Maths in Surveying
Teacher resources

Activity	Page #	Resources required	Assumed knowledge
A: Mapping a Garden or Perimeter of a Building	4	Measuring tape, magnetic compasses, grid paper and geometrical instruments, including ruler and compasses.	Taking bearings using a magnetic compass, mensuration formulae, scale.
B: MiniCAD	6	Software download of MiniCAD (free)	Activity A results
C: Measuring Heights using Shadows	14	Measuring tape	Similar triangles or ratios
D: Marking out the corners of a shed	15	(For each group of 4 students) 30m tape, plumbob (can use string and small weight), spirit level, 4 marker pegs.	Pythagoras' Theorem, area and volume formulae.
E: Marking a Path through a Minefield	18	Preparation: grass activity - galvanised iron roofing nails and flagging tape. Paved surface - chalk. For each group: Copy of the student worksheet, 30m measuring tape, magnetic compass, ball of string, a few galvanised iron roofing nails, sheet of 1 cm grid paper, and geometry instruments.	Compass bearings, measurement, accuracy, intersection of circles

A life without limits

NSW Curriculum references

The following outcomes and relevant content are drawn from the BOSTES site:
http://syllabus.bostes.nsw.edu.au/mathematics/

1. Length concepts: **Used in all activities**

MATHEMATICS K–10 - STAGE 3 - MEASUREMENT AND GEOMETRY **LENGTH**

2. Area concepts: Activity A: Mapping a Garden or Perimeter of a Building

MATHEMATICS K–10 - STAGE 5.1 - MEASUREMENT AND GEOMETRY **AREA AND SURFACE AREA**

3. Volume concepts: **Activity D: Marking out the corners of a shed**

MATHEMATICS K–10 - STAGE 5.2 - MEASUREMENT AND GEOMETRY **VOLUME**

4. Bearings concepts: **Activity A: Mapping a Garden or Perimeter of a Building**

Activity B: MiniCAD

Activity E: Marking a Path through a Minefield

MATHEMATICS K–10 - STAGE 5.2 - MEASUREMENT AND GEOMETRY **RIGHT-ANGLED TRIANGLES (TRIGONOMETRY)**

5. Pythagoras theorem concepts: Activity D: Marking out the corners of a shed

MATHEMATICS K–10 - STAGE 4 - MEASUREMENT AND GEOMETRY **RIGHT-ANGLED TRIANGLES (PYTHAGORAS)**

6. Similar triangle concepts: Activity C: Measuring Heights using Shadows

MATHEMATICS K–10 - STAGE 5.1 - MEASUREMENT AND GEOMETRY **PROPERTIES OF GEOMETRICAL FIGURES**

What is Surveying?

Surveying is the measurement, mapping and analysis of the environment using specialised equipment and technology. The technology and computational analysis are underpinned by mathematics.

The purpose of these activities is to introduce students to the Surveying profession and how maths is applied on a daily basis to projects such as Land Development, the building of roads and other infrastructure, and mining or engineering projects.

Surveyors play a critical role in facilitating the land development and infrastructure growth. Before a school can be built, a surveyor establishes the current site conditions and defines the site boundary. A surveyor will also provide the boundaries and alignments required for an engineering construction project such as a road, tunnel or tower. Before the challenges of rebuilding after an earthquake or a flood or a bushfire, a surveyor will determine the limits of the land environment.

Surveying offers significant opportunities for young people looking for a diverse and varied career. As McCrindle Research found in 2013, the national demand for new Surveyors means graduates are more likely to secure jobs in surveying compared with many other professions. An average of 90% of graduates in full-time employment earn a median starting salary of $55,000.

Surveying offers:
- Varied work, both outdoors and indoors
- Using the latest in modern technology
- A choice of working independently or being part of a larger group
- Strong demand for graduates

Surveying requires:
- Good spatial skills, ability to think and visualise in 3 dimensions
- Attention to accuracy and detail

Visit **www.alifewithoutlimits.com.au** to find out more about Surveying and register for more information on Surveying or your interest in a work experience placement.

Activity A: Mapping a garden, perimeter of a building or similar area

Preparation: Try to choose an area that is not just a simple rectangle, but if that is not possible, a basketball court could be used, perhaps with some extra objects placed on it whose location has to be marked.

Equipment required:	Measuring tape, magnetic compasses, grid paper and geometrical instruments, including ruler and compasses.
Assumed knowledge:	Taking bearings using a magnetic compass, mensuration formulae, scale.
Duration:	30 minutes

A. **Measure up the area.**

Draw a rough sketch map of the area. Choose any corner as starting point and label it 1, then number the other corners in sequence, as in the example shown. The number of points will depend on the shape you are measuring. Use a tape to measure the length of each side.

Now use a magnetic compass to find the direction of the longest side (remember that compass bearings are measured clockwise). If all the corners are right angles, you should be able to work out the directions of the other sides, using the fact that all the corners are right angles. If not, use the compass to find the direction of the other sides too.

B. **Prepare a table of bearings and distances**

Enter the results in the table giving the bearing and distance for each leg (e.g. if there are 10 points – 1 to 2, 2 to 3, … 9 to 10, 10 to 1).

From point number	To point number	Bearing	Distance
1	2		
2	3		
3	4		
4	5		
5	6		
6	7		
7	8		
8	9		
9	10		
10	1		

C. **Draw a map of the area you have measured**

Using your geometry equipment and the data in your table, draw a map of the area on grid paper provided by the surveyor or your teacher. Use a scale of 1 cm to 1 metre, i.e. 1:100.

Mark North clearly on your map.

Check with a surveyor that you have done this correctly.

D. **Use your map to calculate the area of the region.**

Show your working and give your answer (in m^2, to 4 significant figures).

Keep the table carefully. You will need it later, when you enter the data into a computer in Activity B.

Activity B: MiniCAD

Location:	**Classroom with computers**
Duration:	**30 minutes**
Resources:	**Refer to Page 12 for software download**

In this activity, you will learn how to use the Computer Aided Design software package *miniCAD*. You will be shown how to enter into the computer the results from Activity A (Mapping).

Make sure that you have to hand the table of distances and bearings that you made in **Activity A.**
You will use this to draw on the computer an accurate map of your measurements of the area, calculate the area of the figure and overlay an aerial image of the site.

CAD stands for Computer Aided Design / Drafting and miniCAD6 is a powerful CAD program designed for surveyors to produce maps from their survey data. Today you will use it to produce the same map as you have just drawn on graph paper. When you have finished you will be able to print it out.

The following instructions are written for groups mapping a garden feature that includes a circular arc. If the area you have mapped does not have a curved section in its boundary, ignore Steps 5 and 6 and go straight from Step 4 to Step 7..

Step 1 – If it is not already done, open miniCAD6 by double clicking on the desktop icon.

Step 1a – To do this activity you need to load a predefined template file. From the menu select Tools>>Options.

From the Preferences TAB under New Jobs make sure Use a template file is checked. Then select the 3 elipses to the right, navigate to the file \Documents\miniCAD\Support\BPTemplate.mcd and select it. Now close the Program Options dialogue box by selecting the OK button.

Step 2- Then.Start a new job by selecting **File>>New** from the menu.

Step 3 – You should see one point in the middle of the screen, labelled with the number 1.

If a point number is not displayed, move the mouse cursor into the drawing area,
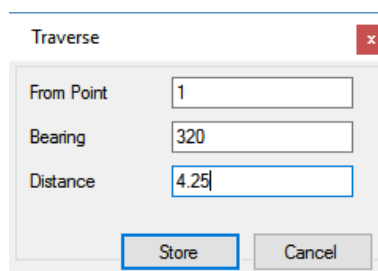
right click and select **Display>>Numbers**

Step 4 – **Select Draw>>Traverse** from the menu. Move the mouse over point 1 and left click when the cursor turns yellow. This is what you do if you are told to "snap to a point".

Next, you will enter the bearings and distances you measured (surveyors call these traverse legs).
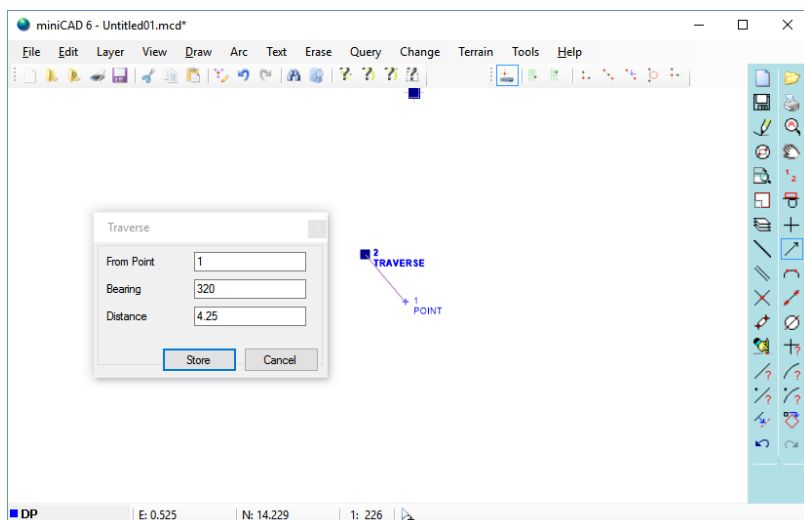
Enter the first bearing and distance from your table.

Ignore the Swing field, unless it is shown in red, when you will need assistance from a surveyor.

Your dialogue box should look like the picture below. Press the **Store** button when finished.

Your screen should now look like the picture below. If it doesn't, see the box below.

> If your drawing looks too small or if it disappears off the screen, you can change the scale by Zooming or move it by Panning.
>
> **Zooming** lets you make the drawing bigger or smaller. **To make it smaller (zoom out)**, roll the wheel of the mouse towards you. **To make it bigger (zoom in)**, roll the wheel away from you.
>
> **Panning** lets you move the drawing around the screen, without changing the scale. **To pan**, hold the wheel of the mouse down and drag the mouse.

Continue entering all your traverse legs:

If you make a mistake select **Edit>>Undo** and re-enter the traverse leg.

The undo command can be used at any time you have a problem. There is also a Redo command if you undo too far.

Below are the bearings and distances for this particular tutorial:

| Number	Bearing	Distance
1 (already entered)	320	4.25
2	50	9.11
3	140	15.75
4	230	9.08
5	320	4.23

If the boundary of the area you are mapping does not contain any circular arcs, when you reach the last point, select **Draw>>Line** and click on the first and last points to complete the map.

If the boundary does contain a circular arc, stop when you get to the last 2 traverse legs (the legs attached to the point on the arc).

Press the Cancel button on the Traverse dialogue box.

> **From now on, you should Cancel each dialogue box when you have finished with it, without needing to be reminded.**

Your screen should now look something like this
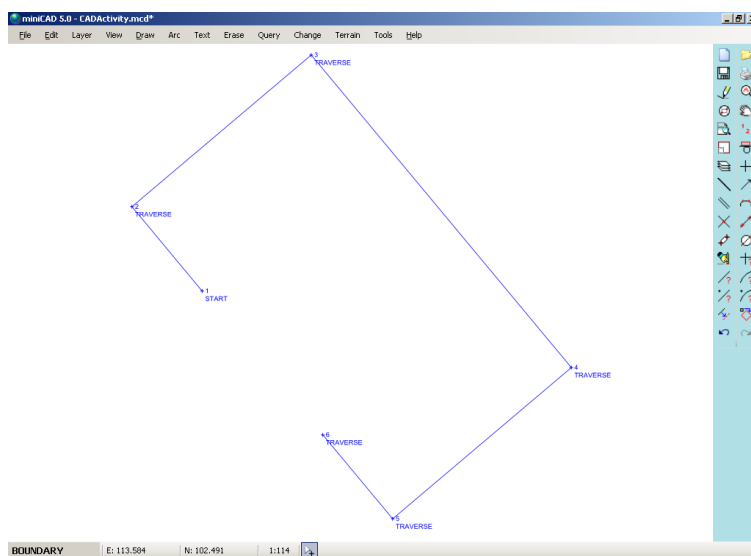
Step 5 – S**elect Arc>>2 Arc Intersection**.
Enter the number of the first endpoint, and the distance measured from it to the point on the arc. Then enter the number of the other endpoint and the distance from it to the point on the arc.
This tells miniCAD to perform a 2 arc intersection. Your dialog box should look like the one below.
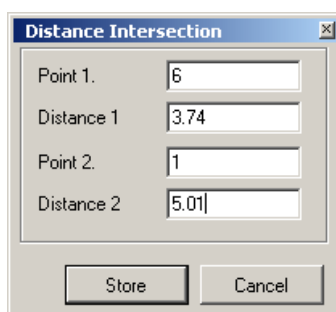
Press the Store button.
Two points should appear on your screen, because two arcs (circles) intersect in two places.
One of the two points should be on the arc location, whilst the other one will be clearly wrong.
Left click your mouse on the wrong point, and press the Delete key on your keyboard to remove it.

**Step 6** – To complete the arc, **select Arc>>3 Pt Arc**.
This command requires you to select the 3 points on the arc in any direction. When you have completed this, press cancel. Your screen should look something like the picture below.
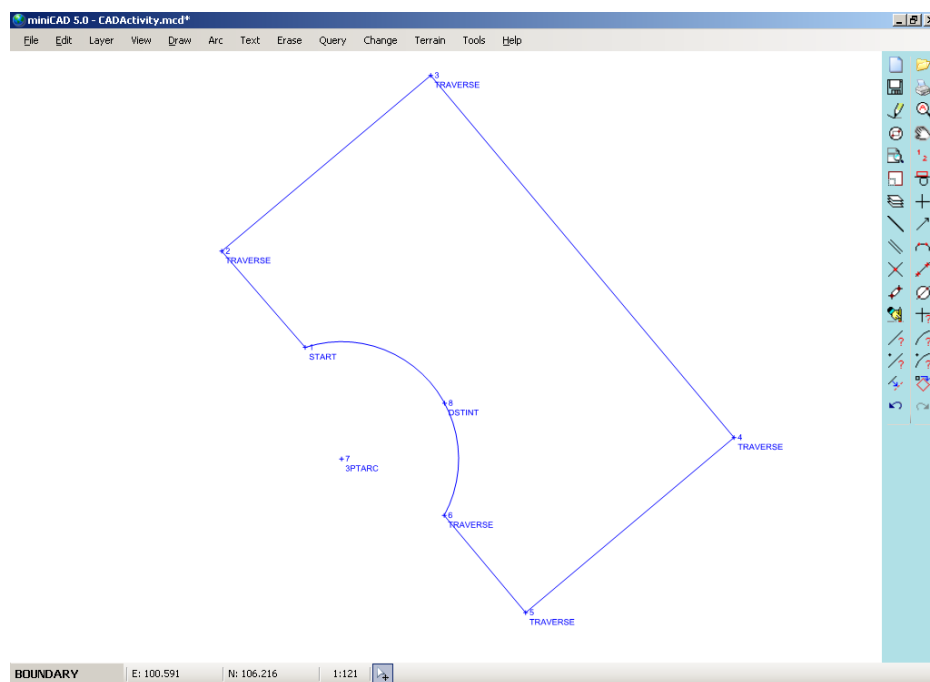
Step 7 – Calculate the area of the lawn using miniCAD

Select Query>>Area from the menu, move your mouse into the centre of the lawn and left click the mouse. The area should be displayed as below.
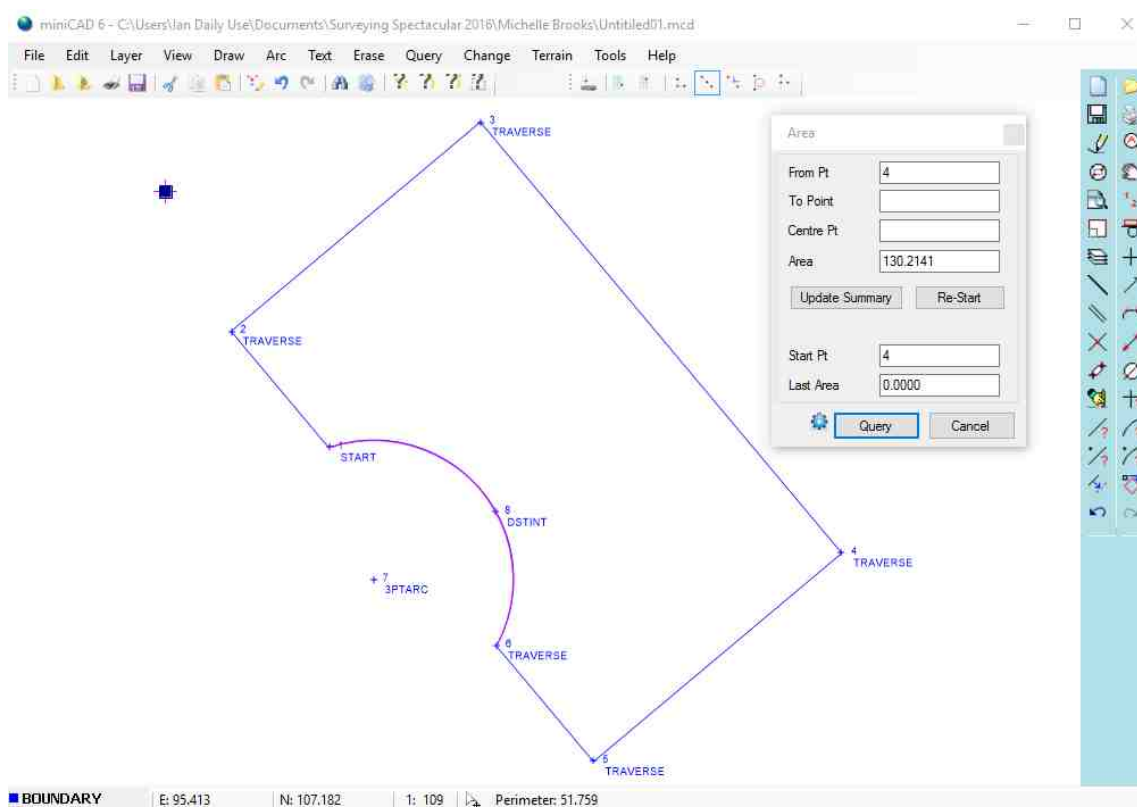
Step 8 – This step is optional. If you have less than 10 minutes available, **skip this step and go on to step 9 to print your map.**

First you need to obtain an **aerial photograph** of the area you have just entered into miniCAD. Open Google Maps on the internet and zoom to the area you have just mapped. The image used in this tutorial can be found at https://goo.gl/maps/zw4tDy59vM62.
Press the **Print Screen** key usually found on the top right of the keyboard. Sometimes the key is labelled PrtSc or PrtScr.

Open Windows *Paint* or another graphics package and paste the image into it. Save it as a TIFF, JPG, BMP, PNG or GIF file. Place this file in the same folder as your miniCAD drawing.
You will now geo-reference the photograph. This involves inserting the photograph into your drawing and aligning it with your map. Follow the instructions on the next page.

Select Draw>>Insert Image from the menu.

Use the mouse to define an area on the screen in which you will place the photograph: Left click on one corner of the screen and drag to the diagonally opposite corner. Make the defined area fill the screen roughly over your drawing. Check that the correct image type is set and select the image file you saved.

Right click the mouse and **select Cancel – Image**.

Right click the again and select **Geo Reference Image**.

Instructions will now appear in the message bar on the bottom right of the screen.

Click on 2 points on the photograph followed by the same 2 points already created in your map. Nothing will happen in the main part of the screen until you have clicked on all four points.

You can pan and zoom the screen while you select these points. You should finish with something like the picture below.
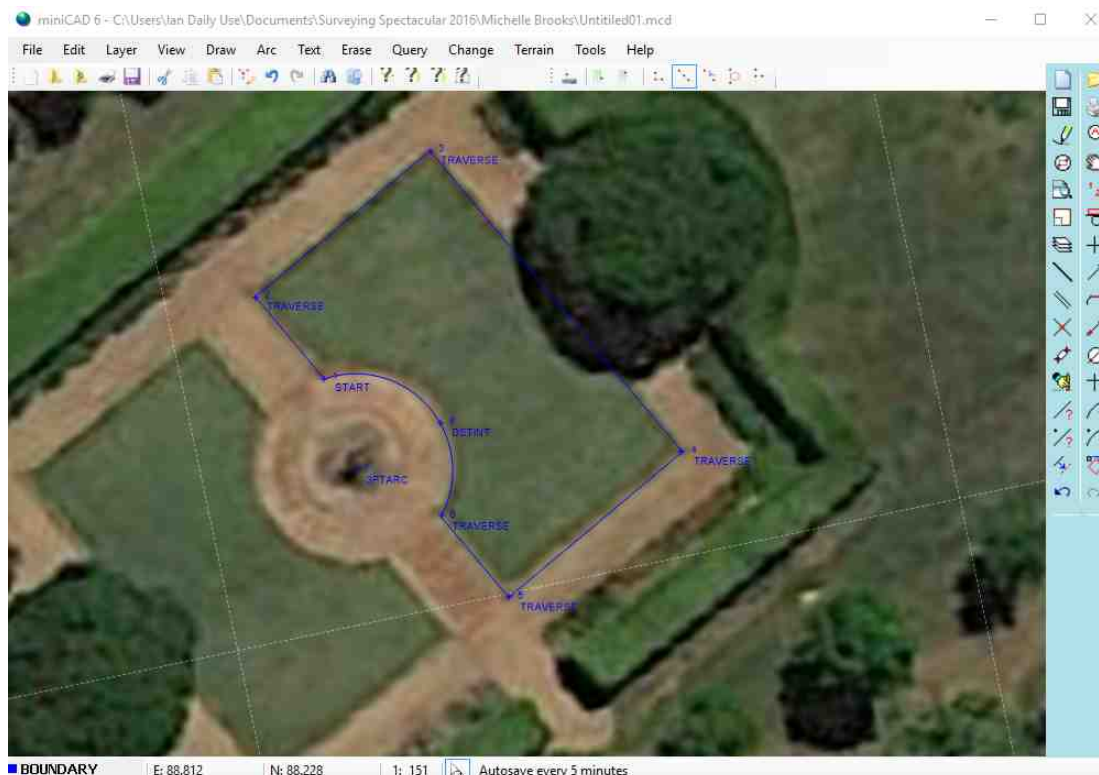
Step 9 – Finally you are ready to **print your drawing**.

Select File>>Plot Window and enter the following information in the dialogue box that appears:

First **select the Title Block**. (A title block provides a border around your plan and some information about the plan.) **From the drop-down list, select BPTitle.ttl**.

Next **drop down to the Scale field** and enter a scale of 150.
Left click your mouse **where you want the bottom left corner of the title block** to be, and the title block will appear on screen. It looks like the outline of a rectangle, in yellow, with a smaller rectangle cut out of it (where the information will go).
If the title block is too small for your plan, change the scale to 150.

P**ut the cursor in the Rotation field** and click on a line in your drawing.
This will align the title block with that line.
You want to get the whole of your plan to lie within the outline of the title block.
If the title block is not quite in the right position, you can move it by left clicking in the drawing area at the location where you think the bottom left-hand corner should be.
You may need to do this a few times as well, before you get it right.
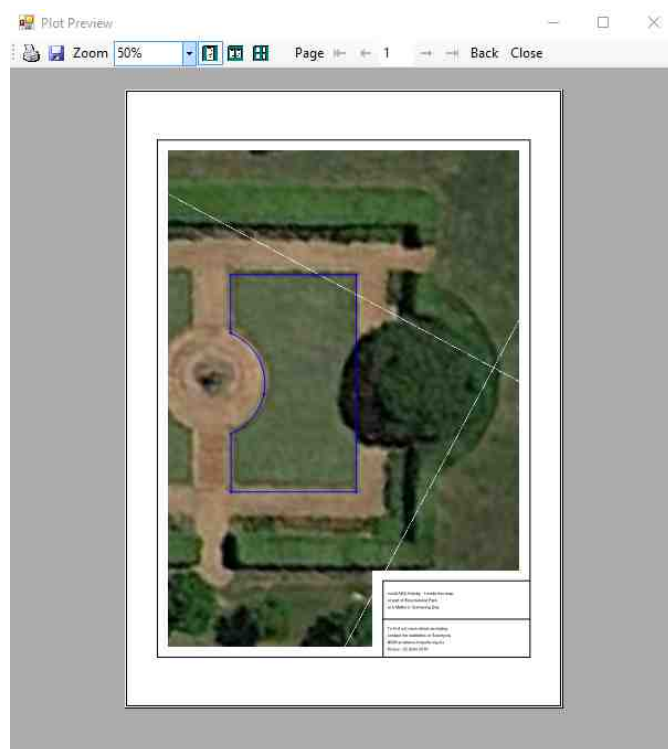
Next select **Output to Print Preview** and **click on the Colour button**.
Ensure the Rows and Columns fields are either blank or have zero in them.
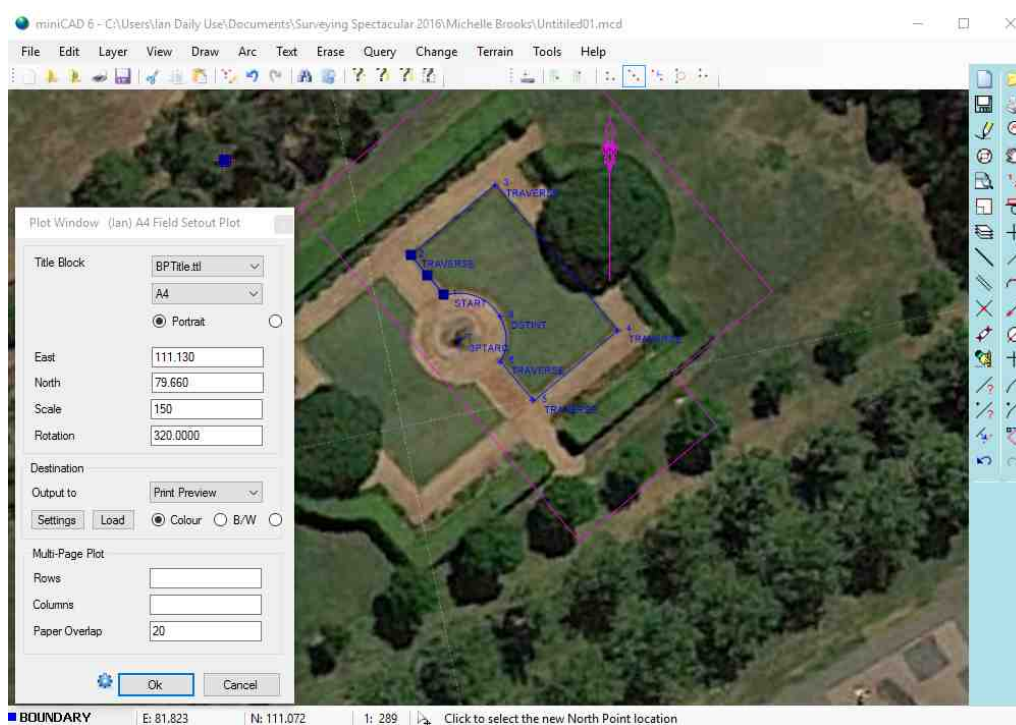
Press OK to view the print preview.

Your plot sheet should look like this:

Press the printer icon in the top left corner of the window above and print your sheet.

Congratulations on completing your miniCAD6 tutorial. Pretty easy isn't it? Press F1 to read the help files and make you an expert in its use. More tutorials and support can be found at http://minicad.mapsoft.com.au/Home/Support.

Activity C: Measuring Heights Using Shadows

Location: **Adjacent buildings**
Duration: **30 minutes**
Assumed knowledge: **Similar triangles or ratios**
Equipment required: **Measuring tape**

In this activity, you will find the height of a structure where you can't reach the top because it is too tall. You can't just run a measuring tape along it, so you need to be clever, and find indirect ways of finding the height.
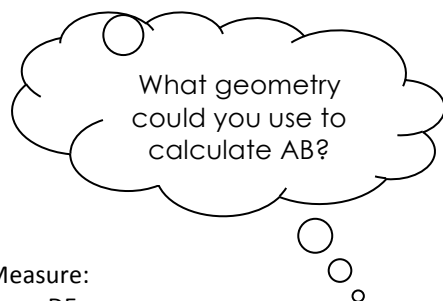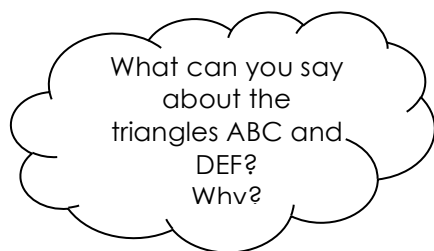
1. Find the height of the top of the structure indicated by your teacher. This may be a building, a tree, a flagpole, or some other structure.

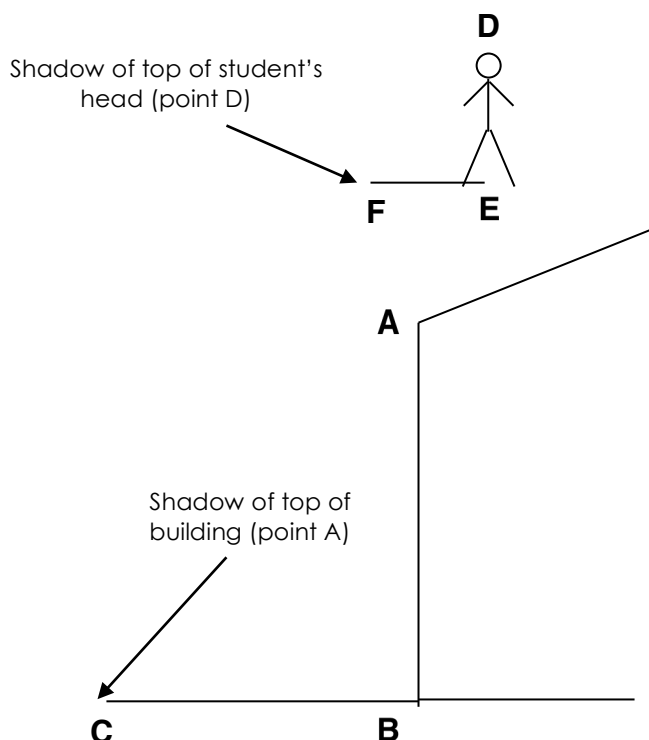You need only a measuring tape.

Ask one of your group to stand upright against a wall. Place a ruler horizontally across their head, and note where it meets the wall. Measure from this point down to the ground to find the student's exact height (DE).
Note where the shadow of the top of the structure falls on the ground (point C).
Mark this point, and measure from the base of the wall to it (BC).

What can you say about the triangles ABC and DEF? Why?

What geometry could you use to calculate AB?

Shadow of top of student's head (point D)

Shadow of top of building (point A)

Measure:

DE = _____ m.
EF = _____ m.
BC = _____ m.
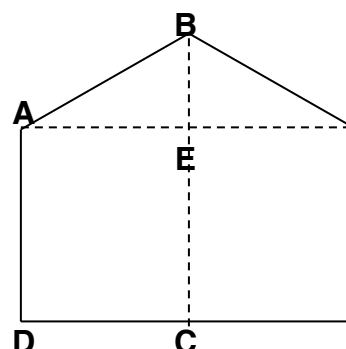Calculate:
AB = _____ m

2. Find the length of the sloping edge of the roof of the building (AB).
Begin by calculating lengths AD and BC (the height above the ground of each corner of the roof), using the same method as you used in part 1.

Measure the distance CD.

Look at the diagram showing the side of the building.

What geometry can you use to find the length of AB?

Activity D: Marking out the corners of a shed

Location:	**Open park/field**
Duration:	**30 minutes**
Assumed knowledge:	**Pythagoras' Theorem, area and volume formulae.**
Equipment required:	(for each group of 4 students) 30m tape, plumbob, spirit level, 4 marker pegs. If

necessary, makeshift plumbobs can be made using string and a small size weight

Preamble: Surveyors are usually employed to set out buildings. There are two reasons for this. Firstly it is important that the building is built in the right shape and that the floor is level. If the building corners are not right angles then it will make it difficult to lay the floor boards, amongst many other problems that will arise. Similar problems will arise if the floor is not level. Secondly the surveyor will make sure that the building is placed inside the boundaries of the block of land. Without the use of a surveyor, it would be much more likely that structures will be built over land boundaries. This would lead to many disputes between neighbours. This exercise allows the students to satisfy the first requirement that the building is both square and level.

Easy exercise

Find a level area large enough to locate a shed 4m long x 3m wide. Students should rotate their jobs so they all get to experience all facets of the shed setout.

1. Push a marker in the ground (this represents 1 corner of the shed)
2. Accurately measure 4 metres with the tape and push a marker in the ground at that location. This represents the 2nd corner of the shed.
3. One student now needs to hold the zero mark on the tape at corner 1. A second student holds the 8 metre mark on the tape at corner 2. A third student holds the 3 metre mark on the tape and stretches the tape tight. Place a marker in the ground at the location of the third student. This is the 3rd corner of the shed.
4. Repeat step 3, with the 3rd student holding the tape at the 5 metre mark. Place a fourth marker at this location, representing the 4th corner of the shed.
5. A surveyor always checks his work is correct. Measure the distance between the 3rd and 4th markers to confirm this is close to 4 metres. Book this reading and see which group gets the best result.

More difficult exercise

Find a site which is sloping. The steeper the slope the harder the exercise. This exercise repeats the above steps and includes a volume calculation. It is important that the first two markers are placed on approximately the same contour on the slope.

1. Push a marker in the ground (this represents 1 corner of the shed)
2. Accurately measure 4 metres with the tape along the same contour as marker 1 and push a marker in the ground at that location. This represents the 2nd corner of the shed.
3. One student now needs to hold the zero mark on the tape at corner A. A second student holds the 8 metre mark on the tape at corner B. A third student, standing on the down hill side of markers 1 & 2 and keeping the tape horizontal, stretches the tape tight. The third student also needs to use the plumbob, to determine a spot vertically below the 3 metre mark on the tape. The fourth student should use the spirit level near the third student to keep the tape as level as possible. Once the tape is level the fourth student should place a marker in the ground at the location of the third student. This is the 3rd corner of the shed. The third student should hold the plumbob string at the height of the tape. Now use the tape to measure the distance from this point to the bottom of the plumbob. Write this distance down as P3.
4. Repeat step 3, with the 3rd student holding the tape level at the 5 metre mark. Place a fourth marker at this location, representing the 4th corner of the shed. Measure the length of the plumbob and book this result as P4.

5. A surveyor always checks his work is correct. Measure the distance between the 3rd and 4th markers to confirm this is close to 4 metres. Use the spirit level and plumbob if this measurement is not level. Book this reading as and see which group gets the best result. Please note that if the distances measured are not horizontal, the shed will not end up having the correct dimensions of 4m x 3m.

6. Calculate the volume of concrete required to purchase for the floor of the shed. This is done using the end area method.
   a. First calculate the area of the vertical right angle triangle formed by markers 1 & 3 and the floor of the shed. This area $A1 = 0.5 (3 \times P3)$.
   b. Next calculate the area of the vertical right angle triangle formed by markers 2 & 4 and the floor of the shed. This area $A2 = 0.5 (3 \times P4)$.
   c. The average area over the length of the shed is $A(av) = 05(A1+A2)$.
   d. The volume of concrete required is then the average area of the ends multiplied by the shed's length, $V = A(av) * 4$.
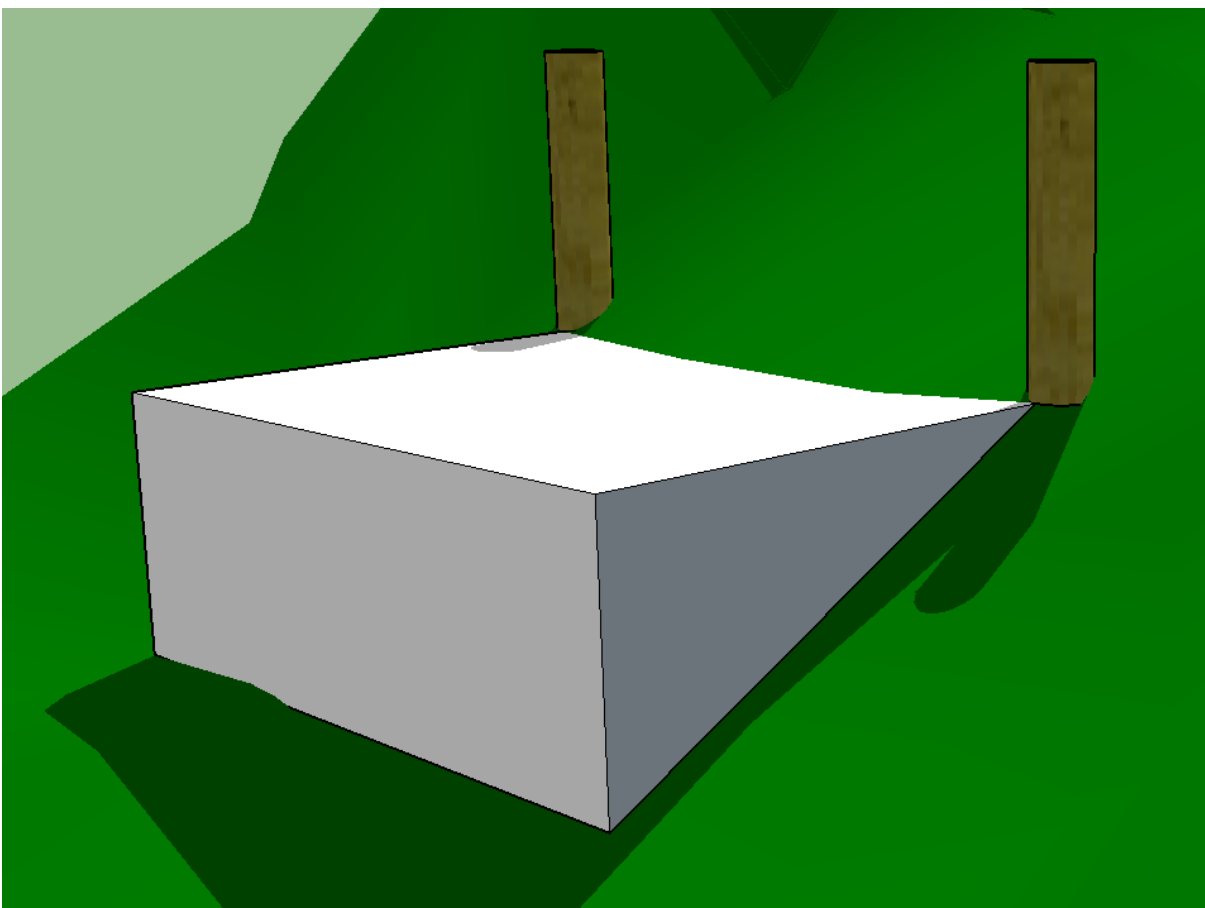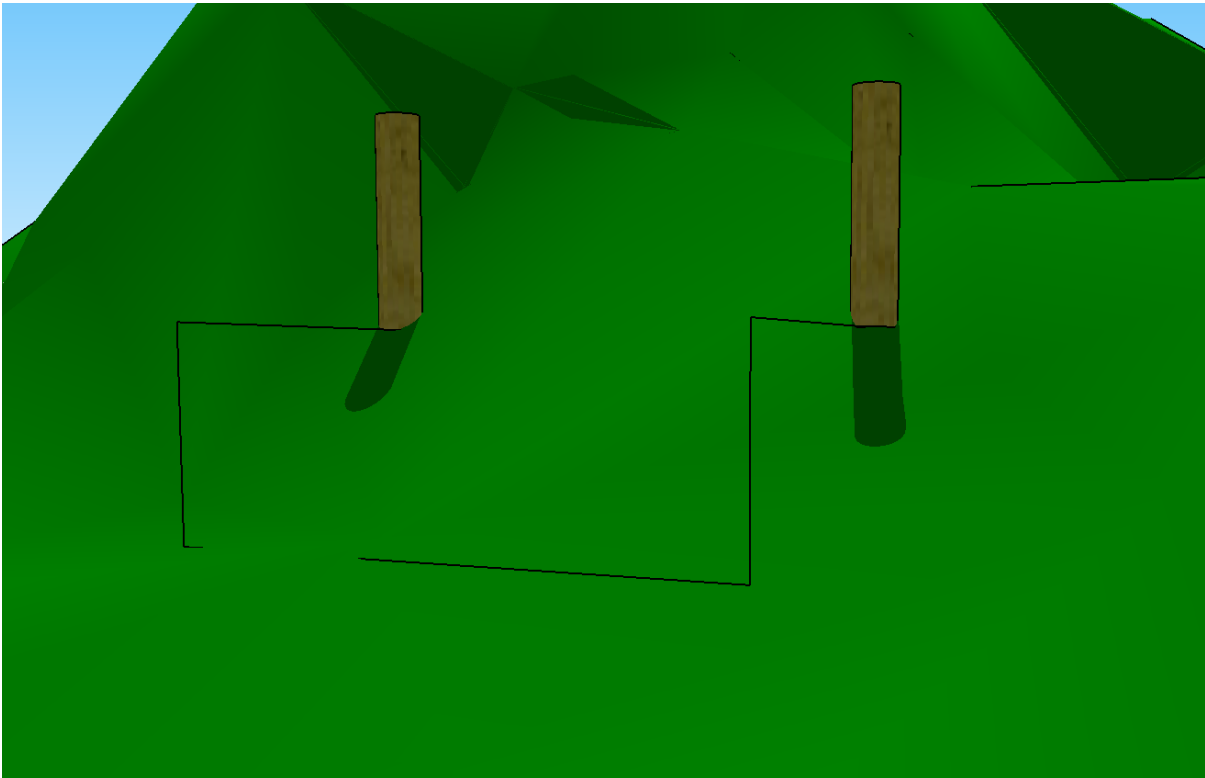
Activity E: Marking a Path through a Minefield

Supervisor sheet

Assumed knowledge: Compass bearings, measurement, accuracy, intersection of circles.
Duration: **30 – 40 minutes**

Equipment required:
    For preparation: If doing the activity on grass, you will need galvanised iron roofing nails and flagging tape to mark out the rectangles. If doing it on a paved surface, mark out the rectangles with chalk.
    For each group: Copy of the student worksheet, 30 m measuring tape, magnetic compass, ball of string, a few galvanised iron roofing nails, sheet of 1 cm grid paper, and geometry instruments—pencil, ruler, compasses and protractor.

Preparation: In the school grounds or some other suitable area like an oval or a park, mark out a rectangle 15.25 m by 10.17 m (note this is one third of a netball court to save you marking out an area). Preferably, it should be laid out on grass, using flagging tape with nails to hold the tape in place, but if that is not possible, mark it with chalk on a paved surface. If several groups are to do the activity simultaneously, you will need to mark out a rectangle for each.
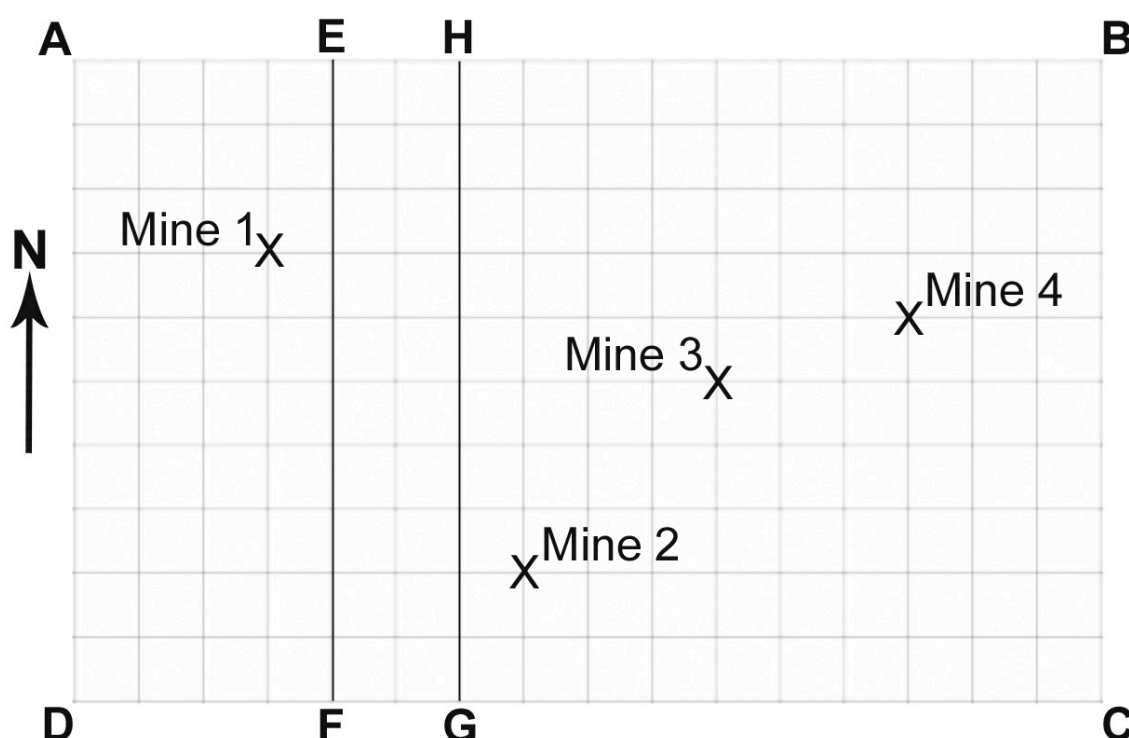
The student worksheet is on the next page.

Assuming coordinates of D are 0,0 then Mine 1 (2.5, 7.0), Mine 2 (6.6, 2.0), Mine 3 (10.0, 5.1),

    Mine 4 (13.5, 6.0)

Solution:

Minefield Map   Scale: 1:100

The solution shown is the only path that meets the requirements and is at right angles to the long sides of the rectangle, and therefore the shortest route. Paths that go at an angle across the area are also possible.

Marking a Path through a Minefield

Student Worksheet

Imagine that land mines have been buried underneath the ground inside the marked rectangle (a block of land). These land mines have been placed by your army and their locations measured relative to 2 corners of the rectangle. Your task is to use information about the positions of the mines to mark out a safe path, so that you can lead a group of refugees through the minefield to safety. In carrying out this task, take care not to step inside the block of land until you have pinpointed the positions of the mines, otherwise you might be blown up! The enemy has placed land mines in unknown locations adjacent to the short sides of this rectangle, so it is not safe to cross to the other side other than inside the rectangle (block of land).

1. Draw a scale map of the rectangle ABCD which contains the mines (see Figure 1). It has been marked out on the ground for you. You are located on side CD and need to cross with the refugees to side AB. Begin by measuring the side CD. Your army has told you that AD and BC are 2/3rds the length of CD. On your grid paper, **draw the rectangle using a scale of 1:100** (i.e. 1 cm to 1 metre). Mark the scale on your map. Assume the line from D to A points North. **Draw an arrow on your grid paper indicating the direction of North**.
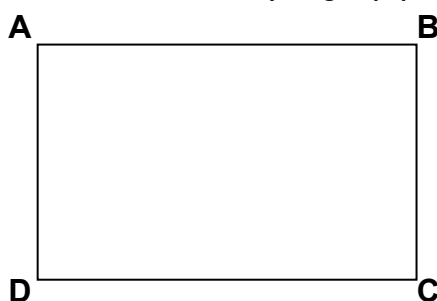

Figure 1

2. Using your geometry tools, draw in the positions of the mines on your map.
Mine 1 is located on a bearing of 142° from A and a distance of 4.0 metres from A.
Mine 2 is located on a bearing of 141° from A and 73° from D.
Mine 3 is located at 7.3 metres from C and 11.2 metres from D.
Mine 4 is located at 4.5 metres from B and 344° from C.

Indicate the position of each mine with an X and a number.

3. Find a safe path from one side of the area to the other and draw it on your map. The path needs to be 2 metres wide and its edges must always be at least 0.9 metres from the mines, in case vibrations from people's footsteps set off one of the mines. Your result may look something like Figure 2. Mark the sides of the path as EF and GH (see methods below).
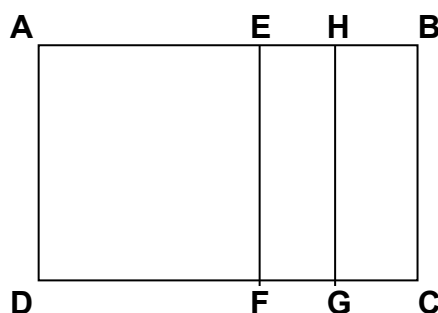

Figure 2

4. Finally, mark your path on the ground: Measure from D to F and mark this point (with something eg a twig). Measure the 2 metres from F to G and also mark this point. Lastly measure the remaining distance from G to C. Add up your 3 measurements DF, FG and GC and make sure they agree with your original measurement. It is important to check your work as you don't want to blow up anyone.

Now the difficult bit. You need to mark where the path cuts the line AB. Think of the best way to do this with the tools you have (a compass and tape). There are 2 obvious ways (but are there others?):

a. Mark out a 3,4,5 triangle. To use this method, measure 3 metres from F along the line CD and mark this point (lets call it P). Measure towards D if F is further from D than C. Otherwise if F is closer to C measure towards D. This is to make sure that the 3 metres falls inside the line CD. Outside the endpoints of line CD you may get blown up! Get one of your group to hold the end of the measuring tape on the ground at P. A second member of the group pulls the tape out along the ground to point G. You should be reading 5 metres on the tape now! Why? This member should now move approximately to the mid point of FG. A third member of the group should now hold 9 metres on the tape and place it on the ground at point F. Now the member still holding the tape at 5 metres should walk approximately down the centre of the path until the tape is pulled tight on the ground. Mark this point (lets call it Q). You should have a 3,4,5 triangle! What is the angle DFQ. Now extend the line FH until it intersects AB at E. Now you can easily mark point H and get your refugees safely across.

b. With a magnetic compass, take a bearing along the long side CD. As a check on your accuracy, take a bearing from D to C. The two bearings should differ by 180° ± 5° (the accuracy of your handheld compass). Now subtract 90° from bearing DC and record this bearing. Stand at point F and turn the compass until you read the recorded bearing. Sight this bearing across to intersect line AB and mark this point (E). (make sure you walk down the centre of the imaginary path so you don't blow yourself up!)

Now regardless of which method you used, measure along line AB to mark points E & H. Make sure you check your work as you did along line CD.

Congratulations. You can now safely take your refugees across this block of land.

If you have time, try using both methods to mark the safe path across the block of land. Which method do you think is more accurate? Why

References/Contacts

QLD	Surveying & Spatial Science – Land Surveying Commission	
	Website:	www.sssi.org.au
	Phone:	(07) 3217 2566
	Email:	reo.qld@sssi.org.au
VIC	Surveying Task Force	
	Website:	www.alifewithoutlimits.com.au
	Phone:	(03) 9326 8173
	Email:	trysurveying@alifewithoutlimits.com.au
NSW	NSW Surveying Taskforce	
	Website:	www.alifewithoutlimits.com.au
	Phone:	(02) 9294 4475
	Email:	trysurveying@alifewithoutlimits.com.au
ACT	Surveying & Spatial Science – Land Surveying Commission	
	Website:	www.sssi.org.au
	Phone:	(02) 6282 2282
	Email:	chair.act@sssi.org.au
SA	Surveying & Spatial Science – Land Surveying Commission	
	Website:	www.sssi.org.au
	Phone:	n/a
	Email:	chair.sa@sssi.org.au
NT	Surveying & Spatial Science – Land Surveying Commission	
	Website:	www.sssi.org.au
	Phone:	(08) 8995 5345
	Email:	chair.nt@sssi.org.au
TAS	Surveying & Spatial Science – Land Surveying Commission	
	Website:	www.sssi.org.au
	Phone:	(03) 6272 2034
	Email:	reo.tas@sssi.org.au
WA	Surveying & Spatial Science – Land Surveying Commission	
	Website:	www.sssi.org.au
	Phone:	(08) 9386 6601
	Email:	reo.wa@sssi.org.au

Teacher support

For questions on how to utilise these resources, please email the following people:

Registered Surveyor
Ian Iredale: ian@mapsoft.com.au

Mathematics Teacher
Mary Barnes: marybarnes@tpg.com.au

MiniCAD software may be downloaded for non-commercial, educational purposes from
http://minicad.mapsoft.com.au/. For any issues with downloading or using the software, please contact Ian Iredale on ian@mapsoft.com.au or 0418 488 342.