may counter occurrences experienced in Serials 4A and B during the Function testing.

- e. *On opening the chain drive side cover, heavy duty lubricant was identified inside the drive housing. It is recommended that 1" to 1.5" drain plugs are fitted on the rear of each housing which can be used to drain lubricant from the housing prior to opening the side covers.*

- f. *Operationally, it is advised to limit employment of this system to the smaller range of anti-personnel minefields. Particularly if large quantities of mines are expected. Although the system has shown the ability to withstand multiple blasts, suffering relatively minor damages, the number of detonations in the higher range of 200gms may render the system ineffective, where repair times and spares reduce the cost effectiveness.*

6.1 ALLU SCH 4-25 Performance Results

Various aspects of the bucket performance were monitored during the trials. This includes details on missed, buried or pushed anti-personnel mines, soil processing times, areas excavated, excavation results and profiles.

Stage 2 provided some valuable information on the performance of the ALLU bucket and L90 AFEL with respect to excavation methodology. Points identified during this stage are explained in detail in this section

6.1.1 Missed, Pushed and Buried Surrogate Anti-personnel Mines

The results for missed, buried and pushed mines are specified in the following sub paragraphs.

a. Missed Surrogate AP Mines

During the conduct of the Stage 2 Phase 1 serials, a total of 5 AP Surrogate Mines were recorded as “missed”. Details of the findings are specified in the table below.

Test	Mine No.	Laid Depth	Laid Distance (from 0 position)	Comments
1/A	#1	20cm	1.0m	Completely untouched, still in position laid. Located using detector during verification of lane.
1/B	NIL	N/A	N/A	N/A
1/C	#3	20cm	2.5m	Top of fuse skimmed by bucket, removing fuse top plate. Followed by wheel print over 50% of mine body.
1/D	#10	20cm	6.5m	Completely untouched, still in position laid. Missed when the bucket was raised to relieve pressure.
1/E	NIL	N/A	N/A	N/A
2/A	NIL	N/A	N/A	N/A
2/B	#1	20cm	0.5m	Completely untouched, still in position laid. Located using detector during verification of lane.
2/C	#1	20cm	0.5m	Completely untouched. Located using detector during verification of lane.
2/D	NIL	N/A	N/A	N/A
2/E	NIL	N/A	N/A	N/A

The findings clearly indicate that the majority of missed mines were within the first 2.5m from the commencement point of the contaminated area, all laid at a depth of 20cm.



Photo of missed mine #1 from serial 1/A. Located during the follow up phase using detector.

Most mines were missed due to the failure to achieve the prescribed excavation depth, set at 20cm for the conduct of the trails. Using the lane profiles taken, it is very evident that failure to attain excavation depth results in mines being “missed”.

This excludes serial 1/D where the missed mine was #10, which was the result of raising the bucket too high during the excavation process. The reason for raising the bucket was based on pressure exerted by collected material, forcing the bucket cutting edge deeper, thereby preventing forward progress of the machine



The potential risk of missed mines is clearly visible here.

Photos of mine #3 from serial 1/C



b. Buried Surrogate AP Mines

On a number of occasions, examples of mines being “buried” were identified. Details of buried mines are detailed in the table below.

Test	Mine No.	Laid Depth	Laid Distance (from 0 position)	Distance Moved (from laid position)
1/A	#3	10cm	2.0m	3.25m
1/B – E, 2/A	NIL	N/A	N/A	N/A
2/B	#3	20cm	2.5m	0.1m
	#8	20cm	5.5m	0.75m
2/C - E	NIL	N/A	N/A	N/A

In cases Serial 1A and Serial 2B, target #3, failure to achieve clearance depth has been identified as the causes for buried mines. When studying the profiles, the failure has been attributed to incorrect excavation technique, where the clearance depth was not achieved until a distance of 2.5m after commencement of the excavation area.



Stage 2 Phase 1 Serial 1A

Although the test target in Serial 2B, #3 had not been moved substantially from its laid position, the fact that it was upside down indicated that the bucket had shifted it. The excavation profiles clearly show that at 2.0m, excavation depth was only 18cm. It is highly probable that the excavation was at the same depth, or slightly above, the laid test target position, and through the action of the progressing bucket, pushed, then rolled and buried the test target.

Test target #8 had in fact been collected in the initial excavation, and on withdrawing the machine had fallen into the excavated area. The operator

attempted to collect the target on the final excavation, but instead pushed it deeper, subsequently burying it.

These observations show clearly that operator experience, combined with various factors in relation to visibility, bucket levelling and hydraulic pressure ratings are crucial to determining either a safe or high risk outcome.

c. Pushed Surrogate AP Mines

During the action of excavation, the force of built up soil within the bucket would physically shift mines, pushing them up and forward. Details of pushed mines are detailed in the table below.

Test	Mine No.	Laid Depth	Distance Moved (from laid position)	Comments
1/A	#9	20cm	4.8m	Exposed, rolled forward of spoil heap
1/B	#10	10cm	2.8m	Partially exposed, located in spoil heap
1/C	#6	0cm	4.65m	Exposed, located on spoil heap
1/D	#8	0cm	3.5m	Buried in spoil heap
1/E	NIL	N/A	N/A	N/A
2/A	NIL	N/A	N/A	N/A
2/B	#9	0cm	1.8m	Exposed, rolled forward of spoil heap
2/C	NIL	N/A	N/A	N/A
2/D	NIL	N/A	N/A	N/A
2/E	NIL	N/A	N/A	N/A



This photo shows a surrogate AP mine left in the spoil heap. “Surfing Mines” are very likely and any clearance project would need to incorporate necessary mechanisms to counter these occurrences.

Photo of AP Mine #10, Stage 2 Phase 1 Serial 1B Sand

The principle cause identified for the movement of mines ahead of the bucket was when the bucket reached capacity. Therefore, instead of cutting and digging, the soil inside the bucket would act as a bulldozer blade, pushing soil forward.

No evidence could be identified if depth of mine was a factor for the movement of mines forward and up. However, with continued operation and increased operator experience, cases of mines being pushed forward reduced considerably.

This was achieved through a more cautious approach, correct levelling of the bucket, and by reversing slightly on completion of the excavation, effectively reducing the pressure within the soil, allowing the material to be lifted and tilted into the bucket cavity.

This photo clearly shows the end result when using a controlled, level excavation technique. Note the absence of any spoil heap.

Photo of excavation, Stage 2
Phase 1 Serial 1E Sand



Improved excavation technique may not avoid the problem of missed, pushed and buried mines completely but it will ensure cases of this nature a minimised. Operators and Supervisors will need to consider this operating principle during mechanical excavation operations.

As a conclusion drawn from these observations it is advised that in any case a thorough secondary follow up is conducted on areas bordering completed excavated lanes. This will counter any mines being left in spoil heaps or rolling outside the identified boundaries (marked) of contaminated areas.

[VIDEO HYPERLINK](#)

6.1.2 Excavation Technique

Excavation technique is directly related to comments made in the test data records for missed, buried and pushed anti personnel mines. Throughout the evaluations it became quite evident that it was extremely difficult to maintain a set depth for the bucket.



Photo of excavation from Stage 2 Phase 1 Serial 1D

This photo provides an excellent example of the variety of factors which contribute towards ineffective excavation technique. Faults seen here are related to excavation depth, visibility and levelling.

As the photo above shows, excavation technique was not restricted to a single factor, but a combination of factors, which are detailed here:

a. Levelling

Bucket levelling was originally raised by the operator early, during the initial stages of the evaluations. Principle complaints revolved around the inability to view the forward edge of the bucket. This blind spot prevented effective angling of the bucket.

It was later identified that the standard levelling device fitted on front end loaders was enclosed in armour plating fitted to the hydraulic cylinders. An improvised levelling device was fitted for the duration of the trials. This effectively eased bucket levelling, but did not resolve visibility issues.

b. Visibility

Visibility for the operator plays a minor role in ineffective excavation technique. The operator claimed that identifying bucket position, in relation to the ground level, and angle of bucket on starting the excavation did pose problems.

One specific reason for the above claims was the actual pivot position of the adaptor. On the ALLU buckets, the adaptor plate is extremely high in comparison to standard buckets. This elevated starting point leads to an incorrect assumption on current bucket position.

Other issues identified were related to the distance between the forward edge of the bucket and the machine. Compared to standard bucket this distance is considerably further. This combined with the very high pivot point, which obstructs a clear view of the bucket leading edge makes it very difficult for the operator to determine the exact position of the bucket leading edge.

c. Hydraulic pressure

Hydraulic pressure was identified as a related fault with respect to missed, buried or pushed test targets and details have been included within this section, although hydraulic pressure is associated with Volvo L90 Performance Data,

Two specific issues were identified with the hydraulic pressures, firstly, when operating in very dense wet soils, particularly top soil, drum rotation would stall temporarily, until sufficient pressure could be diverted to the bucket.

Secondly, the hydraulic pressure within the system was insufficient to hold the bucket level. On a number of occasions during the excavation of soil, the buckets level position was compromised when the leading edge bit too deep, where the bucket was then pulled deeper, and the hydraulic rams had insufficient strength to maintain the bucket at the correct height.

This condition forced the operator to stop the forward progress of the AFEL, withdraw the machine slightly to release the pressure build up, then raise the bucket. This action usually resulted in an over correction, where the bucket was raised too high. When combined with visibility issues, the operator was unaware of the new bucket height, and that the depth of excavation was no longer being achieved.

Discussions involved raising the overall pressure of the system within the Volvo L90. This option did not prove to pose a solution, as hydraulic pressures within the L90 were very near to maximum already. It was agreed that raising pressures to maximum may place too much strain on the system.

Another probable cause included the possibility that the bucket was too heavy for the L90. Bucket weight is registered at 3.4 tonnes, with a live load of an estimated 2.4m³. It was found that the L90 could easily raise or lower the bucket, when full, but easily stalled on addition of drum rotation, especially in wet soils.

d. Adaptor Tilt

When the L90 AFEL was expected to process soil on a slight gradient of approximately 5^Å, it was identified that the bucket drums were not level when placed at maximum vertical lift.

Soil processing was unaffected by this slight incline, however it did result in two fuses being found behind the bottom drum, resting on the skirt.



Fuse located on the rear skirt behind the bottom drum.

Photo of Stage 1
Function Testing -
Serial 4E

Excavation profiles were made using a straight edge, and measuring depth of excavation from ground surface level.

RECOMMENDATIONS

The tests showed that excavation is possible with the ALLU system, fitted to the Volvo L90 AFEL. However, a variety of factors affected the quality of these excavations. By rectifying each of the individual points identified, and implementing a strict internal quality assurance process, the quality of excavation can be dramatically improved. Recommendations are:

- a. *Based on manufacturer specifications, it is not advisable to increase the hydraulic pressure ratings within the system. As pressures are already very close to maximum, increasing the pressure would place the system under considerable strain. As we have shown that bucket performance can be affected during excavation or soil processing, it is therefore recommended that the L90 be fitted with a smaller range of bucket. The 3 series buckets weigh 2.6 tonne, and this reduction in forward weight will effectively relieve an overburdened platform.*

Note: 1. A smaller bucket is directly related to L90 stability issues explained in the Section 6.1. The benefits of a smaller bucket are not only limited to points mentioned here.

- b. *The creation of a working face is vital for a successful excavation. Identification of a correct lead distance is paramount in creating this working face. It is not possible to place the lead distance at a set figure, but will be determined by two very important factors:*
 - i) *The clearance depth, and*
 - ii) *A satisfactory gradient on which the prime mover can enter, and exit the contaminated area.*
- c. *Length of excavations should be restricted to a set manageable length, determined by the site, the terrain, vegetation and command and control issues. In the case of these evaluations this was set to a 2m lead distance. In some cases this may have been the primary cause for not achieving excavation depth at the commencement point of the contaminated area.*
- d. *Where contracted excavation depth has not been attained, the operator should withdraw the machine and redo the excavation until depth has been reached. This will prevent cases where the machine “walks” on unprepared ground.*
- e. *Visibility is a key issue in operating the bucket. Although operator skills increase with time and practice, and their judgement on bucket level, angle on excavation and moment when full capacity is reached, will develop, it is recommended to fit a wide angle camera , to assist with these operating skills. The camera should be positioned in such a way that a full open view of the bucket leading edge is provided. Levelling can be enhanced with an adjustable leveller fitted to either of the main hydraulic ram cylinders, visible from the cabin interior.*
- f. *Operationally, operators and supervisors need to ensure that all of the above points are achieved, and maintained. Effective instruction on courses and stringent follow up QA procedures will ensure quality of excavation is maintained.*
- g. *On exiting the working area, the machine and tool inspection procedures should include a complete visual inspection, including the removal of built up soil behind the bottom drum on the skirt. This will ensure that mine and UXO debris are not left lying in this position.*
- h. *It is recommended the manufacturer considers the following modifications:*
 - i) *Modification of the adaptor assembly to lower the pivot point, by lowering the overall adaptor mount by an estimated 200mm, and angling the top pivot point towards the prime mover .*

- ii) *Modification of the rear skirt, either by shortening or by angling it away from the bottom drum to allow soil to move away from the drum more freely.*

Note: 1. The above recommendations for modification may be alleviated if a smaller bucket is used. A three series bucket will naturally lower the pivot point, thereby providing greater vertical lift and tilt, and possibly negate soil resting on the skirt.

6.1.3 Soil Processing Times

During the tests of the ALLU SCH 4-25 Bucket, time to process bucket loads of soil was monitored. Processing times for the three soil conditions are detailed below.

Stage 1 Function Test SAND

Ser.	Volume (m ³)	Average Volume	Processing Time (sec)	Average Time
1/A	2.39	2.03 m ³	13.85	24.3 sec
1/B	2.40		18.23	
1/C	2.49		16.1	
2/A	2.60		12.1	
3/A	2.32		14.45	
3/B	1.80		12.86	
3/C	3.65		12.62	
4/A	0.8		12.45	
4/B	1.2		94.35	
4/C	1.3		33.85	
4/J	1.1		26.43	
4/K	2.3		24.27	

Stage 1 Function Test GRAVEL

Ser.	Volume (m ³)	Average Volume	Processing Time (sec)	Average Time
1/D	2.21	2.077 m ³	12.72	16.89 sec
1/E	2.30		13.73	
1/F	2.42		12.23	
2/B	1.89		18.0	
3/D	2.32		12.42	
3/E	2.27		13.67	
3/F	2.64		14.34	
4/D	1.69		18.67	
4/E	1.47		27.34	
4/F	1.56		25.78	

Stage 1 Function Test TOP SOIL

Ser.	Volume (m ³)	Average Volume	Processing Time (sec)	Average Time
1/G	1.02	1.345 m ³	18.7	25.43 sec
1/H	1.14		21.04	
1/I	1.62		37.46	
4/G	1.50		18.44	
4/H	1.71		37.27	
4/I	1.08		19.67	

Due to climatic conditions, serials 2/C, 3G, H and I were not completed. It was proposed to complete these serials at a latter stage. Unfortunately this was not the case and the serials were removed from the program near completion of the testing period.

Overall, the bucket performed above expectation with respect to soil flow and processing times. Using the heavy duty drum configurations assembled, flow rates were expected to be much slower, because of the screen set size of 23mm x 48mm, which was thought to be restrictive, but necessary,. The results clearly show that this was not the case, achieving a relatively high rate in Sand and Gravel soil conditions of 20.6 seconds for 2.0535m³ of soil.

NOTE: Converted to area, using a contracted depth of 20cm, the system has the potential to excavate 10.27m² every 21 seconds, although this figure cannot be sustained over a whole operation period. The results do indicate the ability to achieve a relatively good processing rate. This would certainly be applicable if standard buckets were employed to conduct the excavations, and the ALLU system was solely employed in soil processing roles.

A marked reduction in capacity was registered for Top Soil, combined with slower processing times. When compared to Sand and Gravel volumes, the bucket effectively achieved 65% of soil volume.

6.1.4 Areas Excavated

Based on soil processing times, the times required to excavate contaminated test lanes during Stage 2 Phase 1 were also recorded.

Times were recorded from commencement of the excavation, to completion of the excavated lane, including travelling from the contaminated area to the processing area, and the processing of soil.

Soil processing areas were placed parallel to the evaluation lanes. The L90 was required to excavate to lane, reverse through the entry point, realign and move to the soil processing area, then continue with excavations. Total turn around distance travelled was 35m on average for each excavation completed.

Areas excavated recorded against time are detailed in the tables below:

Stage 2 Phase 1 Excavation Evaluations SAND

Ser.	Length (m)	Width (m)	Area (m ²)	Average Area	Excavation Time (min/sec)	Average Time (min/sec)
1/A	11	2.55	28.05	21.42m ²	14:38	11:46
1/B	8	2.55	20.4		11:04	
1/C	8.5	2.55	21.68		14:54	
1/D	7	2.55	17.85		10:26	
1/E	7.5	2.55	19.13		7:07	

Stage 2 Phase 1 Excavation Evaluations GRAVEL

Ser.	Length (m)	Width (m)	Area (m ²)	Average Area	Excavation Time (min/sec)	Average Time (min/sec)
2/A	8.5	2.55	21.68	20.91m ²	9:28	11:55
2/B	8	2.55	20.4		14:45	
2/C	8.5	2.55	21.68		9:48	
2/D	8	2.55	20.4		13:24	
2/E	8	2.55	20.4		11:32	

From both evaluations conducted, the system has the ability to complete an average of 21.165m² every 12:00 minutes, indicating an hourly excavation rate of 105m².

When compared to flail or tiller units, this figure does not inspire great production rates. However, the system is intended for areas classified as difficult for standard mechanical and manual methodologies, and a substantial risk reduction process is included during the soil processing activities.

This figure will also need to be weighed against volume of material excavated, as the depth of excavation is the determining factor.

System turn around times are critical to productive output, selection of processing areas will need to conform with safety related distances, but will also need to be located as close as possible to the contaminated areas.

Total soil volumes were not calculated due to the inconsistency in the excavations, the reasons are specified in Section 6.1.2

Excavation profiles were taken on each of the serials completed. The measurements were taken using a straight placed at ground surface level, and depth of excavation measurements taken at pre-determined intervals along the straight edge.

The profile provide a very clear visual representation of each lane, reinforcing points identified with respect to missed, buried and pushed mines, and also to factors affecting excavation technique, and the resulting consequences of not achieving full excavation depth.

The following tables summarise the depths registered on each of the lanes. Scale diagrams of each excavation are attached at Annex E.

Stage 2 Phase 1 Excavation Profiles SAND

Ser.	Length	Interval						
		0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
1/A	0.0m	12cm	16cm	13.5cm	12cm	13cm	17cm	10cm
	2.8m	14cm	17cm	13.5cm	14cm	15cm	19cm	13cm
	6.5m	21cm	22cm	21.5cm	20cm	21cm	23.5cm	23cm
1/B	0.0m	13cm	20cm	20cm	19.5cm	19.5cm	21cm	21cm
	2.5m	26.5cm	30.5cm	30cm	31cm	31.5cm	31cm	19cm
	6.5m	12.5cm	23.5cm	23.5cm	23.5cm	24cm	23.5cm	15cm
1/C	0.0m	19.5cm	22.5cm	19.5cm	18.5cm	17cm	18cm	15.5cm
	4.5m	33.5cm	31cm	34cm	34cm	33cm	30cm	16cm
	5.4m	12.5cm	20.5cm	19cm	17cm	15.5cm	17cm	10cm
1/D	0.0m	24cm	30cm	22.5cm	25cm	24cm	34cm	22cm
	2.5m	23cm	28.5cm	28.5cm	30cm	29.5cm	32.5cm	27cm
	5.8m	19cm	22.5cm	23cm	23cm	24.5cm	25cm	0cm
1/E	0.0m	19cm	22.5cm	19.5cm	18.5cm	16.5cm	19cm	16cm
	1.0m	27cm	28cm	23.5cm	24.5cm	23cm	28.5cm	27cm
	3.0m	26.5cm	29.5cm	28cm	29cm	30cm	30cm	30cm
	7.0m	31cm	29cm	30cm	30cm	31cm	30.5cm	31cm

Stage 2 Phase 1 Excavation Profiles GRAVEL

Ser.	Length	Interval						
		0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
2/A	0.0m	13cm	16cm	19cm	19cm	17.5cm	21cm	18cm
	2.8m	17cm	20.5cm	20cm	21cm	18.5cm	23cm	22.5cm
	6.5m	20.5cm	20cm	22cm	22.5cm	23cm	23.5cm	24cm
2/B	0.0m	2cm	0cm	2cm	3cm	4cm	8cm	3cm
	2.0m	20cm	26cm	13cm	18cm	15cm	22.5cm	14cm
	6.5m	28cm	35cm	27cm	29cm	28cm	31cm	31cm
2/C	0.0m	10cm	12.5cm	7.5cm	10cm	10cm	17.5cm	17cm
	2.0m	17.5cm	22cm	25.5cm	26.5cm	27.5cm	32cm	30cm
	6.5m	21cm	25.5cm	26.5cm	28cm	30cm	33cm	32.5cm
2/D	0.0m	16cm	21.5cm	15cm	17cm	19cm	26.5cm	25.5cm
	1.5m	22.5cm	26.5cm	27cm	32cm	31cm	36cm	36cm
	5.0m	26cm	31cm	31cm	34cm	34cm	41cm	41cm
2/E	0.0m	24.5cm	28.5cm	27cm	29cm	28cm	31cm	28cm
	3.0m	26cm	31.5cm	25cm	28cm	28cm	33cm	32cm
	7.0m	28cm	31.5cm	33cm	33.5cm	32.5cm	33.5cm	33.5cm

RECOMMENDATIONS

- a. *Soil processing areas need to be located as close as possible to the contaminated area, taking into account organisation SOPs and country NTSGs. Close locations will facilitate a much reduced turn around time, and increase productivity overall.*
- b. *Reporting on front end loader productivity should also include volumes of soil excavated or processed, in addition to surface area. Data on volume is required to determine the system efficiency in contrast to other mechanical systems, where surface area is the standard used.*

To enhance productivity it may be advisable to place the prime movers with standard buckets in the excavation role, and dedicate the ALLU system to soil processing. This recommendation is based on potential figures provided earlier. To evaluate the most effective concept, more tests and data focusing on productivity are needed. One of the versatile benefits of this system is that bucket configurations can be altered at any time and adapted to the situation.

6.1.5 Thrown Items

During the conduct of the various serials within stages 1 and 2, items physically thrown from the bucket during soil processing actions were recorded.

The factors leading to components of mines thrown out of the bucket are not clear. In most cases, components of surrogate mines #5 were thrown from the bucket. Surrogate mines #5 were placed on the surface of material within the bucket. It could be that all soil is processed through the drums, and any remaining mines or components of mines are bounced by the rotating action of the drums. However, this does not explain why components from mines #2 were also ejected, as these surrogates are placed on the base of the bucket, and then covered in soil.



View of thrown fused top plate. The insert shows that a complete Top Plate, with fuse, cannot pass through the drums without receiving some form of damage from the rotating blades

– Function Test Serial 3B Sand

Throughout the tests a total of 6 items were discharged from the bucket, in various states. The table below provides specific details of items thrown from the ALLU bucket.

Serial	Item	Fused	Mine #	Neutralised
2/B	Top Plate	No	#2	Yes
3/B	Top Plate	Yes	Unknown	No
4/B	Mine Body	No	#5	Yes
4/C	Top Plate	No	#5	Yes
4/F	Mine Body	No	#5	Yes
4/I	Mine Body	No	#2	Yes

It was also noted during the conduct of Live Mine evaluations that soil was ejected from the bucket during detonations. The thrown soil was fine material only. Although not observed during the tests, objects including other live items could be thrown from the bucket when a mine detonates.

6.1.6 Soil Build Up

Soil build up within the bucket was noted on various occasions, mainly associated with Top Soil ground conditions. Wet material was certainly the major cause for built up material within the bucket. Measures to counteract the built up of material were discussed and implemented: running the machine at higher revolutions, thereby providing more power to the drums, combined with counter rotating the drums at very short intervals and shaking of the bucket. This combination had a limited effect in Top Soil, but provided good results in Gravel soil conditions. It was concluded that it will never be entirely possible to avoid or remove all built up material inside the bucket. Therefore precautions will need to be taken when removing the machine from the contaminated area.

The manufacturer recommends processing coarse aggregate in the bucket to act as a cleaning agent, although this may not be practical in some locations and environs.

Soil build up is noted in the following areas:

- a. corners, or any sharp angles,
- c. between discs on the drums
- d. in front of the counter blades on the bucket base, and
- e. at the rear of the bottom drum, on the skirt.



Built up Top Soil in bucket corners and along sharp angles.

Note material between drum discs.

RECOMMENDATIONS

- a. *To prevent possibilities of live or live damaged items being ejected from the bucket during soil processing actions, it is recommended to fit a suitable closing lid on the bucket. The lid will need to be robust enough to withstand the rigors of day to day work, but also be open enough to allow the forces from any detonation to escape. A strong durable frame, covered in a mesh wire would be the preferred construction. Operation will need to be hydraulic, controlled from within the cabin.*
- b. *Soil build up within the bucket can never be fully avoided. Therefore the bucket has to be inspected when the machine is required to exit the contaminated area. Bucket inspection will need to be incorporated in any machine inspection processes.*
- c. *It is recommended that high capacity air compressors and water jets be included in maintenance packages to support the unit. These tools prove very useful in clearing buckets and working tools from built up material.*
- d. *The manufacturer should also consider the following recommendation:*
 - i) *If the ALLU SCH system is employed in excavation roles, wear and tear from abrasive soils will rapidly damage framework construction. It is recommended that sacrificial wear plates are added to the base of the bucket, on the leading cutting edge and at cutting points along the bucket edge.*

7.1 Volvo L90 AFEL Performance Results

With respect to the Volvo L90 AFEL, various points have already been discussed in previous sections of this document. These points relate to levelling, visibility, hydraulic pressures and adaptor tilt. They are directly related to ALLU SCH issues and were explained accordingly.

Unfortunately, due to the cancellation of Stage 2 Phase 2 and Stage 4, various other aspects involving performance specifications could not be monitored. The points detailed here are therefore very limited. Without additional evaluations, further comments on machine performance details cannot be made.

The one remaining point that hasn't been discussed so far is the stability of the machine. Two main points were attributed to L90 stability issues, being bucket weight and machine height.

7.1.1 Bucket Weight

As mentioned in Section 6.1, the bucket weight, when loaded, proved too heavy for the Volvo L90, affecting hydraulic pressure ratings. The largest load recorded during the tests was 3.65m³. Combined with a bucket weight of 3.4 tonnes, this is an enormous forward weight to balance on a single front axle. The result of such a forward weight was complete loss of traction on the rear axle, where in one example the rear axle cleared the ground completely.

Apart from obvious safety implications, the operator was forced to steady the machine by initially stopping, then using the bucket to force the rear axle down, and subsequently drag the machine from the contaminated area. This practice could only be considered as unsafe.

7.1.2 Machine Height

Although not affecting machine performance adversely, the high centre of gravity did result in horizontal sway. This is due to the extended cabin, where an armoured cupola has been fitted. Horizontal sway was quite noticeable when the machine was expected to traverse rather minor inclines or gradients, or when turning with the bucket loaded.

7.1.3 Traction

As expected, traction problems were encountered, especially during wet conditions. Most notable in Top Soil ground conditions, traction was lost on various occasions. Such conditions would have been classed as very difficult by any standards. However in an international deployment environment, operations would be expected to continue, unless definitive safety issues prevent this.

As with most heavy machinery operating in landmine clearance activities, the use of chains is vital, increasing traction and the overall performance of the machine.

7.1.4 Power

As the tests were not primarily designed to evaluate power issues the information gathered in this respect was limited. Therefore only few details can be commented on here. However, from a general perspective, the Volvo L90 displayed adequate power to conduct excavations, move with loaded buckets and process soil.

The only point that could be identified as a shortcoming was when the L90 was expected to engage the bucket when carrying out other actions, either raising the bucket or if requested to reverse during processing. The L90 would then display moments of being under powered. This is directly linked to hydraulic pressures. This shortcoming does not affect the operation, but should be a point noted to operators and supervisors.

Fuel consumption is expected to be considerably higher than during standard daily employment of the L90. Although no data has been collected on this issue, higher fuel consumption is expected due to the requirement that the machine must be run at high engine revolutions during soil processing activities.

RECOMMENDATIONS

In support of recommendations made in Section 6.1.2, the following should be considered:

- a. Due to the weight and stability issues with respect to the L90 AFEL and 4-25 Bucket, it is recommended that a smaller, lighter bucket be employed. The manufacturer has stated that the drums used on the 4-25 can be easily placed into existing frames for other series buckets. On this machine platform, the Volvo L90, it is therefore recommended to use a 3-25 Series bucket.
- b. The maximum load permissible should be limited to 2.5m³. It was quite evident that loads higher than this started to affect the stability of the L90 AFEL. A smaller bucket would effectively restrict the maximum load.
- c. The armoured cupola, fitted above the cabin should be removed. This will reduce overall weight by approximately 500kg, and lower the centre of gravity considerably. This will reduce the amount of sway the machine displays when working on slight gradients.
- d. Chains should be included in the support package, as well as adding weight to the machine, below the centre of gravity, it will contribute to stability by reducing sway, whilst considerably improving traction.

TEST RESULTS DATA – STAGE 1 FUNCTION TEST

Stage 1 Function Test - SAND

Test	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
2/A	Simulation AP – No Fuse	3	0	3	0	0
3/A	Simulation AP – Fused	3	0	3	0	0
3/B	Simulation AP – Fused	3	0	3	0	0
3/C	Simulation AP – Fused	3	2	1	0	0
4/A	Simulation AP – Fused	6	1	3	0	2
4/B	Simulation AP – Fused	6	3	1	0	2
4/C	Simulation AP – Fused	6	1	5	0	0
4/J	Simulation AP – Fused	6	0	6	0	0
4/K	Simulation AP – Fused	6	1	5	0	0

RESULTS	42	8	30	0	4
		19%	71%	0%	10%

Stage 1 Function Test GRAVEL

Test	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
2/B	Simulation AP – No Fuse	3	0	3	0	0
3/D	Simulation AP – Fused	3	0	3	0	0
3/E	Simulation AP – Fused	3	0	3	0	0
3/F	Simulation AP – Fused	3	1	2	0	0
4/D	Simulation AP – Fused	6	3	3	0	0
4/E	Simulation AP – Fused	6	4	2	0	0
4/F	Simulation	6	2	4	0	0

	AP – Fused					
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RESULTS	30	10	20	0	0
		33%	67%	0%	0%

Stage 1 Function Test TOP SOIL

Test	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
2/C	Simulation AP – No Fuse	NOT TESTED				
3/G	Simulation AP – Fused	NOT TESTED				
3/H	Simulation AP – Fused	NOT TESTED				
3/I	Simulation AP – Fused	NOT TESTED				
4/G	Simulation AP – Fused	6	1	5	0	0
4/H	Simulation AP – Fused	6	2	4	0	0
4/I	Simulation AP – Fused	6	0	6	0	0

RESULTS	18	3	15	0	0
		17%	83%	0%	0%

Due to the extreme weather conditions, it was not possible to complete Serials 2C and 3G - I for the Top Soil ground conditions.

TEST RESULTS DATA – STAGE 2 EXCAVATION EVALUATIONS

Stage 2 Phase 1 SAND

Test	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
1/A	Simulation AP – No Fuse	10	2	5	0	3
1/B	Simulation AP – Fused	10	1	8	0	1
1/C	Simulation AP – Fused	10	2	6	0	2
1/D	Simulation AP – Fused	10	1	7	0	2
1/E	Simulation AP – Fused	10	2	8	0	0

RESULTS	50	8	34	0	8
		16%	68%	0%	16%

Stage 2 Phase 1 GRAVEL

Test	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
2/A	Simulation AP – No Fuse	10	6	4	0	0
2/B	Simulation AP – Fused	10	3	3	0	4
2/C	Simulation AP – Fused	10	4	5	0	1
2/D	Simulation AP – Fused	10	3	7	0	0
2/E	Simulation AP – Fused	10	8	2	0	0

RESULTS	50	24	21	0	5
		48%	42%	0%	10%

1. A marked improvement noted over time, possibly operator improvement, mixed soil conditions
2. A third testing regime using Top Soil was plotted, but due to weather and ground conditions removed from the program.

TEST RESULTS DATA – STAGE 3 LIVE MINE TESTING

Stage 3 Phase 1 Live Mines Testing SAND

Test	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
1/A	Live – Fused M49 AP	1	1	0	0	0
1/B	Live – Fused M49 AP	1	0	1	0	0
1/C	Live – Fused M49 AP	1	1	0	0	0
1/D	Live – Fused #10 AP	1	1	0	0	0
1/E	Live – Fused #10 AP	1	1	0	0	0
1/F	Live – Fused #10 AP	1	1	0	0	0

RESULTS	6	5	1	0	0
		83%	17%	0%	0%

Stage 3 Phase 1 Live Mines Testing GRAVEL

Test	Mine Type	Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
2/A	Live – Fused M49 AP	1	1	0	0	0
2/B	Live – Fused M49 AP	1	0	1	0	0
2/C	Live – Fused M49 AP	1	1	0	0	0
2/D	Live – Fused #10 AP	1	1	0	0	0
2/E	Live – Fused #10 AP	1	1	0	0	0
2/F	Live – Fused #10 AP	1	1	0	0	0

RESULTS	6	5	1	0	0
		83%	17%	0%	0%

TEST RESULTS DATA – FUSES

Stage 1 Function Test SAND

Test	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
3/A	Simulation AP – Fused	3	3	0	0	0
3/B	Simulation AP – Fused	3	1	1	0	1
3/C	Simulation AP – Fused	3	2	0	0	1
4/A	Simulation AP – Fused	6	2	1	0	3
4/B	Simulation AP – Fused	6	3	1	0	2
4/C	Simulation AP – Fused	6	4	2	0	0
4/J	Simulation AP – Fused	6	2	2	1	1
4/K	Simulation AP – Fused	6	4	2	0	0

RESULTS	39	21	9	1	8
		54%	23%	3%	20%

Stage 1 Function Test GRAVEL

Test	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
3/D	Simulation AP – Fused	3	3	0	0	0
3/E	Simulation AP – Fused	3	3	0	0	0
3/F	Simulation AP – Fused	3	1	1	0	1
4/D	Simulation AP – Fused	6	3	2	0	1
4/E	Simulation AP – Fused	6	4	1	0	1
4/F	Simulation AP – Fused	6	5	1	0	0

RESULTS	27	19	5	0	3
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	70%	19%	0%	11%
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Stage 1 Function Test TOP SOIL

Test	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
3/G	Simulation AP – Fused	NOT TESTED				
3/H	Simulation AP – Fused	NOT TESTED				
3/I	Simulation AP – Fused	NOT TESTED				
4/G	Simulation AP – Fused	6	4	0	0	1
4/H	Simulation AP – Fused	6	3	2	0	1
4/I	Simulation AP – Fused	6	4	1	0	0

RESULTS	18	11	3	0	2
		61%	17%	0%	11%

One fuse during Serials 4/G and 4/I could not be found. This accounts for the 11% discrepancy in the results.

Stage 2 Phase 1 SAND

Test	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
1/A	Simulation AP – Fused	10	6	0	1	3
1/B	Simulation AP – Fused	10	8	0	1	1
1/C	Simulation AP – Fused	10	7	0	1	2
1/D	Simulation AP – Fused	10	5	1	2	2
1/E	Simulation AP – Fused	10	7	2	1	0

RESULTS	50	33	3	6	8
		66%	6%	12%	16%

Stage 2 Phase 1 GRAVEL

Test	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
2/A	Simulation AP – Fused	10	8	0	0	2
2/B	Simulation AP – Fused	10	5	1	0	4
2/C	Simulation AP – Fused	10	8	0	0	2
2/D	Simulation AP – Fused	10	7	2	0	1
2/E	Simulation AP – Fused	10	8	2	0	0

RESULTS	50	36	5	0	9
		72%	10%	0%	18%

Stage 3 Phase 1 Live Mines Testing SAND

Test	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
1/A	Live – Fused M49 AP	1	1	0	0	0
1/B	Live – Fused M49 AP	1	0	0	0	1
1/C	Live – Fused M49 AP	1	1	0	0	0
1/D	Live – Fused #10 AP	1	1	0	0	0
1/E	Live – Fused #10 AP	1	1	0	0	0
1/F	Live – Fused #10 AP	1	1	0	0	0

RESULTS	6	5	0	0	1
		83%	0%	0%	17%

Stage 3 Phase 1 Live Mines Testing GRAVEL

Test	Mine Type	FUSES				
		Quantity	Mechanically Triggered	Mechanically Neutralised	Live Damage	Live
2/A	Live – Fused M49 AP	1	1	0	0	0
2/B	Live – Fused M49 AP	1	0	0	0	1
2/C	Live – Fused M49 AP	1	1	0	0	0
2/D	Live – Fused #10 AP	1	1	0	0	0
2/E	Live – Fused #10 AP	1	1	0	0	0
2/F	Live – Fused #10 AP	1	1	0	0	0

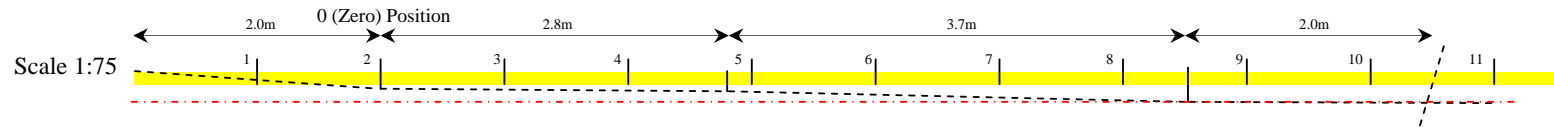
RESULTS

6	5	0	0	1
	83%	0%	0%	17%

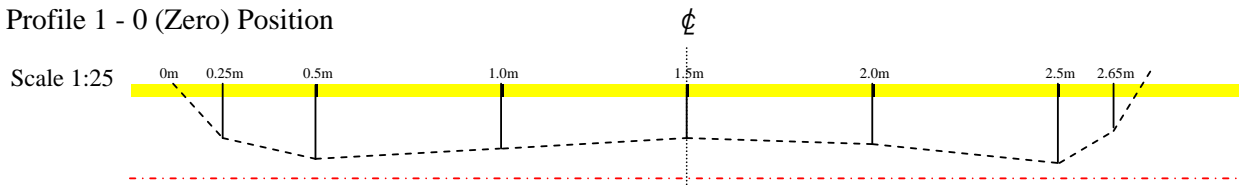
EXCAVATION PROFILES

Stage 2 Phase 1 Test 1A SAND

Cross Section 1.5m ϕ

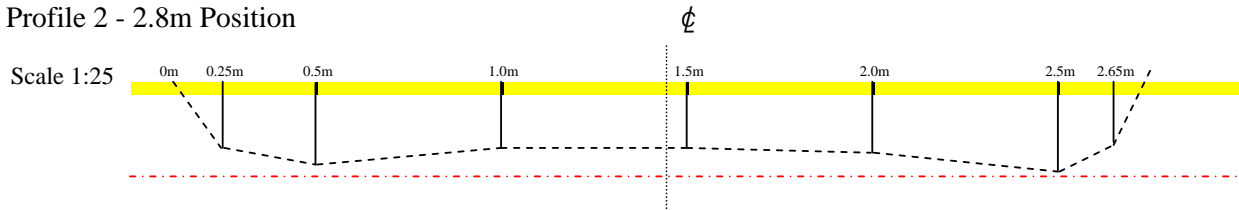


Profile 1 - 0 (Zero) Position



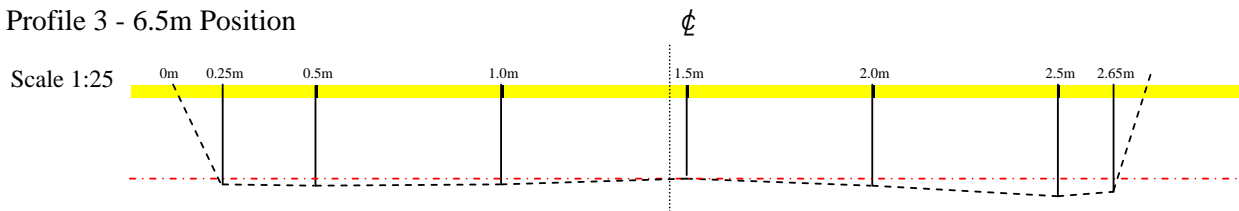
Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
0.0m	12	16	13.5	12	13	17	10

Profile 2 - 2.8m Position



Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
2.8m	14	17	13.5	14	15	19	13

Profile 3 - 6.5m Position

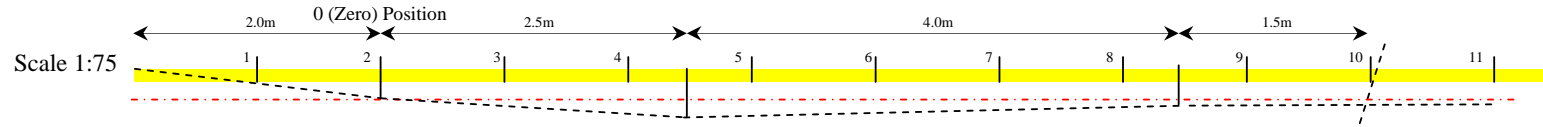


Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
6.5m	21	22	21.5	20	21	23.5	23

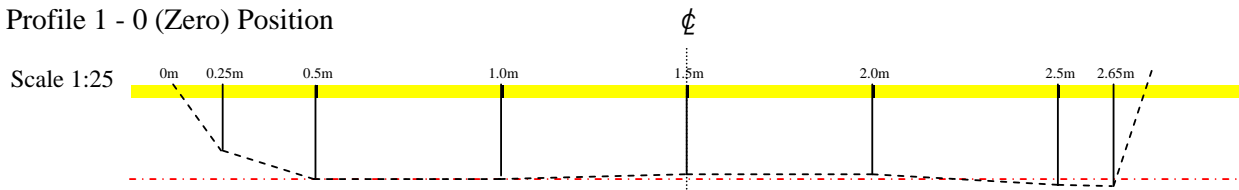
EXCAVATION PROFILES

Stage 2 Phase 1 Test 1B SAND

Cross Section 1.5m ϕ

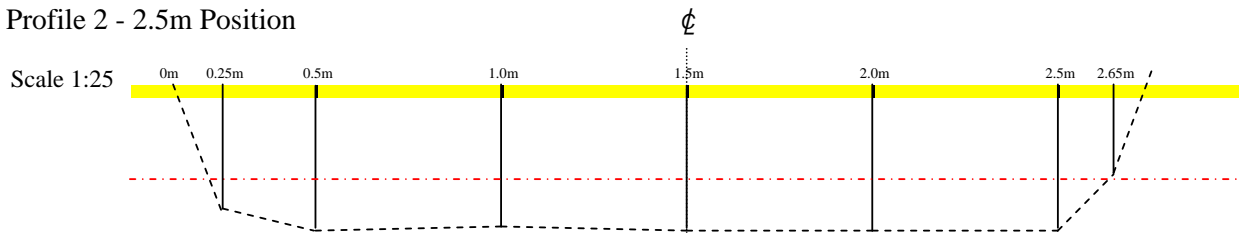


Profile 1 - 0 (Zero) Position



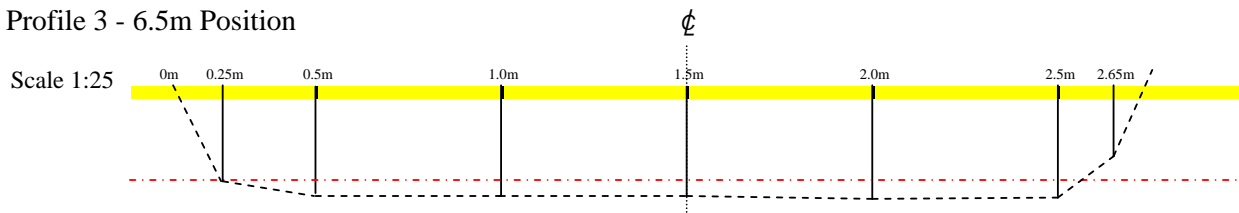
Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
0.0m	13	20	20	19.5	19.5	21	21

Profile 2 - 2.5m Position



Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
2.5m	26.5	30.5	30	31	31.5	31	19

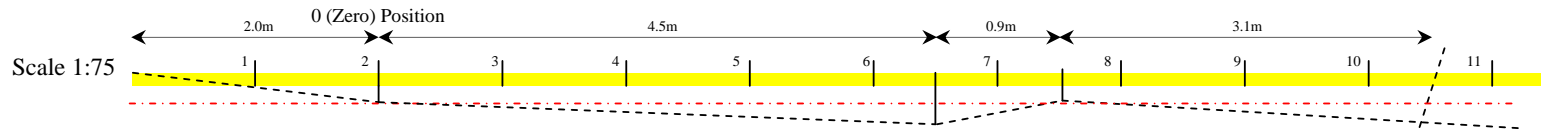
Profile 3 - 6.5m Position



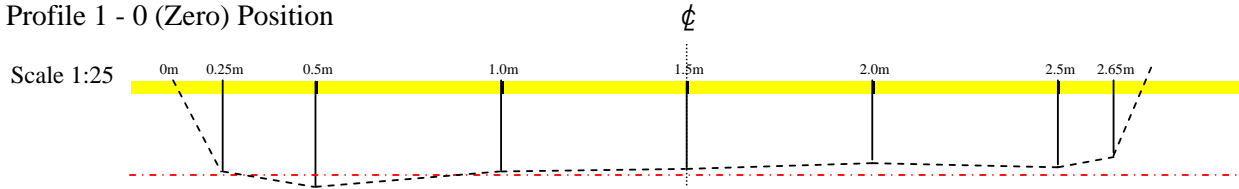
Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
6.5m	12.5	23.5	23.5	23.5	24	23.5	15

Stage 2 Phase 1 Test 1C SAND

Cross Section 1.5m ϕ

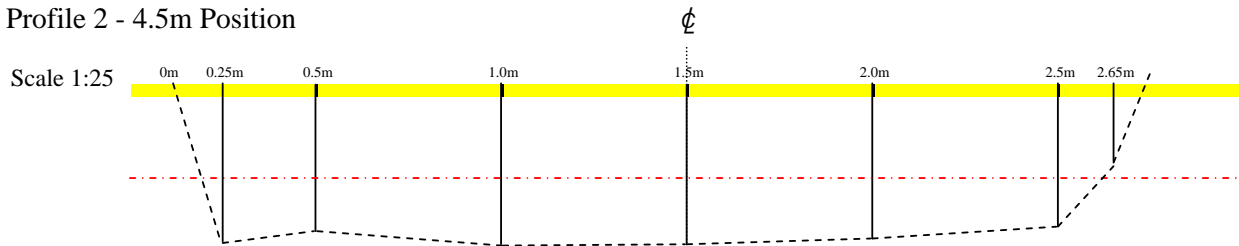


Profile 1 - 0 (Zero) Position



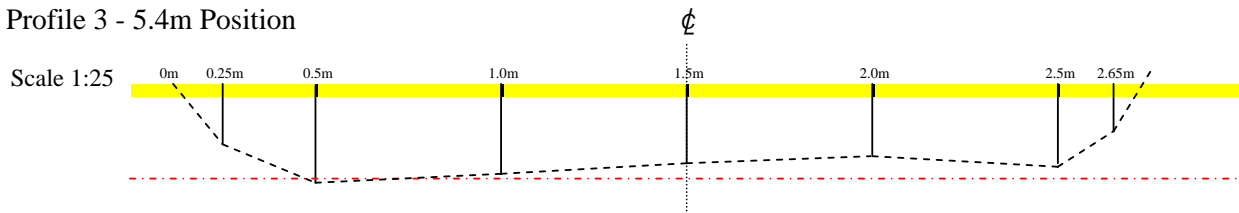
		Width						
Length		0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
0.0m		19.5	22.5	19.5	18.5	17	18	15.5

Profile 2 - 4.5m Position



		Width						
Length		0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
4.5m		33.5	31	34	34	33	30	16

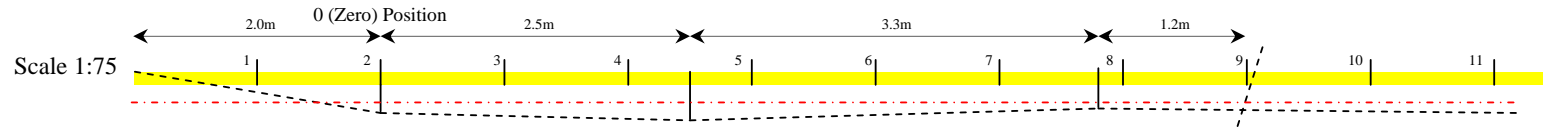
Profile 3 - 5.4m Position



		Width						
Length		0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
5.4m		12.5	20.5	19	17	15.5	17	10

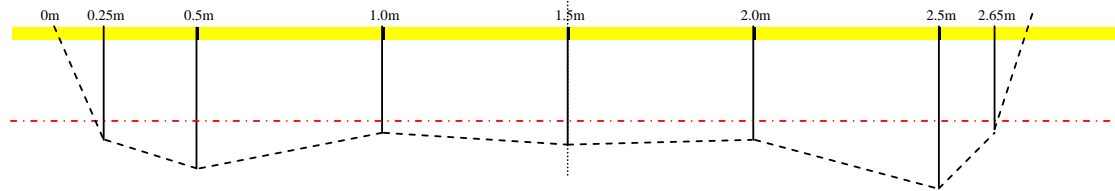
Stage 2 Phase 1 Test 1D SAND

Cross Section 1.5m ϕ



Profile 1 - 0 (Zero) Position

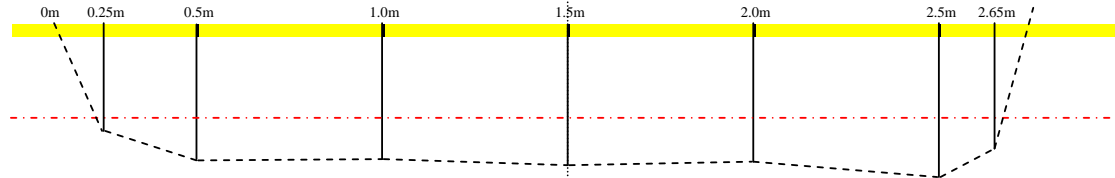
Scale 1:25



		Width						
Length	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m	
0.0m	24	30	22.5	25	24	34	22	

Profile 2 - 2.5m Position

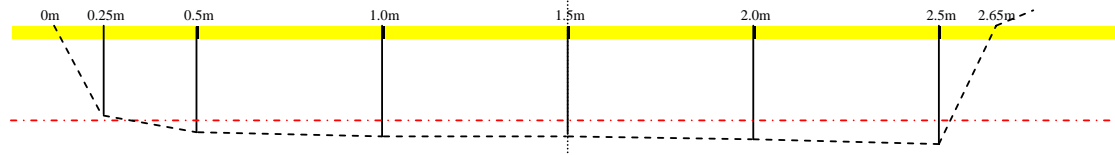
Scale 1:25



		Width						
Length	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m	
2.5m	23	28.5	28.5	30	29.5	32.5	27	

Profile 3 - 5.8m Position

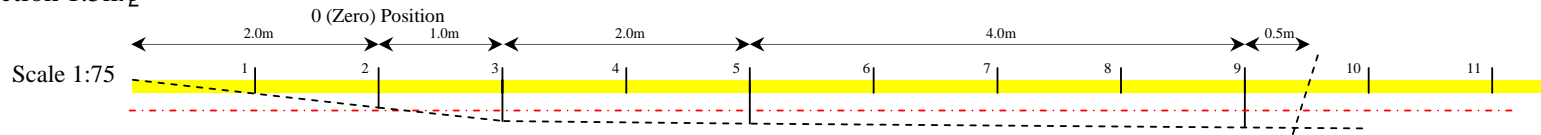
Scale 1:25



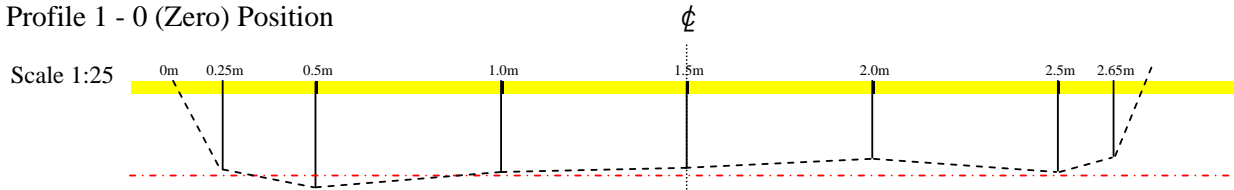
		Width						
Length	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m	
5.8m	19	22.5	23	23	24.5	25	0	

Stage 2 Phase 1 Test 1E SAND

Cross Section 1.5m ϕ

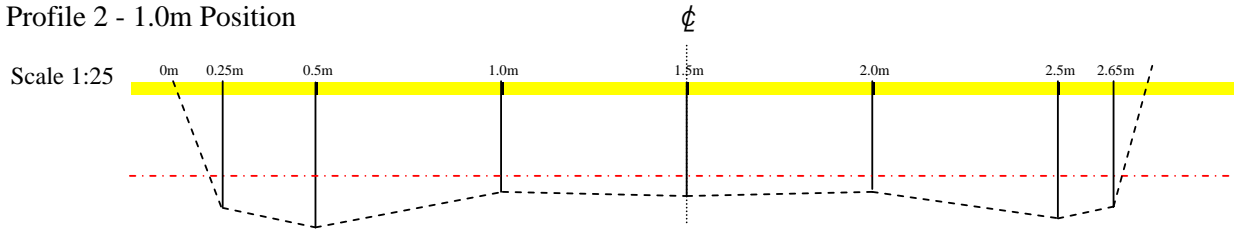


Profile 1 - 0 (Zero) Position



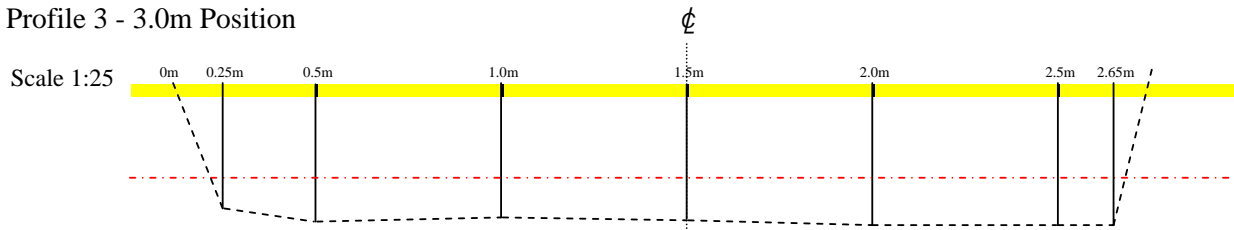
Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
0.0m	19	22.5	19.5	18.5	16.5	19	16

Profile 2 - 1.0m Position



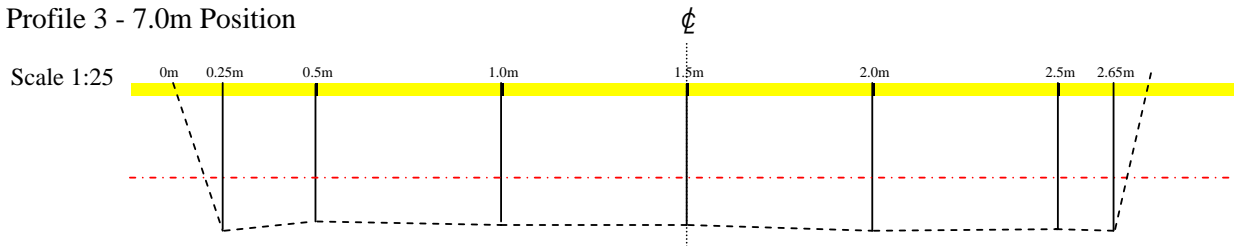
Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
1.0m	27	28	23.5	24.5	23	28.5	27

Profile 3 - 3.0m Position



Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
3.0m	26.5	29.5	28	29	30	30	30

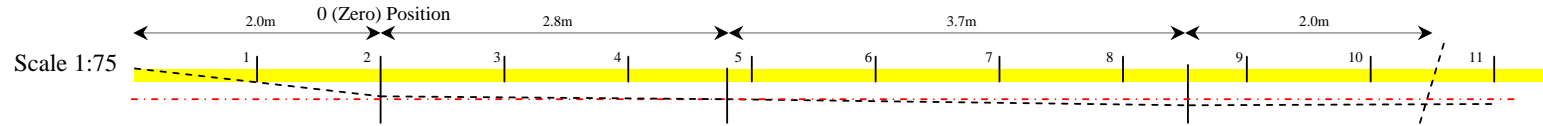
Profile 3 - 7.0m Position



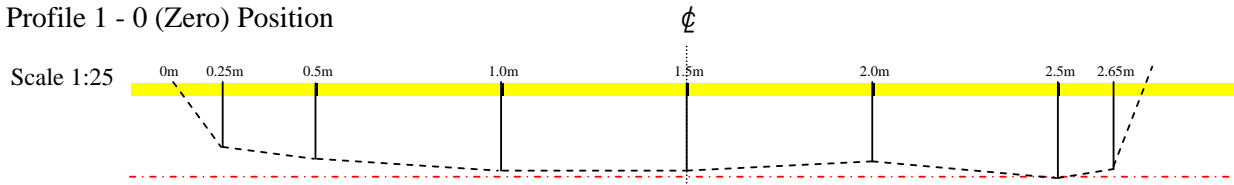
Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
7.0m	31	29	30	30	31	30.5	31

Stage 2 Phase 1 Test 2A GRAVEL

Cross Section 1.5m ϕ

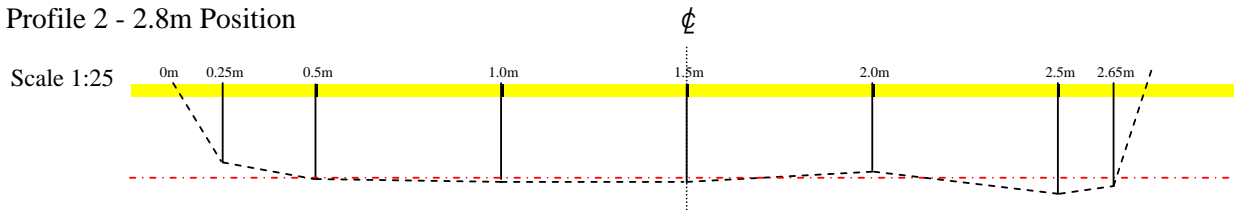


Profile 1 - 0 (Zero) Position



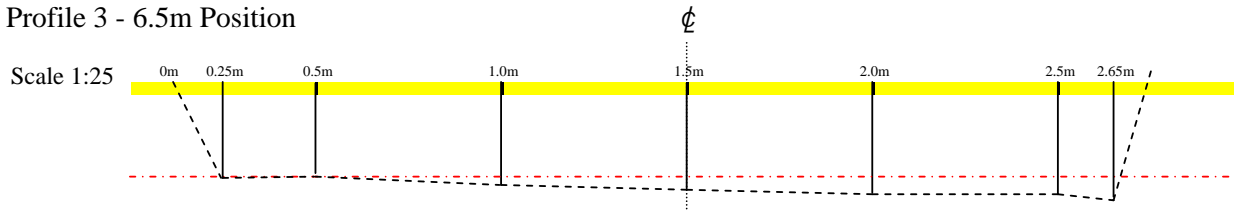
Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
0.0m	13	16	19	19	17.5	21	18

Profile 2 - 2.8m Position



Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
2.8m	17	20.5	20	21	18.5	23	22.5

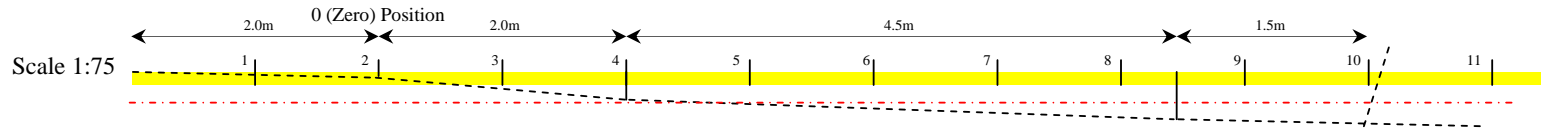
Profile 3 - 6.5m Position



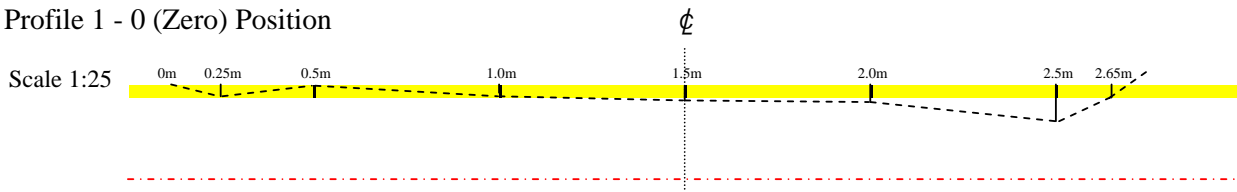
Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
6.5m	20.5	20	22	22.5	23	23.5	24

Stage 2 Phase 1 Test 2B GRAVEL

Cross Section 1.5m ϕ

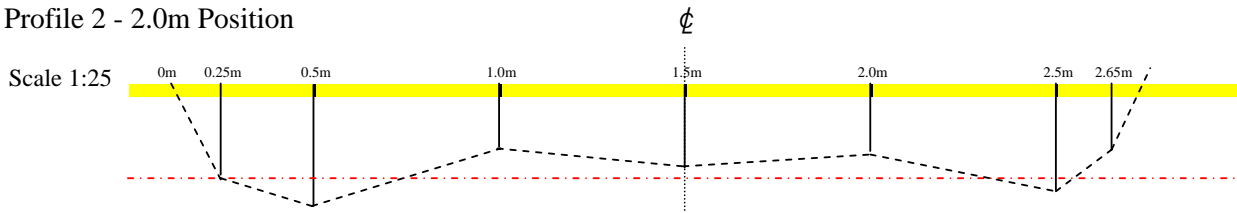


Profile 1 - 0 (Zero) Position

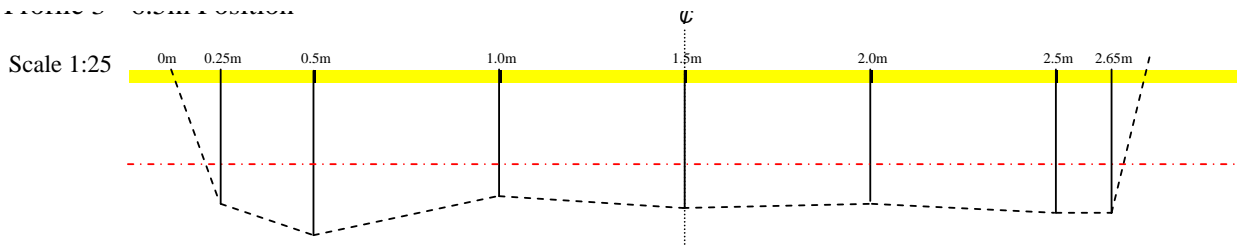


Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
0.0m	2	0	2	3	4	8	3

Profile 2 - 2.0m Position



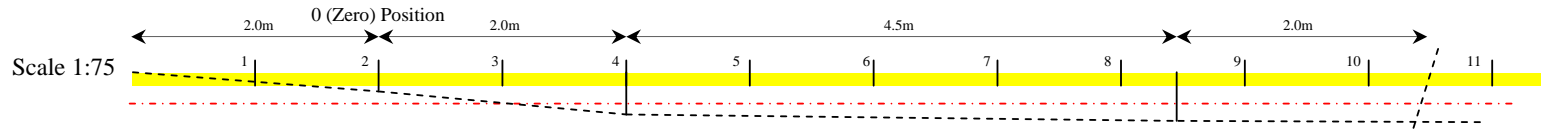
Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
2.0m	20	26	13	18	15	22.5	14



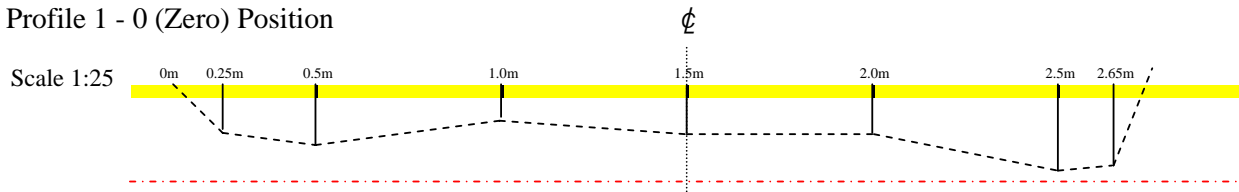
Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
6.5m	28	35	27	29	28	31	31

Stage 2 Phase 1 Test 2C GRAVEL

Cross Section 1.5m ϕ

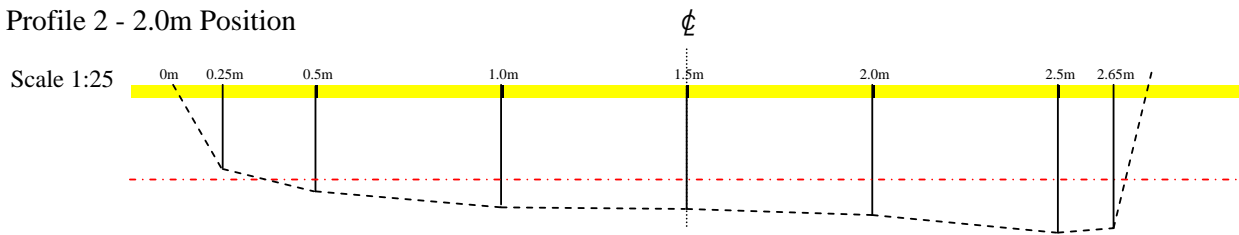


Profile 1 - 0 (Zero) Position



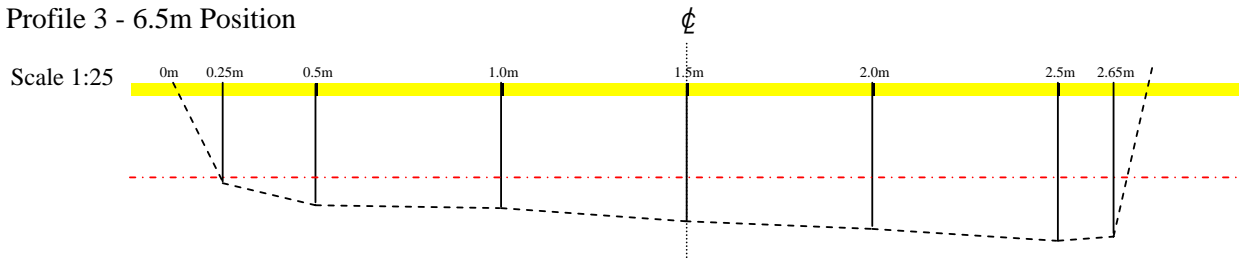
Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
0.0m	10	12.5	7.5	10	10	17.5	17

Profile 2 - 2.0m Position



Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
2.0m	17.5	22	25.5	26.5	27.5	32	30

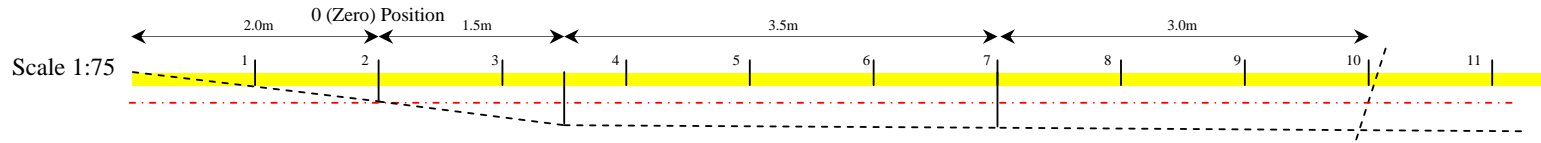
Profile 3 - 6.5m Position



Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
6.5m	21	25.5	26.5	28	30	33	32.5

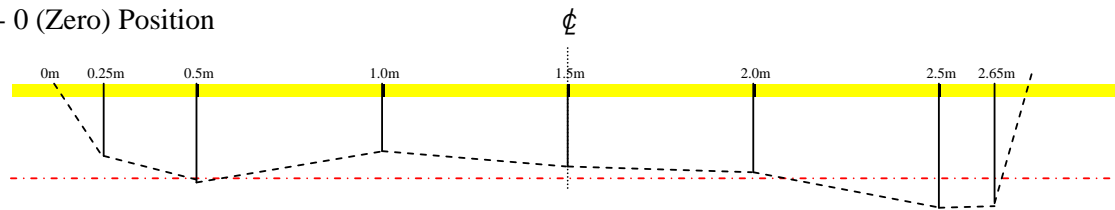
Stage 2 Phase 1 Test 2D GRAVEL

Cross Section 1.5m ϕ



Profile 1 - 0 (Zero) Position

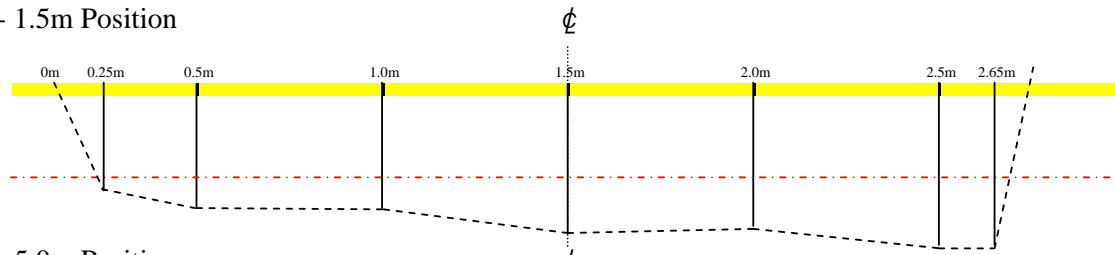
Scale 1:25



		Width					
Length	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
0.0m	16	21.5	15	17	19	26.5	25.5

Profile 2 - 1.5m Position

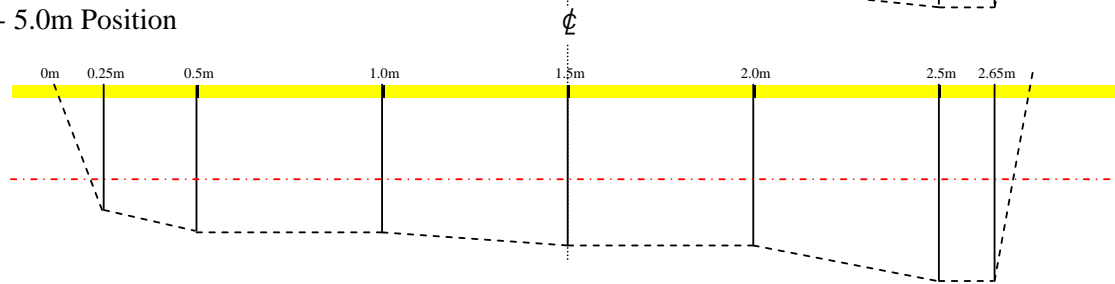
Scale 1:25



		Width					
Length	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
1.5m	22.5	26.5	27	32	31	36	36

Profile 3 - 5.0m Position

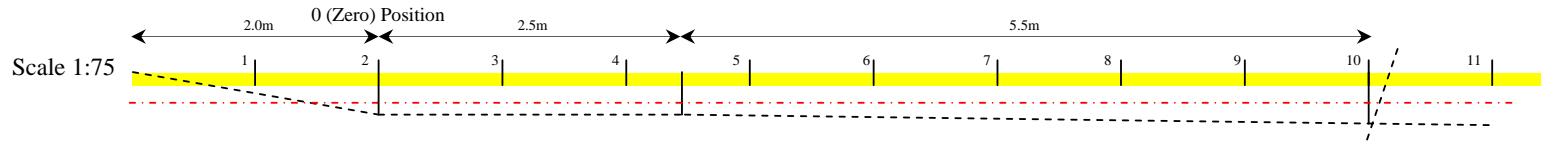
Scale 1:25



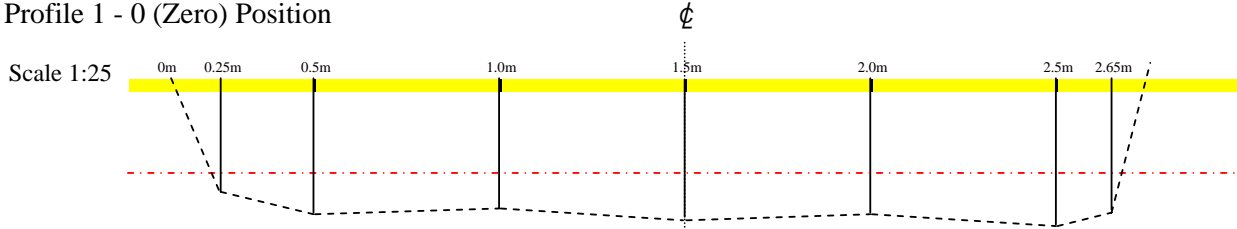
		Width					
Length	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
5.0m	26	31	31	34	34	41	41

Stage 2 Phase 1 Test 2E GRAVEL

Cross Section 1.5m ϕ

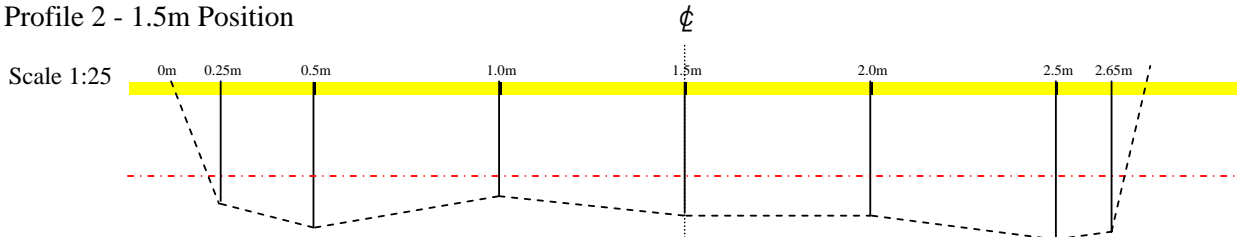


Profile 1 - 0 (Zero) Position



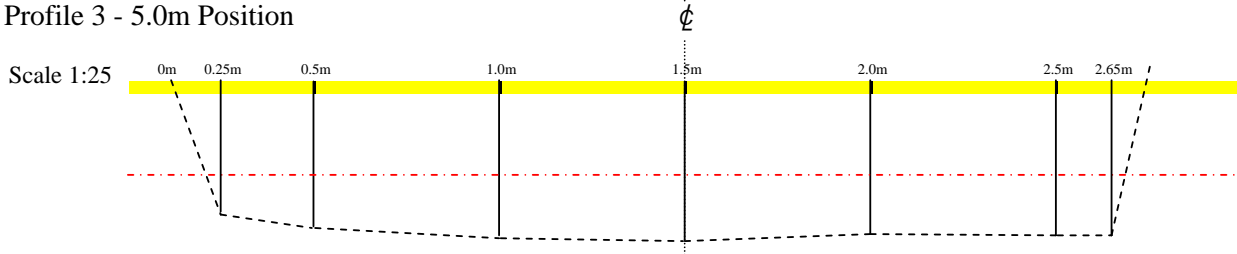
Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
0.0m	24.5	28.5	27	29	28	31	28

Profile 2 - 1.5m Position



Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
2.5m	26	31.5	25	28	28	33	32

Profile 3 - 5.0m Position



Length	Width						
	0.25m	0.5m	1.0m	1.5m	2.0m	2.5m	2.65m
8.0m	28	31.5	33	33.5	32.5	33.5	33.5