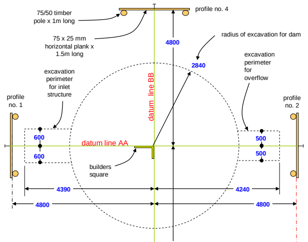
APPENDIX F: Technical and Construction

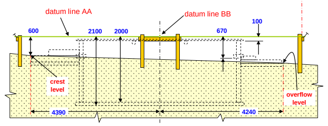
APPENDIX F1. Standard RWH Dam: **Drawings**

Printing options for on-site use of these drawings:

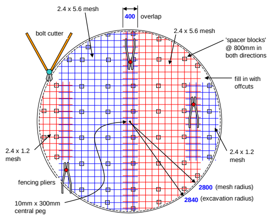
- **Twelve A4 sheets, bound as a booklet, OR**
- **Two A1 sheets, laminated back-to-back, OR**
- **One A0 plan sheet**



Dwg 1 - Set up of Profiles and outline of Excavation

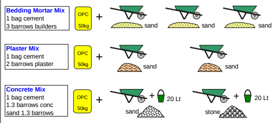


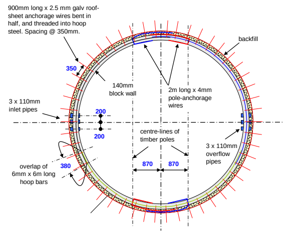
Dwg 2 - Section through Datum line AA



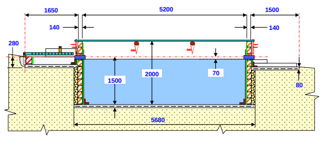
Dwg 3- Arrangement of ref 193 mesh in floor (cut from 2.4m x 60m roll)

Table 1 - Mixes for RWH Tanks

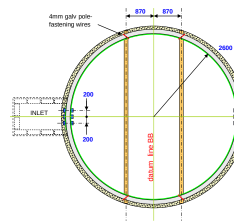




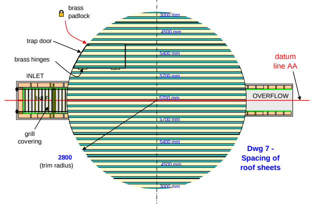
Dwg 4- Arrangement of 6mm hoop steel bars, and 4mm & 2.5 mm galvanised wires - at 400mm below roof level



Dwg 5 - Sectional Dimensions



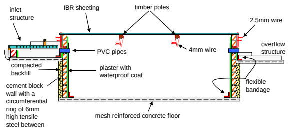
Dwg 6 - Position of Roof Poles



Dwg 7 - Spacing of roof sheets

Table 2 : Bill of materials (including inlet and overflow)

quantity incl waste		units	material	area of application	% waste assumed
dam	I & O				
14	1.6	m	2.45m wide ref 13 mesh	floor	5%
1		kg	4 mm wires (cutting length = 2000mm)	wall / roof	20%
4		kg	2.5 mm wires (cutting length = 900 mm)	wall / roof	13%
1		kg	1.6mm binding wire	floor / wall	5%
27		bars	6m x 6mm hoop Y bars	wall	0%
28	3	barrows	river sand (total = 1.8m3)	floor / inlet	15%
28	3	barrows	19mm stone (total = 1.8m3)	floor / inlet	15%
30	3	bags	50kg bags	floor/wall/inlet	15%
6	0.5	drum	water (200-litre drums)	floor/wall/inlet	50%
33	1.4	sq m	cement blocks	wall / inlet	5%
	18	bricks	bricks	overflow	15%
2		m	pvc pipe (6 pipes x 300mm long)	wall	10%
8	0.5	barrows	barrows mortar sand (total = 0.5m3)	wall	15%
9	0.5	barrows	barrows plaster sand (total = 0.6m3)	wall	15%
16	4	1m	200mm wide flexible bandage	floor/wall	5%
36	4	litres	waterproof coat (superlaycold)	wall	9%
2		poles	5.4m x 125/100 poles	roof	0%
3		sheets	0.5mm x 5.7m galv IBR sheeting	roof	0%
2		sheets	0.5mm x 5.4m galv IBR sheeting	roof	0%
2		sheets	0.5mm x 4.5m galv IBR sheeting	roof	0%
2		sheets	0.5mm x 3.0m galv IBR sheeting	roof	0%
32		screws	sheet fastening wood-screws (6mmx65mm)	roof	5%
32		screws	roof washers	roof	5%
1		lock	brass lock	trapdoor	0%
2		hinges	brass hinges	trapdoor	0%
16		bolts	M5 x 20mm gutter bolts and nuts	trapdoor	0%
	1	cover	protective cover	inlet	0%
	1	sq m	chicken mesh (strainers for PVC pipes)	inlet/overflow	0%



Dwg 8 : Elements of Design

Table 3: Additional Notes on the Drawings and Tables

Dwg 1 : The quality of the eventual structure will be improved and the time taken to build it will be reduced if profiles are erected before any construction commences. These should take the form of a Maltest cross, with each profile approximately 4800mm away form the centre of the dam. Nylon fish lines may be strung between the the profiles (fastened to the nails in the horizontal plank). The two datum lines (AA and BB) so formed make it easy for subsequent measurements, and are used to establish the position of (1) the centre of the dam, (2) the perimeter for excavating, (3) the walls, (4) the timber poles, and (5) the sheeting.

Dwg 2 : The datum lines are equally useful for setting out the various key elevations, such as depth of excavation, depth of floor-slabs, invert level of PVC pipes, top of the wall. The horizontal planks of all four profiles must be 600mm above the 'crest level' of the yet-to-be-built inlet structure. The crest level is the prevailing ground level on the perimeter of the inlet structure 4390mm from the centre of the dam - it determines all the levels associated with the dam and inlet structure, but not that of the overflow structure, which is determined by the 'overflow level'. (The overflow level is not related to the crest level or datum lines, and is simply the prevailing ground level at 4240mm from the centre of the dam - it determines the level of the overflow's floorslab).

Dwg 3 : The configuration of the assembled ref 193 mesh used to reinforce the concrete floor is shown. The individual pieces of 1.2m x 2.4m (2off) and 5.6m x 2.4m (2 off) are cut from a 60m roll. They are assembled and tied together with 1.6mm binding wire in a suitable flat space somewhere outside the hole, and trimmed into a circle of radius 2.8m. The assembly is now lowered into the hole, and then lifted onto 50mm high concrete 'spacer-blocks' every 800mm in both directions. This has the effect of positioning the mesh in the centre of the 100mm slab. Note that the minimum overlap is 400mm. There is a 40mm clearance to the side of the excavation.

Dwg 4 : Three 6mm x 6m reinforcing bars are tied together, with a minimum overlap of 380mm, to form a hoop that lies in the centre of the wall at the start of each course. At the top of the eighth course 900mm long x 2.5mm sheet-anchorage wires, bent in half, are inserted into the hoop and made to protrude radially outwards. These wires are spaced 350mm appart all the way around the circumference. In addition four 4mm U-shaped pole-anchorage wires are positioned directly below where the future timber poles will be installed, i.e. 870mm off datum line BB. The legs of the U are unequal, being respectively 600mm and 1250mm, while the base of the U is 150mm, making the full length 2m long. These wires also placed beneath the hoop steel. The long leg is on the outside of the dam.

Dwg 5 : The key dimensions of the tank for a 30m3 capacity are indicated. The tank protrudes by at 500 mm out of the ground.

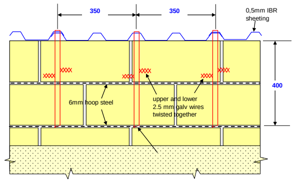
Dwg 6 : Three 110mm PVC pipes, each 300mm long and spaced 200mm apart, are positioned in the inlet and overflow sides of the dam. Their invert levels are 670mm below the datum lines.
In the top course two 125/100 treated timber poles, 5.4m long, are placed in prepared openings in the wall and spaced 870 mm from datum line BB. If the poles are not straight they must be rotated so that they arch upwards as this increases the stiffness of the roof. Finally the poles are bricked in, and later fastened using the 4mm wires, with the long leg of the wire going over the pole

Dwg 7 : This shows the layout of the IBR roof sheeting. The first sheet is placed such that its central ridge lies directly below datum line AA. The other sheets are simply lipped in the sequence indicated. The sheets must extend over the edge of the wall by the same amount on both sides. Although the sheets are 762mm wide, after overlapping their cover width is only 686mm. One of the 5400mm sheets is cut to make provision for a trap door, which has two strong 100mm brass hinges to attach it to the adjacent 5.7m sheet. Six M5 x 20mm gutter bolts and nuts are used to attach each hinge. (Consult appendix F11 for the detailed sequence showing how to make the trap door). The tap door is locked by means of a pad-lock.

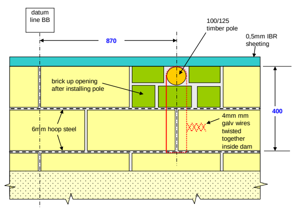
The sheets are fastened to the poles using the appropriate screws (see dwg 11), and to the wall by means of wires as indicted in fig 9 and 11. Finally the sheets are cut to a radius of 2800mm, which should ensure that the sheets overlap the outside wall by approximately 60mm.

Dwg 8 : This is a cross section through datum line AA and shows the various components of the dam. Each component may be identified in table 2, where the quantities are given.

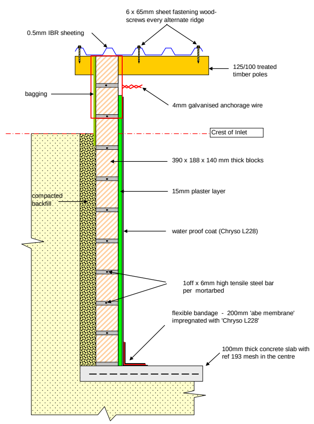
Dwg 9 : This elevational view of the outside of the wall shows how the roof sheeting is anchored to the wall using 2,5mm galvanised fencing wire that was embedded into the wall at least 400mm below the top. The wires are spaced 350mm apart all the way around the circumference. Two wires are used at each point, each 900mm long. The first is anchored into the wall in the mortarbed between the eight and ninth course - as expalined in dwg 5. The second is bent into an upside down U, the legs of which are pushed through 3mm holes drilled in the roof sheeting. The hole spacing should not be less than 30mm, and clearly the base of the U must correspond with this spacing. The upper and lower wires may now be tied off as indicated.



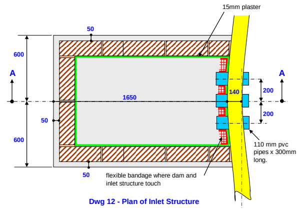
Dwg 9 - Detail for Fixing sheets to Wall (view from outside of wall)



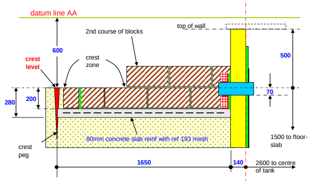
Dwg 10 - Detail for Fixing Beam (view from outside of wall)



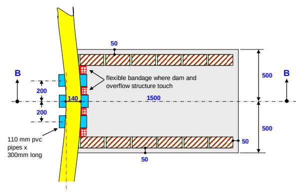
Dwg 11 - Section through Wall at Roof-Pole



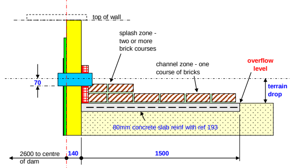
Dwg 12 - Plan of Inlet Structure



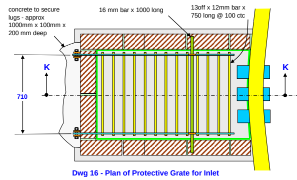
Dwg 13 - Section A-A through Inlet Structure



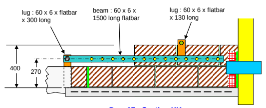
Dwg 14 - Plan of Overflow Structure



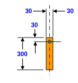
Dwg 15 - Section B-B through Overflow Structure



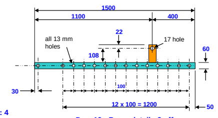
Dwg 16 - Plan of Protective Grate for Inlet



Dwg 17 - Section KK



Dwg 18 - Lug detail : 4 off



Dwg 19 - Beam detail : 2 off

Dwg 10 : This is a view of the wall from the outside of the tank, and shows how the roof-pole opening is filled in with brick and mortar once the pole is in the correct position. Thereafter the pole is fastened to the wall by means of the 4mm galv wires that were previously embedded at least 400mm below the top of the wall. See also notes under 'Dwg 4'.

Dwg 11 : This shows a section of the wall built on top of a 100mm mesh reinforced concrete slab. In this wall 10 courses of 390 x 188 x 140 blocks are used, with 12mm mortarbeds and perps, giving a vertical module of 200mm. Clearly this module will vary from area to area depending on the height of the blocks. A hoop, made up of three 6mm high tensile steel bars, is built into each mortar-bed in all but the bottom bed. 4mm galvanised wires are built into the wall to anchor the beams - discussed more fully in dwg 4. A 15mm thick layer of plaster is applied to the wall's internal face (see table 1 for proportioning). This is followed by the application of two coats of 'Chryso L228' to the walls as per the instructions on the packaging. Where the wall meets the floor a 200mm abe membrane is placed, impregnated with 'Chryso L228'. The membrane reinforces the corner, and prevents leakage in the event of cracks developing at the wall/floor interface (which may occur as a result of thermal, or moisture, or settlement movements). The upper section of the drawing shows how the IBR sheeting is fastened to the timber poles - every alternate ridge there is a 65 x 6mm sheetfixing woodscrew anchoring the sheets to the poles. Around the circumference U shaped 2.5mm wires (each 900mm long) are pushed through drilled holes in the ridges of the sheeting and tied off against other 2.5 mm galv wires (also 900mm long) that were previously built into the wall approximately 400mm below roof level (see also dwg 9).

Dwg 12 : This is a plan view of the inlet prior to the installation of the protective cover. It consists of a 1650mm x 1200mm x 80mm thick concrete slab reinforced with ref 193 mesh. The mesh is cut such that it has a 40mm clearance relative to the walls of the excavation, and its cut size is therefore 1570mm x 1120mm. Prior to casting, the mesh is supported on 50mm concrete blocks spaced at 800mm in both directions. 390 x 140 x 188 high blocks are laid on top of the slab as indicated, with only one course in the 'crest' zone where the water runoff flows in, and an additional course in the 'berm' zone which touches the dam's wall. Finally two coats of ChrysoL228 are applied in the areas where the inlet and tank touch. Before the second coat is applied, a 200mm wide abe membrane is laid down and this must be fully impregnated by the second coat.

Dwg 13 : This is a sectional view of the inlet structure taken through the centre line. Note that the crest is 600mm lower than datum line AA - and this becomes the reference level for the construction of the inlet.

Dwg 14 : The same principles apply here as for the construction of the inlet discussed above in dwg 12. The main differences are that the floor slab is slightly smaller (1500mm x 1000mm x 80mm), and bricks rather than blocks will suffice (since the overflow channel does not need to be deep).

Dwg 15 : This is a sectional view of the overflow structure taken through datum line AA. Note that the elevation of the structure is referenced to the prevailing level of the ground at the exit of the overflow, and thus bears no relation to datum line AA.

Dwgs 16 - 19 : These dwgs show how a protective grill may be placed over the inlet. There is sufficient detail given for a workshop to manufacture it.

Table 1 : This gives the mix proportions for mortar (for building the walls of the dam, inlet and overflow); for plaster (to render the respective wall on their inside faces); and for concrete (for the various floorslabs). In each case the proportioning relates to one bag of cement.

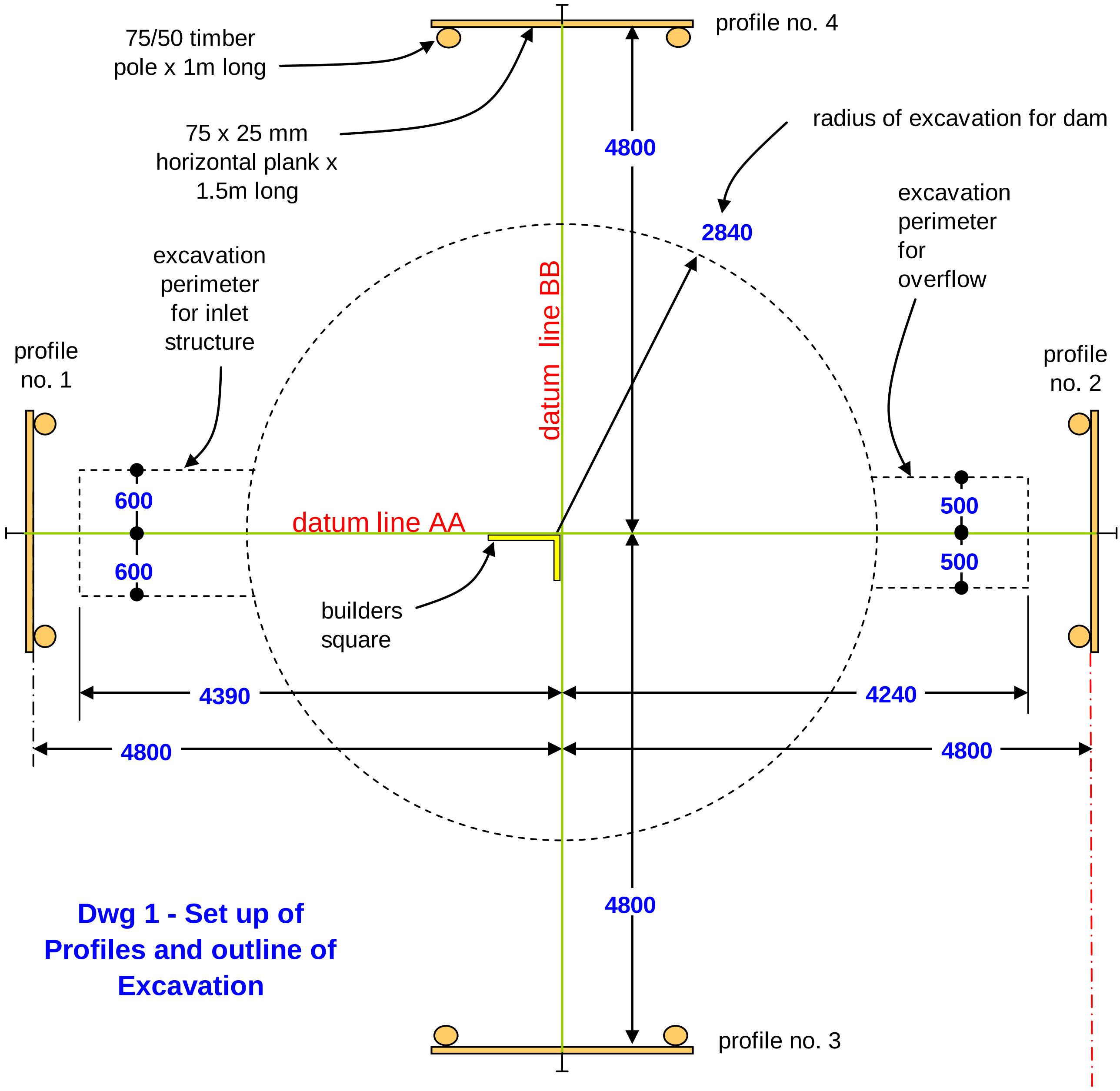
Table 2 : This is a bill of materials for the complete tank. These quantities include a wastage factor on some of the materials - see the last column for the percentage waste assumed.

Table 3 : This table makes brief observations on the various drawings shown here describing the Standard RWH tank. For a more in depth discussion on the various materials and construction approaches see appendices F4, F9, and F11.

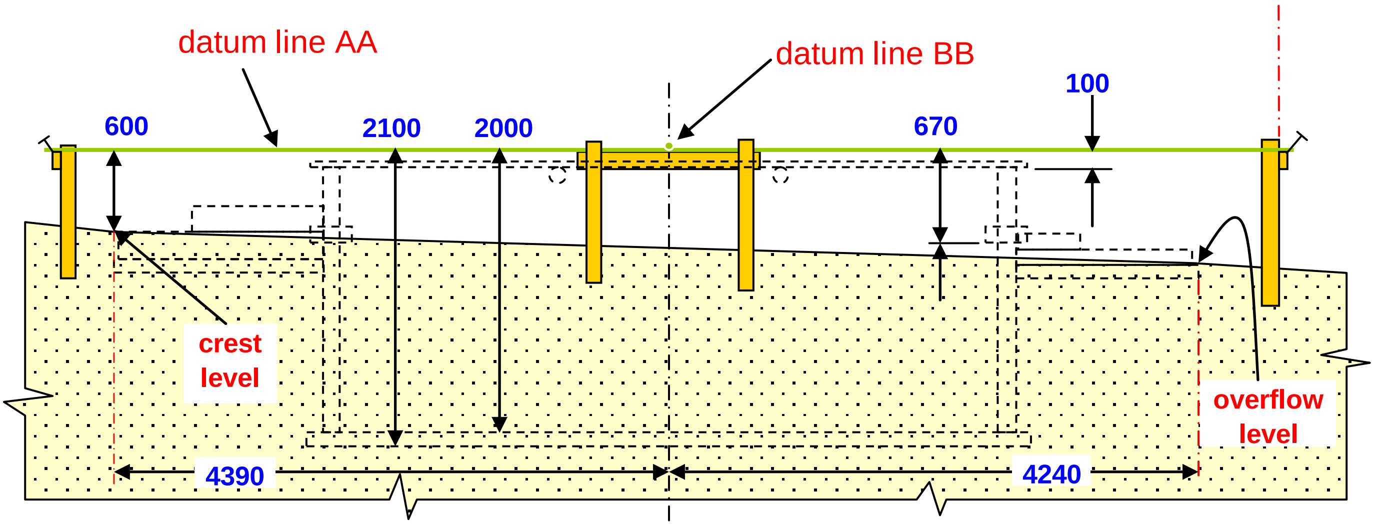
Appendix 6 : Standard RWH Dam

Sunken Cylindrical Tank : 30m^3 : Block Wall on top of RC slab : May2007

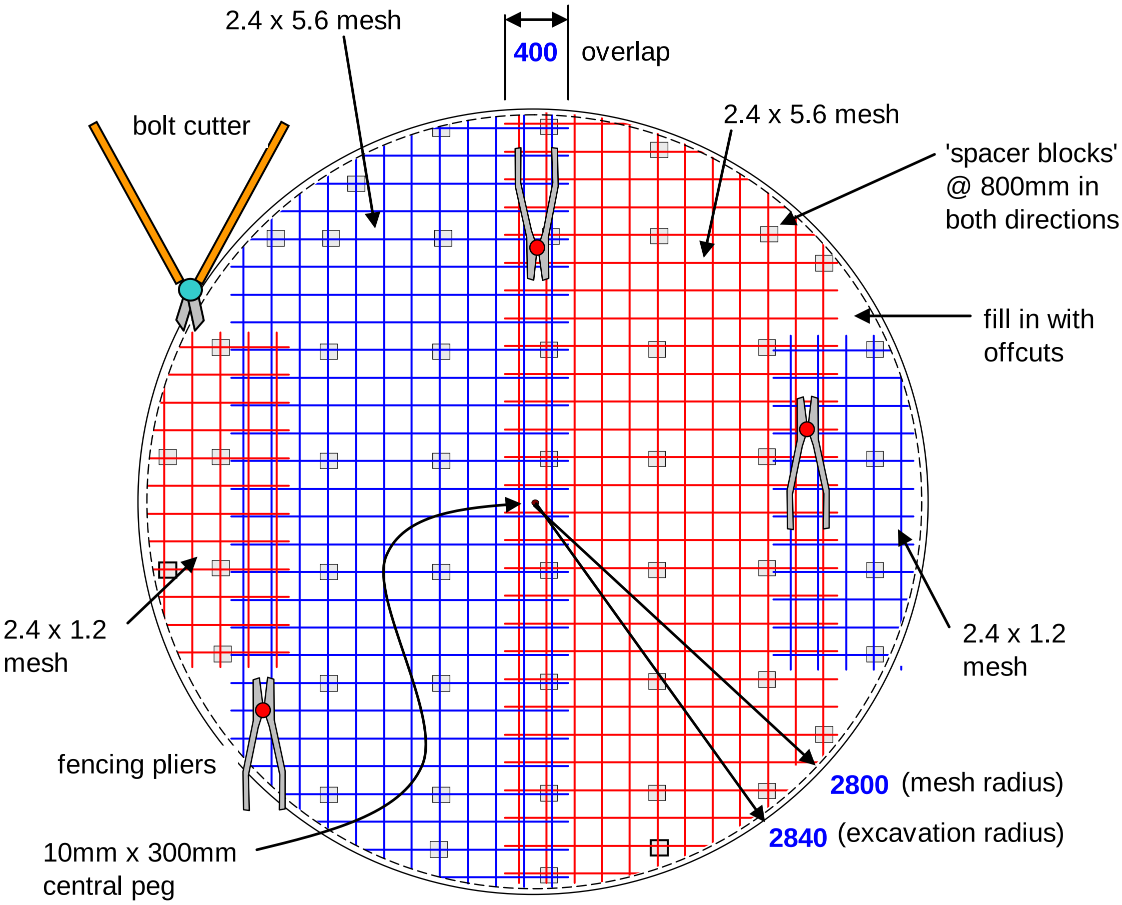
Note: The 12 pages shown above may be printed and either handed out as stapled sheets, or arranged as above and laminated. The main emphasis in these drawings is the finished product. See appendix F4 and F5 which respectively describe and illustrate the construction process.
Navigation: It is useful to set the screen on 25% to view all the pages at once, then click near the image you are looking for and revert back to 100% for detailed view. Note however that the sketches are somewhat distorted on the screen, with the y-axis being larger than the x-axis. This is a necessary 'trick' to obtain the correct aspect ratio when printing.



Dwg 1 - Set up of Profiles and outline of Excavation



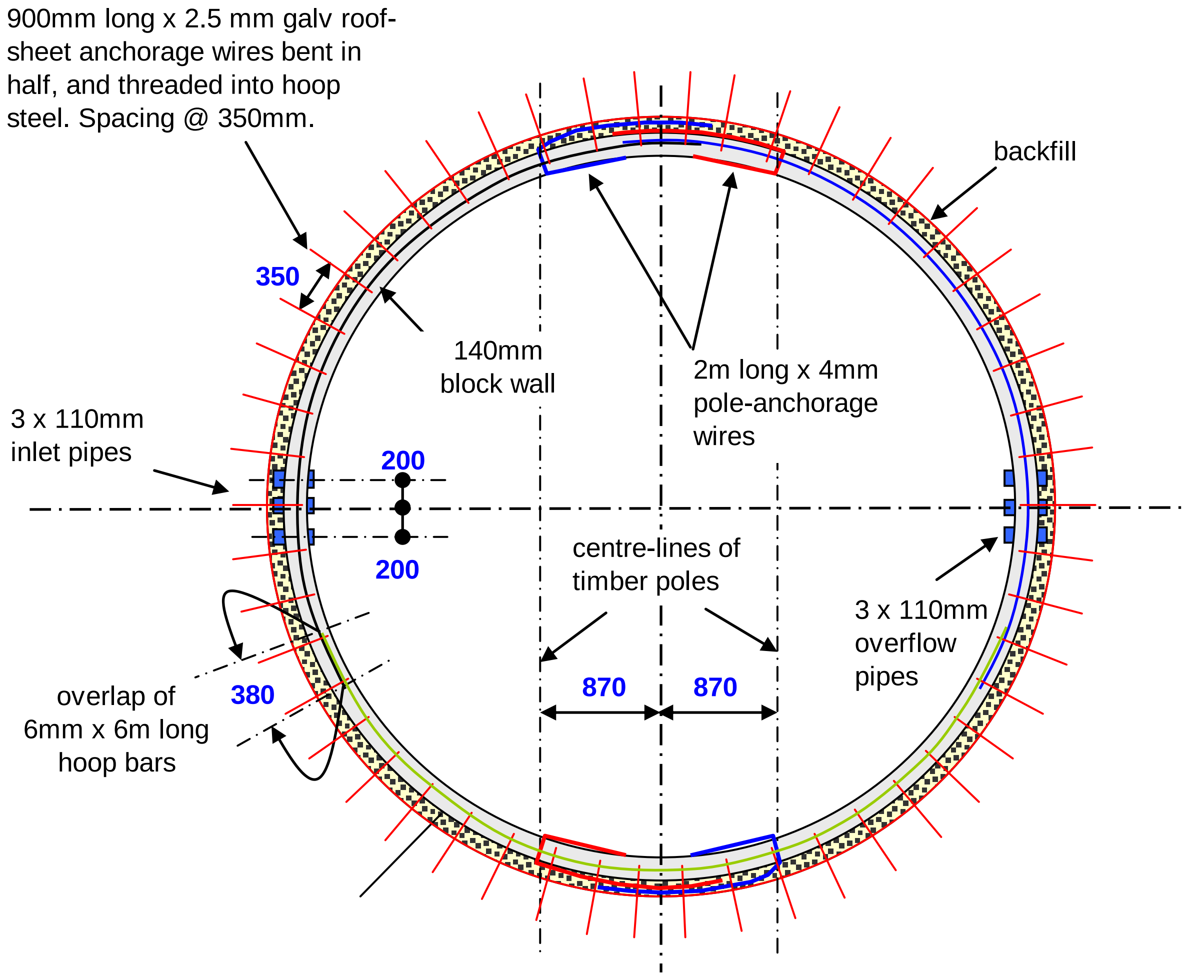
Dwg 2 - Section through Datum line AA



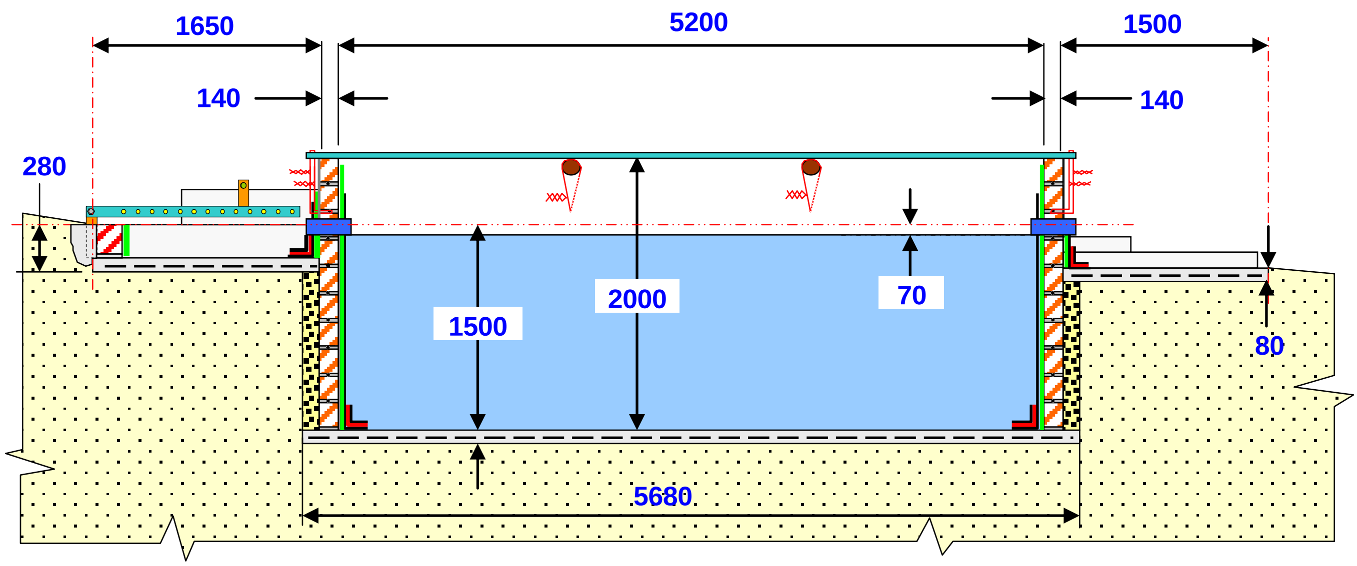
Dwg 3- Arrangement of ref 193 mesh in floor (cut from 2.4m x 60m roll)

Table 1 - Mixes for RWH Tanks

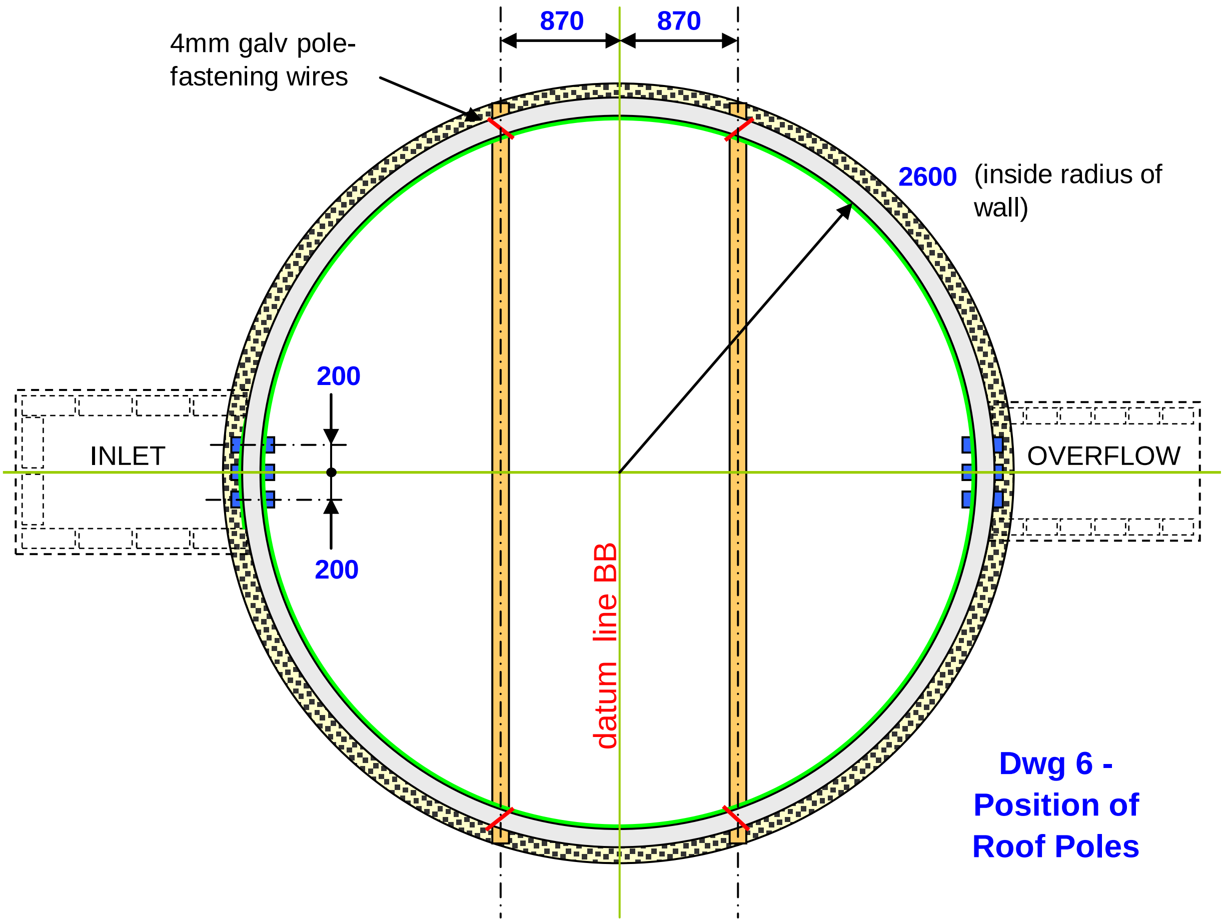
Bedding Mortar Mix 1 bag cement 3 barrows builders	OPC 50kg	+	sand, sand, sand
Plaster Mix 1 bag cement 2 barrows plaster	OPC 50kg	+	sand, sand
Concrete Mix 1 bag cement 1.3 barrows conc sand 1.3 barrows	OPC 50kg	+	sand + 20 Lt, stone + 20 Lt



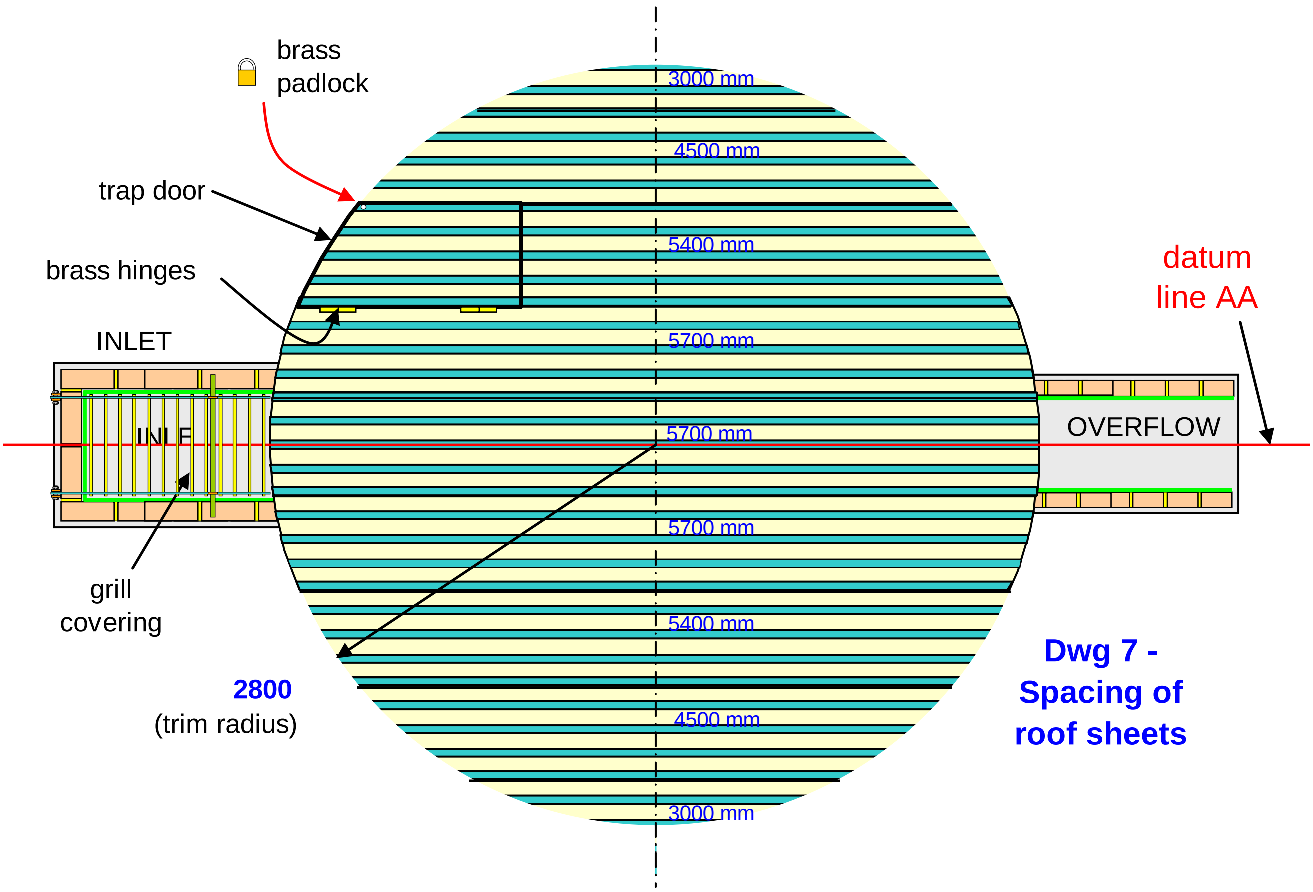
Dwg 4- Arrangement of 6mm hoop steel bars, and 4mm & 2.5 mm galvanised wires - at 400mm below roof level



Dwg 5 - Sectional Dimensions



Dwg 6 - Position of Roof Poles



Dwg 7 - Spacing of roof sheets

Table 2 : Bill of materials (including inlet and overflow)

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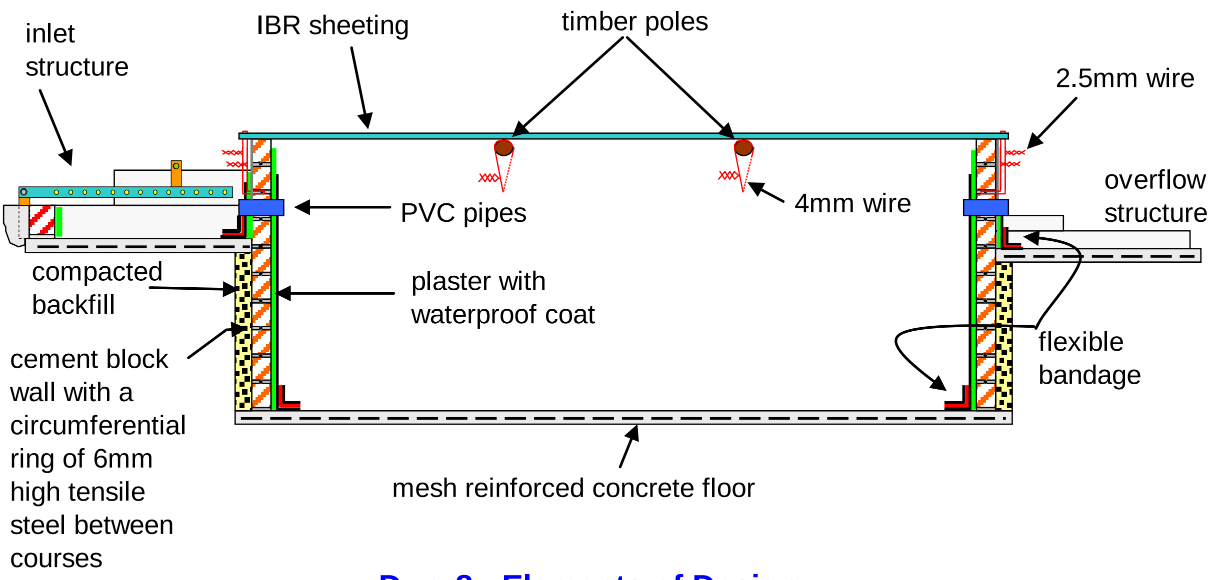
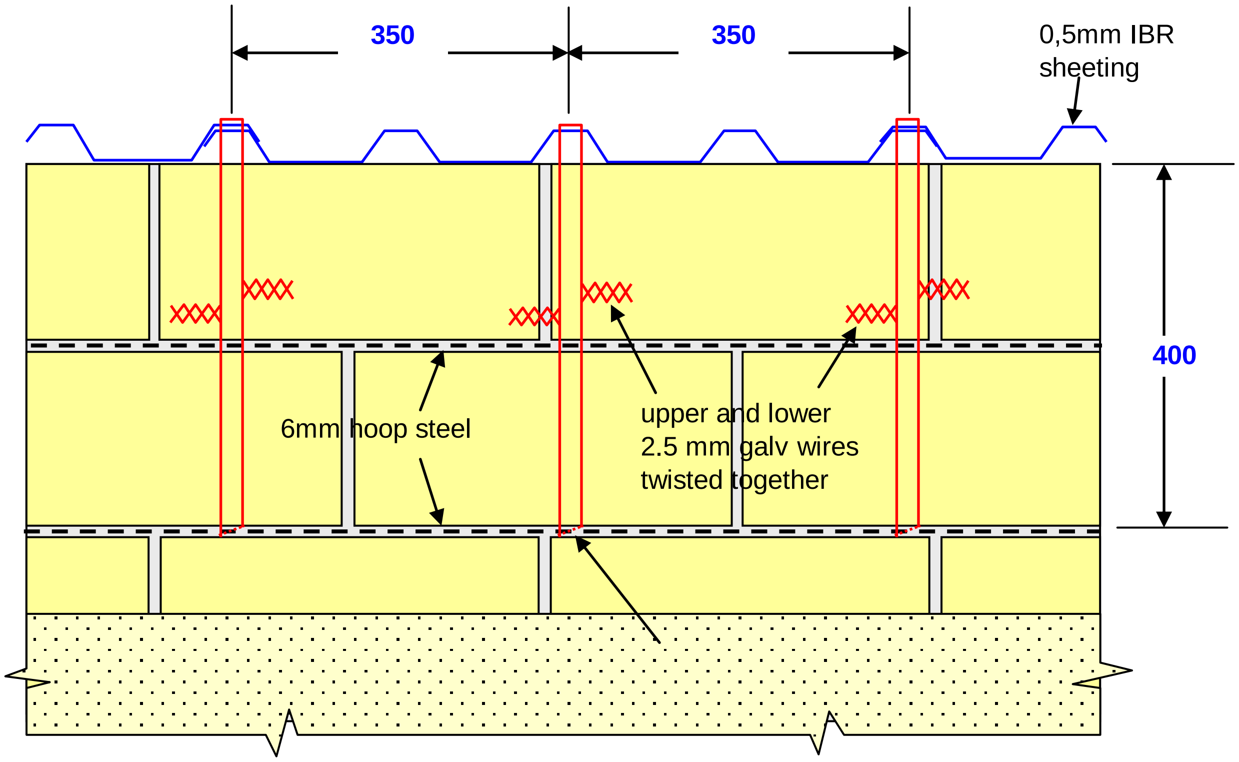
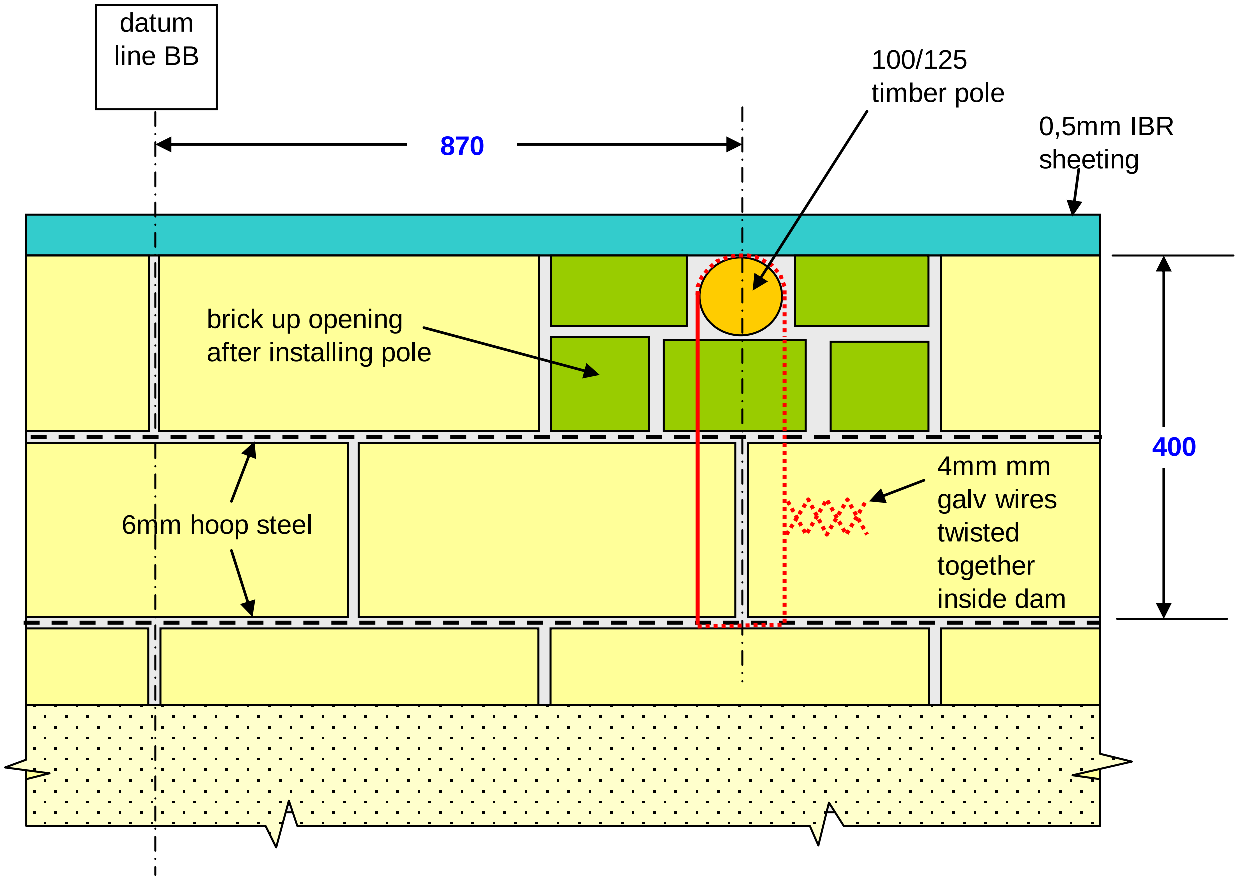
28	3	barrows	river sand (total = 1.8m3)	floor / inlet	15%
28	3	barrows	19mm stone (total = 1.8m3)	floor / inlet	15%
30	3	bags	50kg bags	floor/wall/inlet	15%
6	0.5	drum	water (200-litre drums)	floor/wall/inlet	50%
33	1.4	sq m	cement blocks	wall / inlet	5%
	18	bricks	bricks	overflow	15%
2		m	pvc pipe (6 pipes x 300mm long)	wall	10%
8	0.5	barrows	barrows mortar sand (total = 0.5m3)	wall	15%
9	0.5	barrows	barrows plaster sand (total = 0.6m3)	wall	15%
16	4	1m	200mm wide flexible bandage	floor/wall	5%
36	4	litres	waterproof coat (superlaycold)	wall	9%
2		poles	5.4m x 125/100 poles	roof	0%
3		sheets	0.5mm x 5.7m galv IBR sheeting	roof	0%
2		sheets	0.5mm x 5.4m galv IBR sheeting	roof	0%
2		sheets	0.5mm x 4.5m galv IBR sheeting	roof	0%
2		sheets	0.5mm x 3.0m galv IBR sheeting	roof	0%
32		screws	sheet fastening wood-screws (6mmx65mm)	roof	5%
32		screws	roof washers	roof	5%
1		lock	brass lock	trapdoor	0%
2		hinges	brass hinges	trapdoor	0%
16		bolts	M5 x 20mm gutter bolts and nuts	trapdoor	0%
	1	cover	protective cover	inlet	0%
	1	sq m	chicken mesh (strainers for PVC pipes)	inlet/overflow	0%



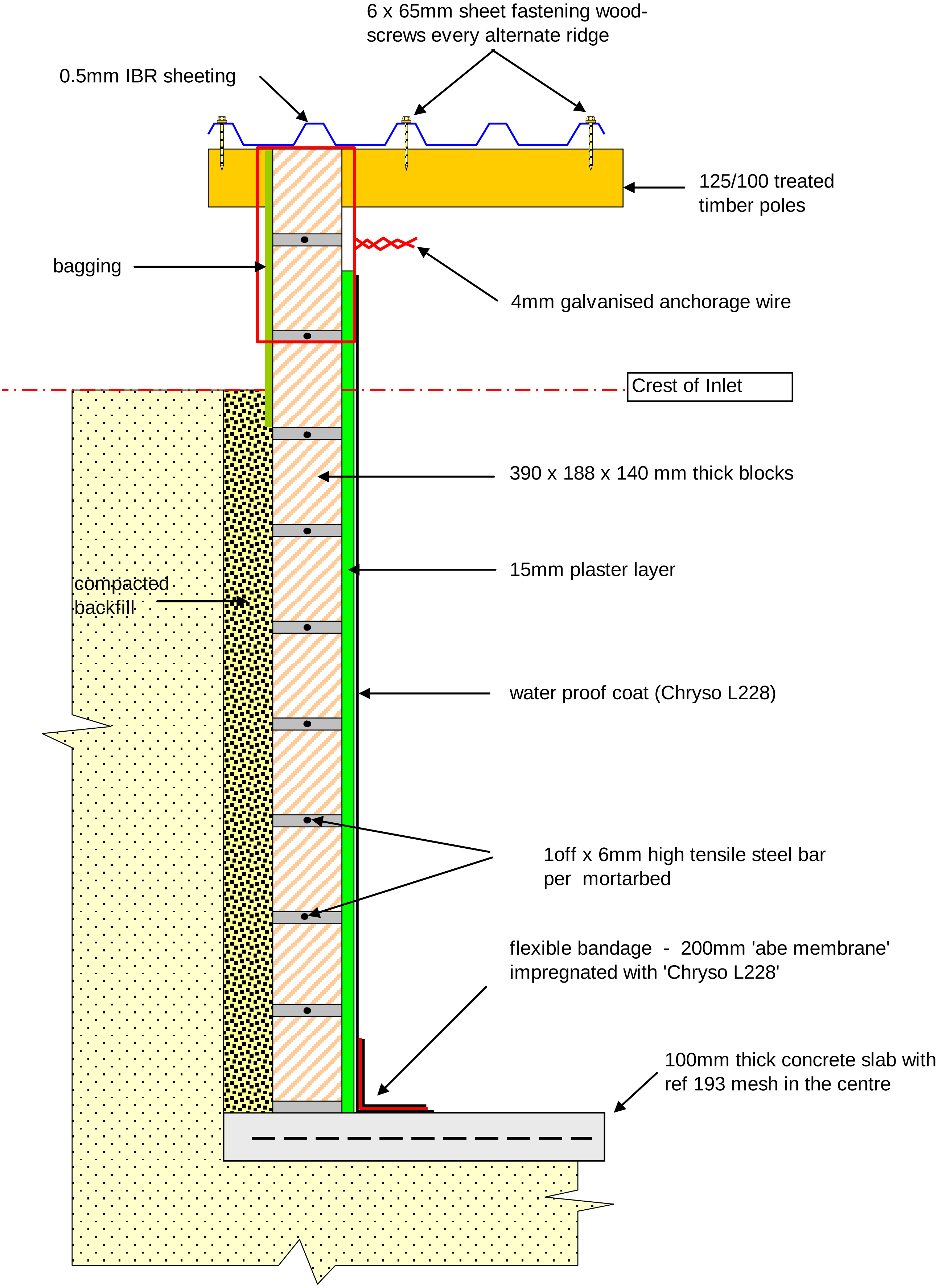
Dwg 8 : Elements of Design



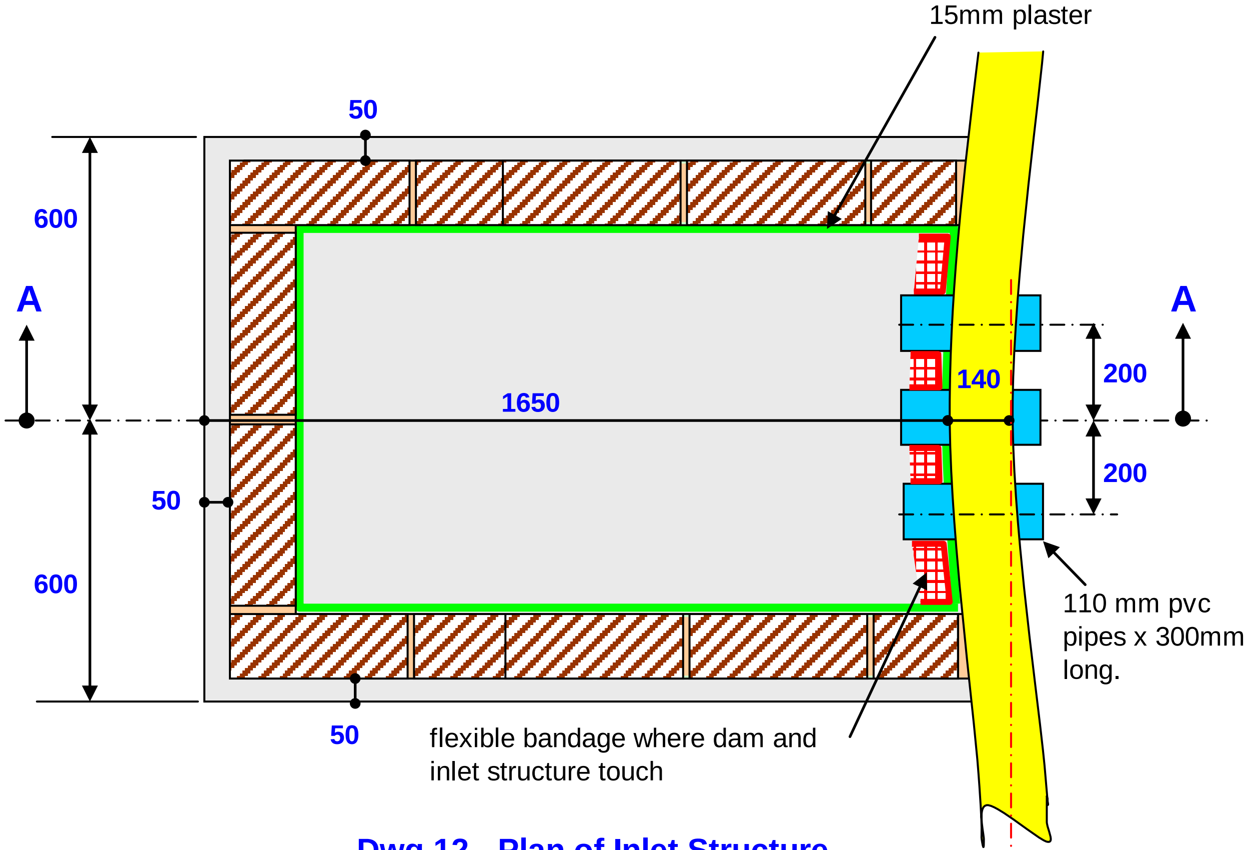
Dwg 9 - Detail for Fixing sheets to Wall (view from outside of wall)



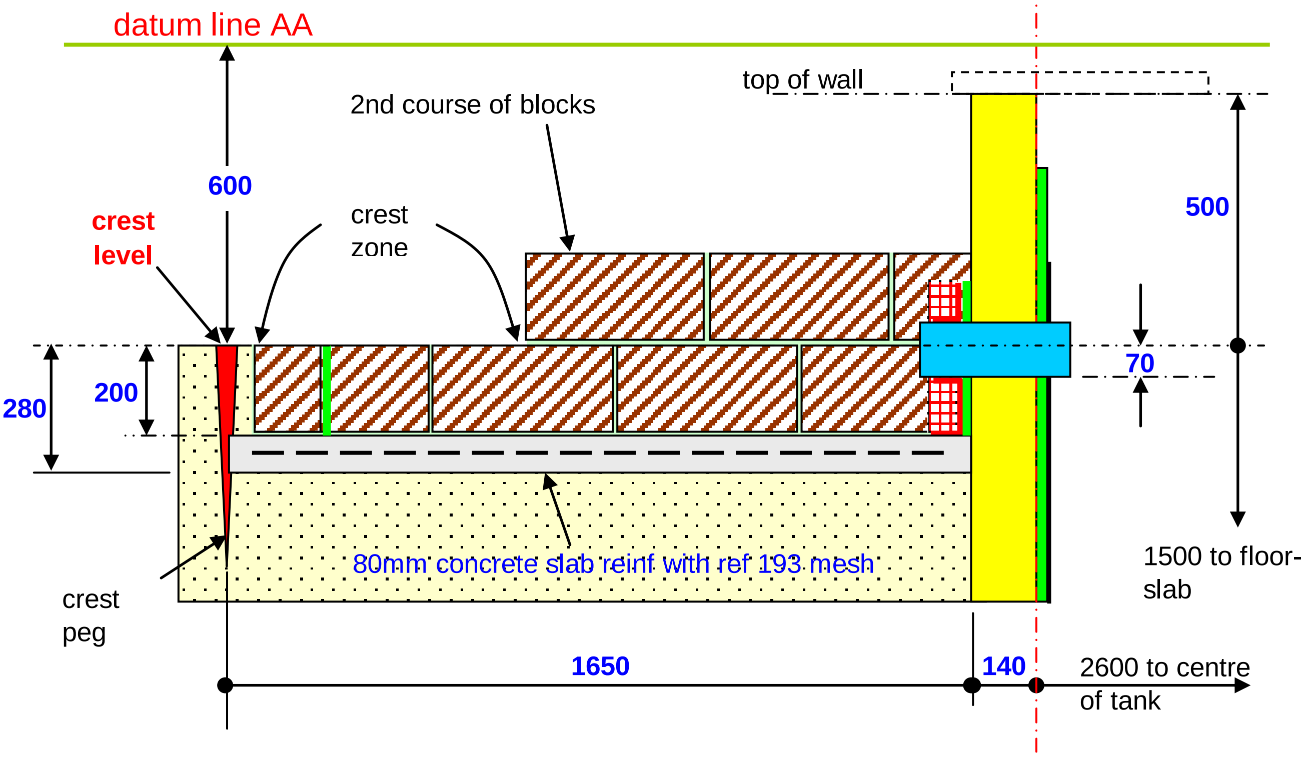
Dwg 10 - Detail for Fixing Beam (view from outside of wall)



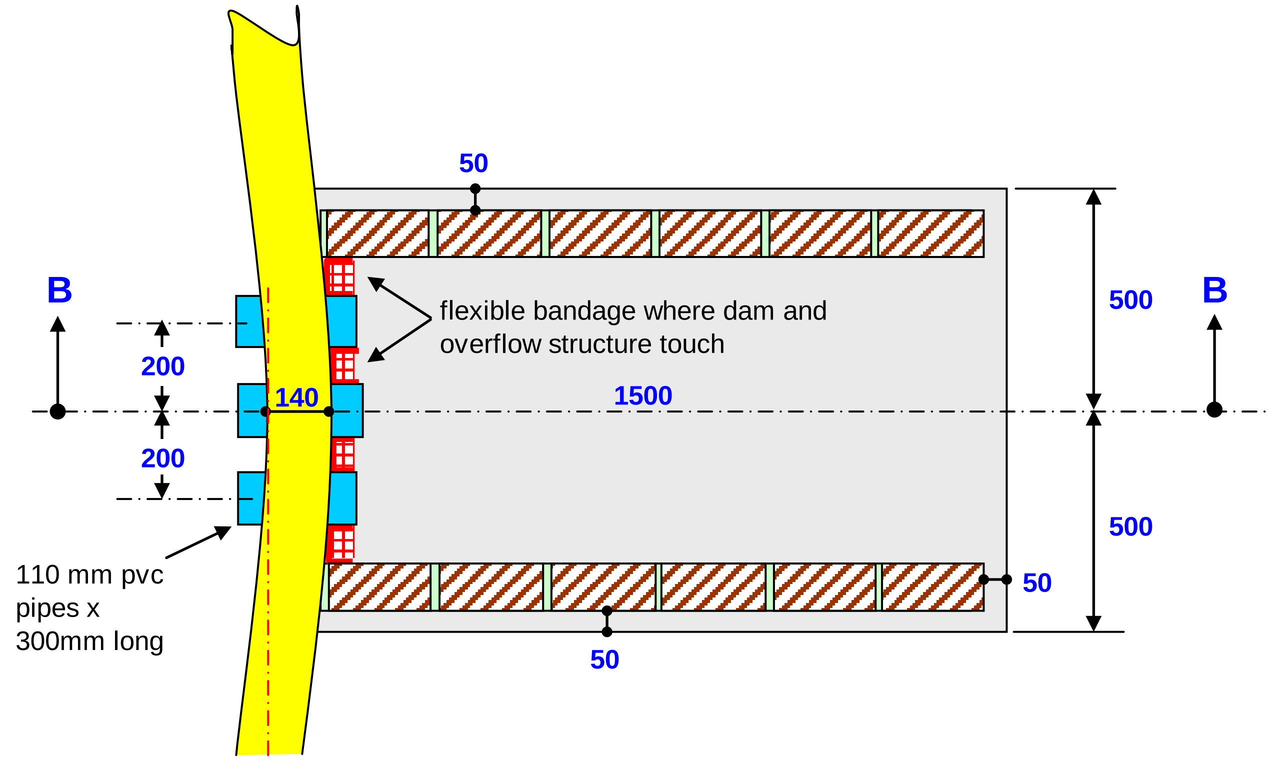
Dwg 11 - Section through Wall at Roof-Pole



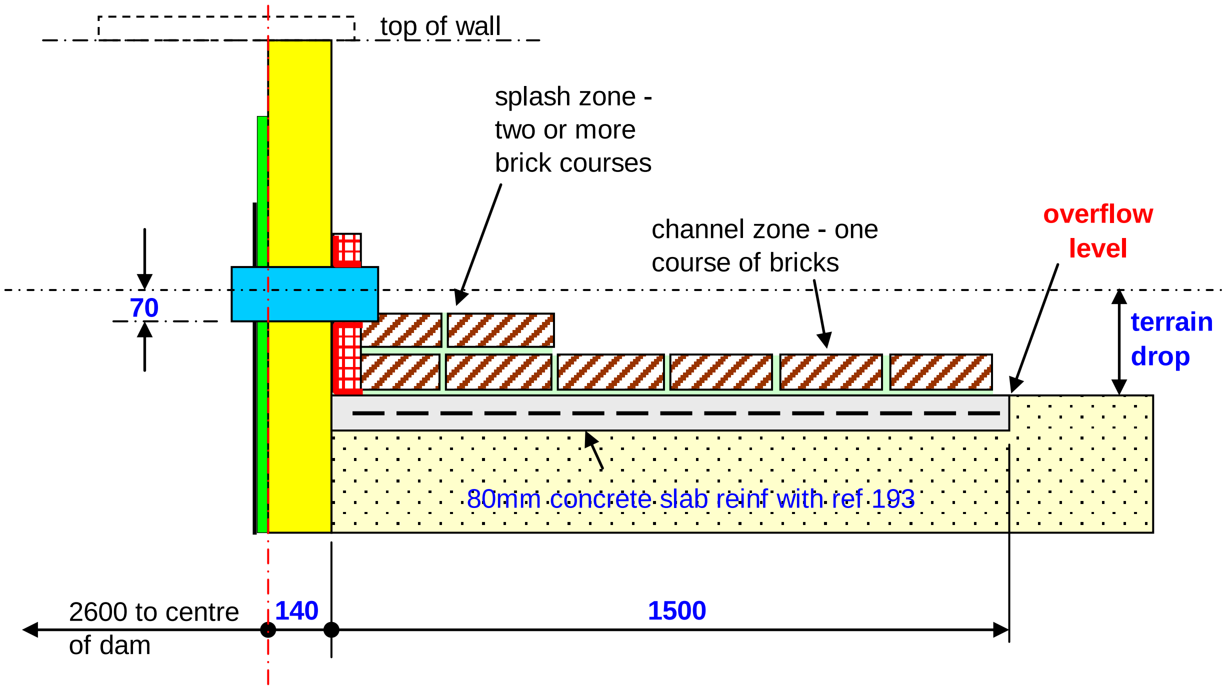
Dwg 12 - Plan of Inlet Structure



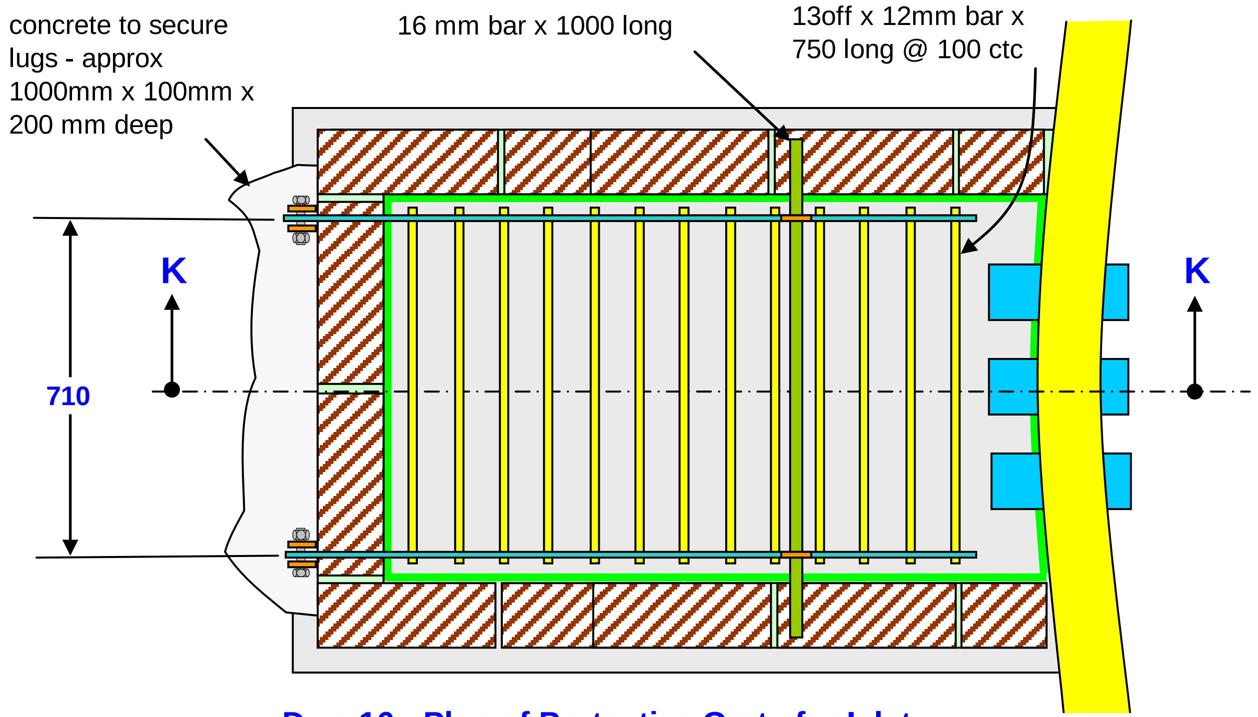
Dwg 13 - Section A-A through Inlet Structure



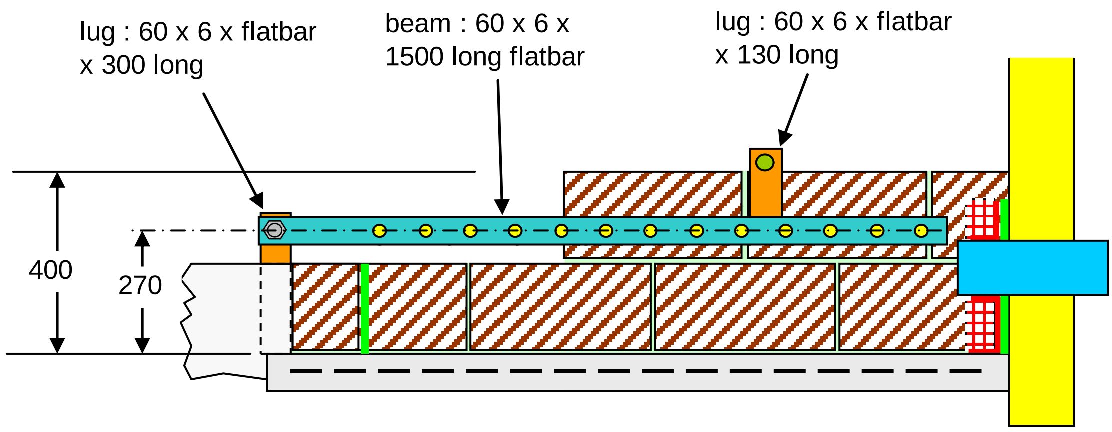
Dwg 14 - Plan of Overflow Structure



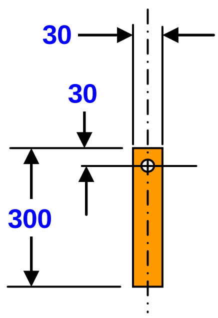
Dwg 15 : Section B-B through Overflow Structure



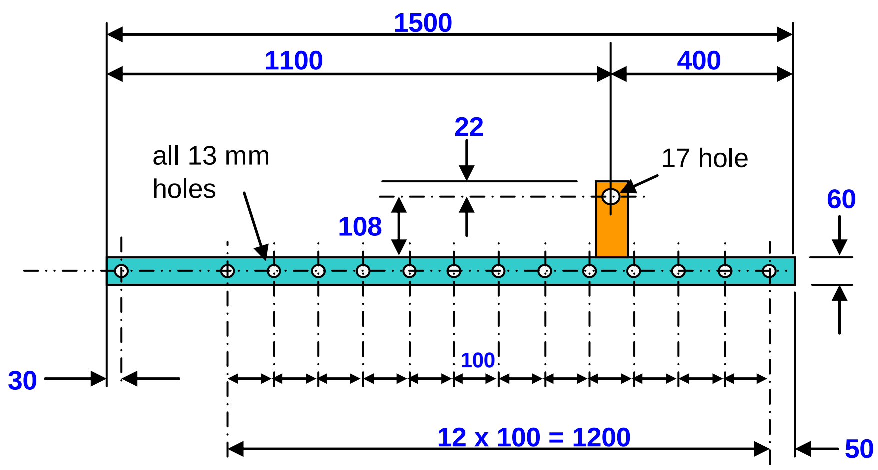
Dwg 16 - Plan of Protective Grate for Inlet



Dwg 17 - Section KK



Dwg 18 - Lug detail : 4 off



Dwg 19 - Beam detail : 2 off

Table 3: Additional Notes on the Drawings and Tables

Dwg 1: The quality of the eventual structure will be improved, and the time taken to build it will be reduced, if profiles are erected before any construction commences. These should take the form of a Maltese cross, with each profile approximately 4 800mm away form the centre of the RWH Dam. Nylon fish lines may be strung between the the profiles (fastened to the nails in the horizontal plank). The two datum lines (AA and BB) so formed, make it easy for subsequent measurements, and are used to establish the position of (1) the centre of the RWH Dam; (2) the perimeter for excavating; (3) the walls; (4) the timber poles; and (5) the sheeting.

Dwg 2: The datum lines are equally useful for setting out the various key elevations, such as depth of excavation, depth of floor-slabs, invert level of PVC pipes, top of the wall. The horizontal planks of all four profiles must be 600mm above the 'crest level' of the yet-to-be-built inlet structure. The crest level is the prevailing ground level on the perimeter of the inlet structure, 4 390mm from the centre of the RWH Dam – it determines all the levels associated with the dam and inlet structure, but not that of the overflow structure, which is determined by the 'overflow level'. (The overflow level is not related to the crest level or datum lines, and is simply the prevailing ground level at a 4 240mm distance downhill from the centre of the dam – this determines the level of the overflow's floorslab).

Dwg 3: The configuration of the assembled Ref. 193 mesh used to reinforce the concrete floor is shown. The individual pieces of 1.2m x 2.4m (2 off) and 5.6m x 2.4m (2 off) are cut from a 60m roll. They are assembled and tied together with 1.6mm binding wire in a suitable flat space somewhere outside the hole, and trimmed into a circle of radius 2.8m. The assembly is now lowered into the hole, and then lifted onto 50mm high concrete 'spacer-blocks' every 800mm in both directions. This has the effect of positioning the mesh in the centre of the 100mm slab. Note that the minimum overlap is 400mm. There is a 40mm clearance to the sides of the excavation.

Dwg 4: Three 6mm x 6m reinforcing bars are tied together, with a minimum overlap of 380mm, to form a hoop that lies in the centre of the wall at the start of each course. At the top of the eighth course, 900mm long x 2.5mm sheet-anchorage wires, bent in half, are inserted into the hoop and made to protrude radially outwards. These wires are spaced 350mm apart all the way around the circumference. In addition, four 4mm U-shaped pole-anchorage wires are positioned directly below where the future timber poles will be installed, i.e. 870mm off datum line BB. The legs of the U are unequal, being respectively 600mm and 1 250mm, while the base of the U is 150mm, making the full length 2m long. These wires are also placed beneath the hoop steel. The long leg of the U is on the outside of the dam.

Dwg 5: The key dimensions of the tank for a 30m^3 capacity are indicated. The tank protrudes by 500mm out of the ground.

Dwg 6: Three 110mm PVC pipes, each 300mm long and spaced 200mm apart, are positioned in the inlet and overflow sides of the dam. Their invert levels are 670mm below the datum lines.

In the top course, two 125/100 treated timber poles, 5.4m long, are placed in prepared openings in the wall and spaced 870 mm from datum line BB. If these roof poles are not straight, they must be rotated so that they arch upwards, as this increases the stiffness of the roof. Finally, the roof poles are bricked in, and later fastened using the 4mm wires, with the long leg of the wire going over the roof pole.

Dwg 7: This shows the layout of the IBR roof sheeting. The first sheet is placed such that its central ridge lies directly below datum line AA. The other sheets are simply lipped in the sequence indicated. The sheets must extend over the edge of the wall by the same amount on both sides. Although the sheets are 762mm wide, after overlapping their cover width is only 686mm. One of the 5 400mm sheets is cut to make provision for a trap door, which has two strong 100mm brass hinges to attach it to the adjacent 5.7m sheet. Six M5 x 20mm gutter bolts and nuts are used to attach each hinge. (Consult Appendix F5 for the detailed sequence showing how to make the trap door). The trap door is locked by means of a brass pad-lock.

The sheets are fastened to the poles using the appropriate screws (see Dwg 11), and to the wall by means of wires as indicted in Fig 9 and 11. Finally, the sheets are cut to a radius of 2 800mm, which should ensure that the sheets overlap the outside wall by approximately 60mm.

Dwg 8: This is a cross section through datum line AA and shows the various components of the RWH Dam. Each component may be identified in Table 2, where the quantities are given.

Dwg 9: This elevational view of the outside of the wall shows how the roof sheeting is anchored to the wall, using 2,5mm galvanised fencing wire that was embedded into the wall at least 400mm below the top of the wall. The wires are spaced 350mm apart all the way around the circumference. Two wires are used at each point, each 900mm long. The first is anchored into the wall in the mortarbed between the eight and ninth course - as explained in Dwg 5. The second is bent into an upside down U, the legs of which are pushed through 3mm holes drilled in the roof sheeting. The hole spacing should not be less than 30mm, and clearly the base of the U must correspond with this spacing. The upper and lower wires may now be tied off as indicated.

Dwg 10: This is a view of the wall from the outside of the tank, and shows how the roof-pole opening is filled in with brick and mortar once the pole is in the correct position. Thereafter the pole is fastened to the wall by means of the 4mm galvanised wires that were previously embedded at least 400mm below the top of the wall. See also notes under 'Dwg 4'.

Dwg 11: This shows a section of the wall built on top of a 100mm mesh reinforced concrete slab. In this wall, 10 courses of 390 x 188 x 140 blocks are used, with 12mm mortarbeds and perps, giving a vertical module of 200mm. Clearly this module will vary from area to area, depending on the height of the blocks. A hoop, made up of three 6mm high tensile steel bars, is built into each mortar-bed in all but the bottom bed. 4mm galvanised wires are built into the wall to anchor the beams – this is discussed more fully in Dwg 4. A 15mm thick layer of plaster is applied to the wall's internal face (see Table 1 for proportioning). This is followed by the application of two coats of 'Chryso L228' to the walls, as per the instructions on the packaging. Where the wall meets the floor, a 200mm ABE membrane is placed, impregnated with 'Chryso L228'. The membrane reinforces the corner, and prevents leakage in the event of cracks developing at the wall/floor interface (which may occur as a result of thermal, or moisture, or settlement movements). The upper section of the drawing shows how the IBR sheeting is fastened to the timber poles – every alternate ridge, there is a 65 x 6mm sheet-fixing woodscrew anchoring the sheets to the roof poles. Around the circumference, U shaped 2.5mm wires (each 900mm long) are pushed through drilled holes in the ridges of the sheeting and tied off against other 2.5 mm galvanised wires (also 900mm long) that were previously built into the wall approximately 400mm below roof level (see also Dwg 9).

Dwg 12: This is a plan view of the inlet, prior to the installation of the protective cover. It consists of a 1 650mm x 1 200mm x 80mm thick concrete slab reinforced with Ref. 193 mesh. The mesh is cut such that it has a 40mm clearance relative to the walls of the excavation, and its cut size is therefore 1 570mm x 1 120mm. Prior to casting, the mesh is supported on 50mm concrete blocks, spaced at 800mm in both directions. 390 x 140 x 188 high blocks are laid on top of the slab as indicated, with only one course in the 'crest' zone where the rainwater runoff flows in, and an additional course in the 'berm' zone which touches the dam's wall. Finally, two coats of Chryso L228 are applied in the areas where the inlet and the dam wall touch. Before the second coat is applied, a 200mm wide ABE membrane is laid down, and this must be fully impregnated by the second coat.

Dwg 13: This is a sectional view of the inlet structure taken through the centre line. Note that the crest is 600mm lower than datum line AA – and this becomes the reference level for the construction of the inlet.

Dwg 14: This is a plan view of the overflow structure. The same principles apply here as for the construction of the inlet discussed above in Dwg 12. The main differences are that the floor slab for the overflow structure is slightly smaller (1 500mm x 1 000mm x 80mm), and bricks rather than blocks will suffice (since the overflow channel does not need to be deep).

Dwg 15: This is a sectional view of the overflow structure taken through datum line AA. Note that the elevation of the structure is referenced to the prevailing level of the ground at the exit of the overflow, and thus bears no relation to datum line AA.

Dwgs 16 - 19: These drawings show how a protective grill may be placed over the inlet. There is sufficient detail given for a workshop to manufacture the grill.

Table 1: This gives the mix proportions for mortar (for building the walls of the dam, inlet and overflow); for plaster (to render the respective walls on their inside faces); and for concrete (for the various floorslabs). In each case, the proportioning relates to one bag of cement.

Table 2: This is a bill of materials for the complete tank. These quantities include a wastage factor on some of the materials - see the last column for the percentage waste assumed.

Table 3: This table makes brief observations on the various drawings shown here describing the Standard RWH Dam. For a more in depth discussion on the various materials and construction approaches see Appendices F3, F4, and F5.

APPENDIX F2. Workshop Drawings for ‘Central Pole & Radial Arm’

Appendix F2

Workshop Drawings for 'Central Pole & Radial Arm'

These components increase the rate of building sunken RWH dams, and improve their quality.
This is achieved by simplifying the excavation, floor-slab, walling, and plastering processes.

June 2007

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Dams for Africa (Pty) Ltd
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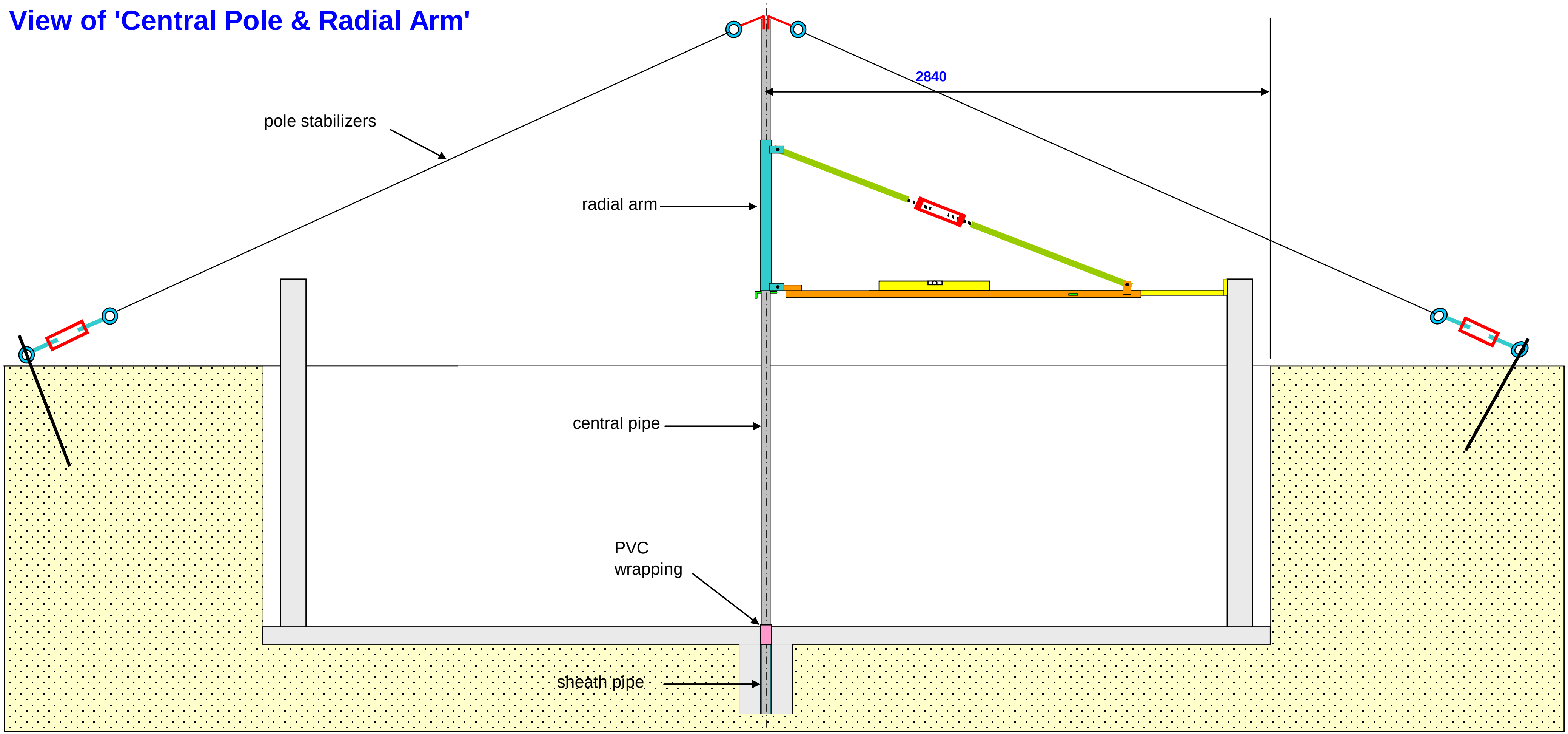
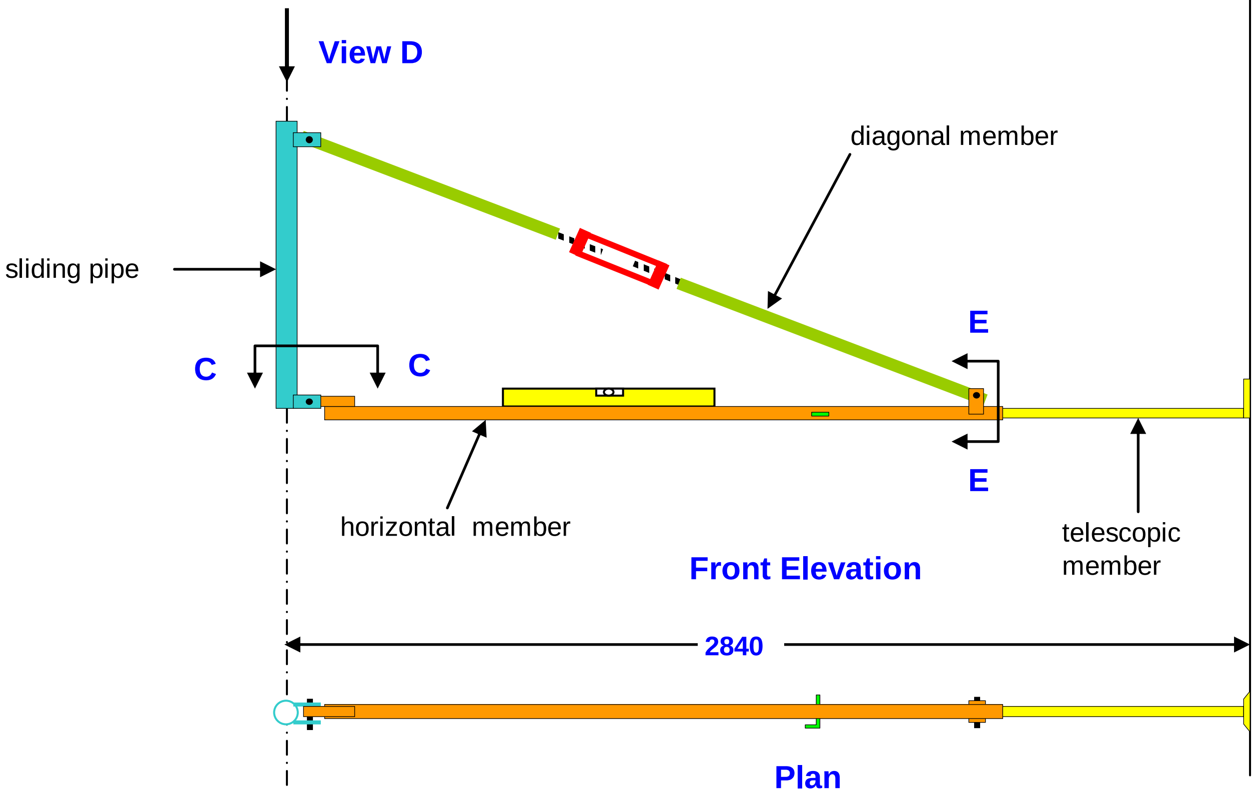
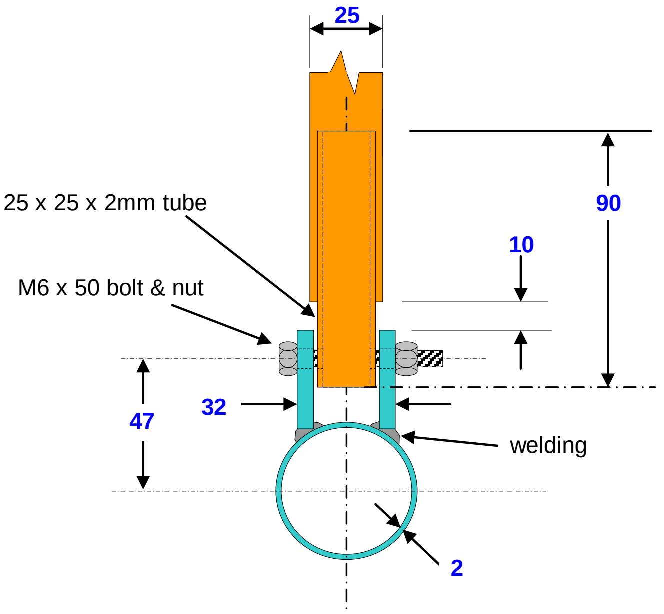
View of 'Central Pole & Radial Arm'



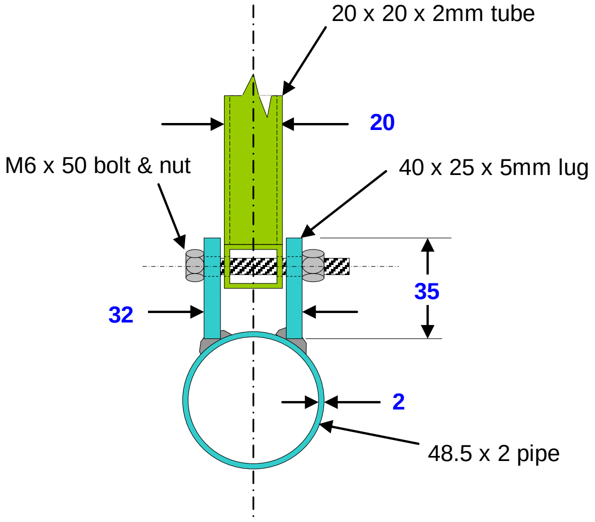
View of Radial Arm



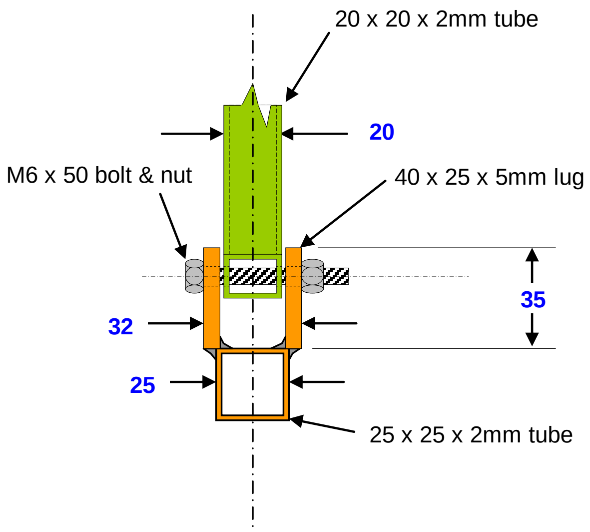
Views of Assembly Points



Section CC

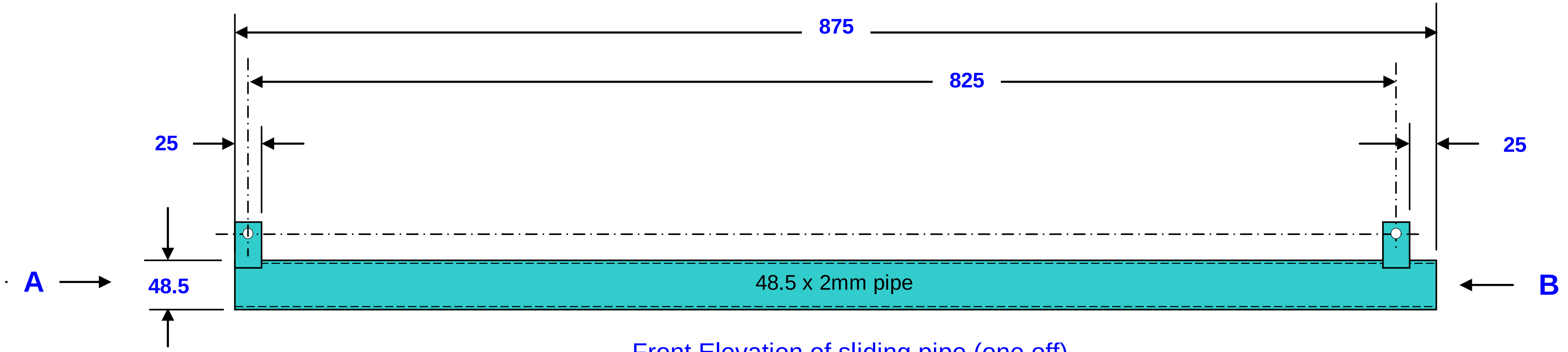


View D

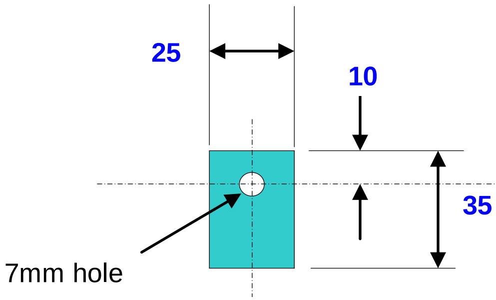


Section EE

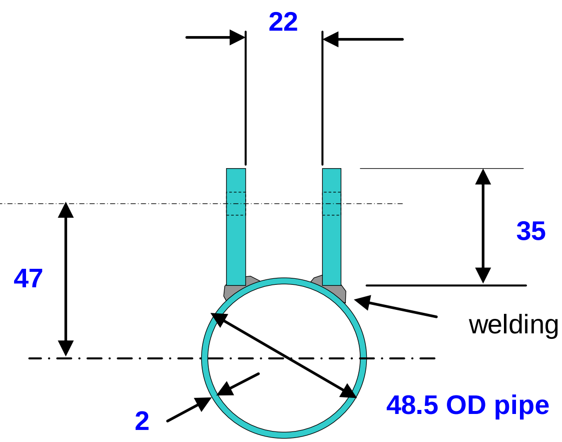
Workshop dwg for Sliding Pipe (1 off)



Front Elevation of sliding pipe (one off)

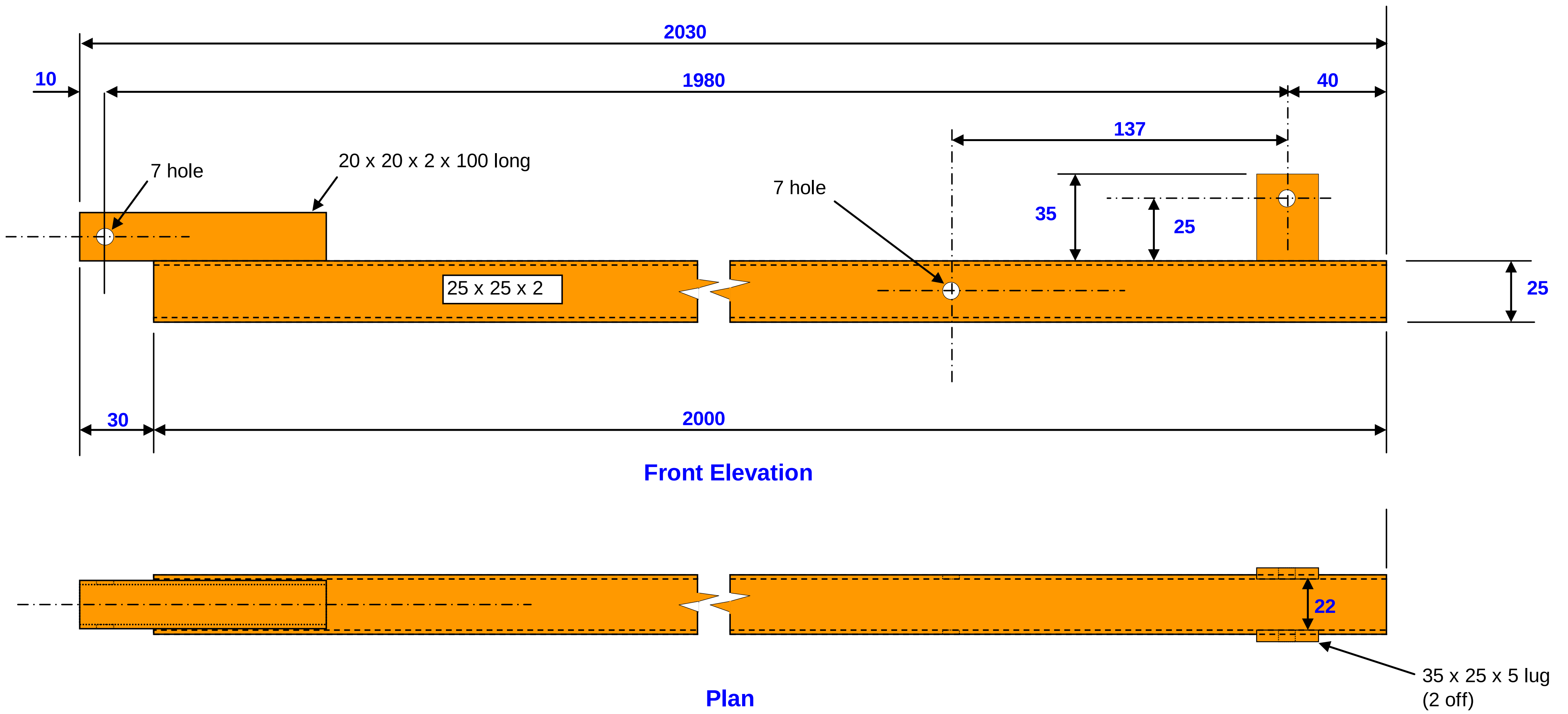


Front Elevation of lug (4 off)

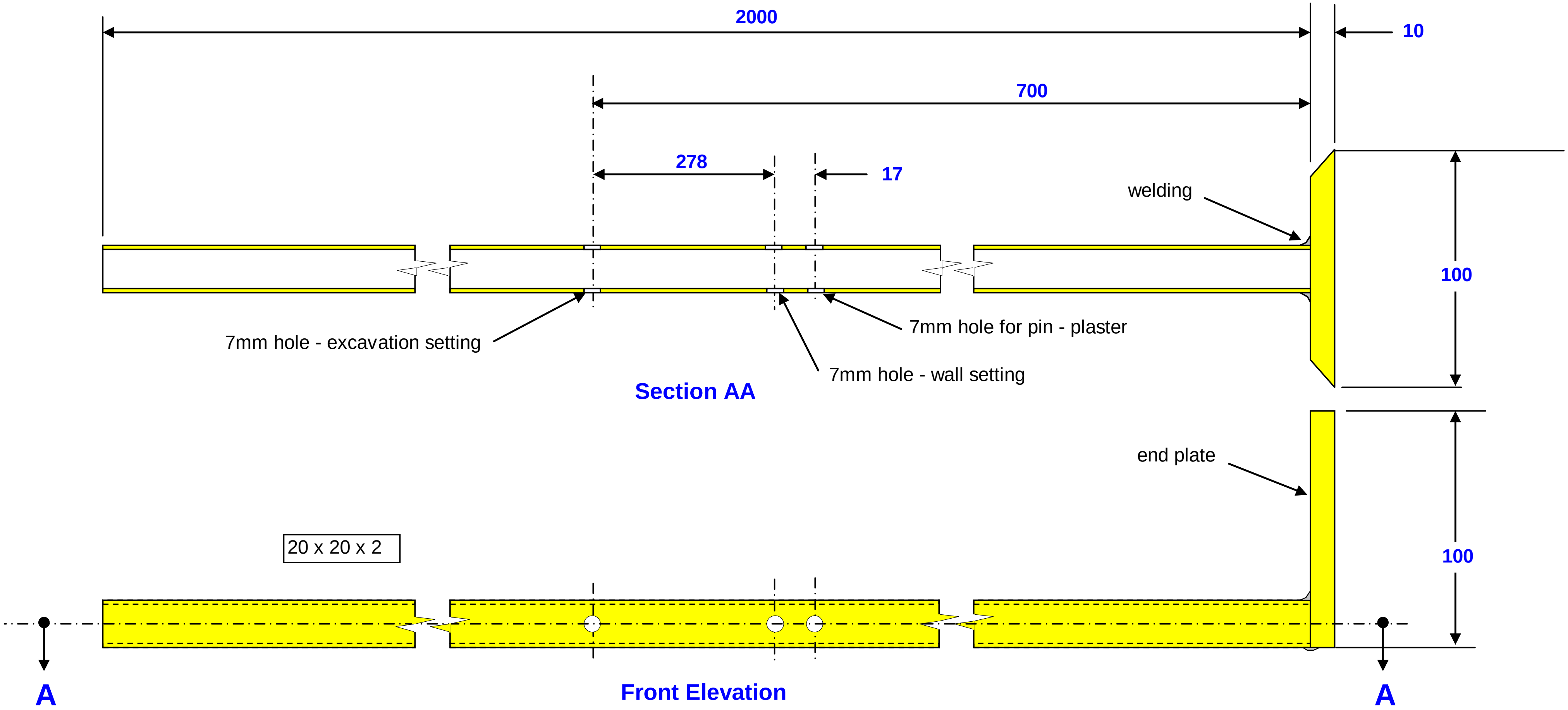


End Views A and B

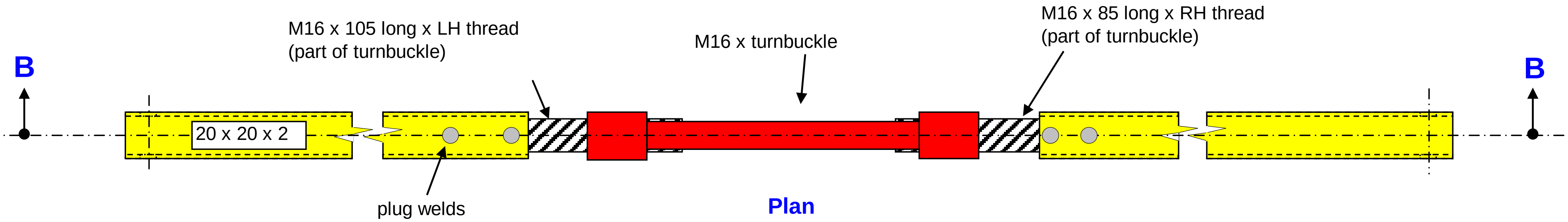
Workshop dwg for Horizontal Member (1 off)

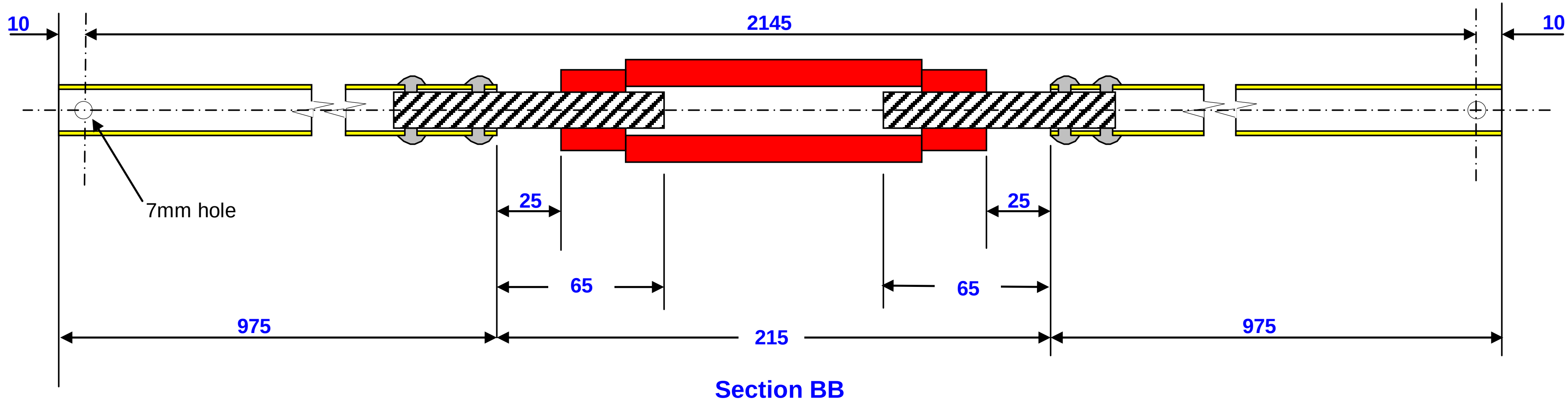


Workshop dwg for Telescopic Member (1 off)



Workshop dwg for Diagonal Member (1 off)

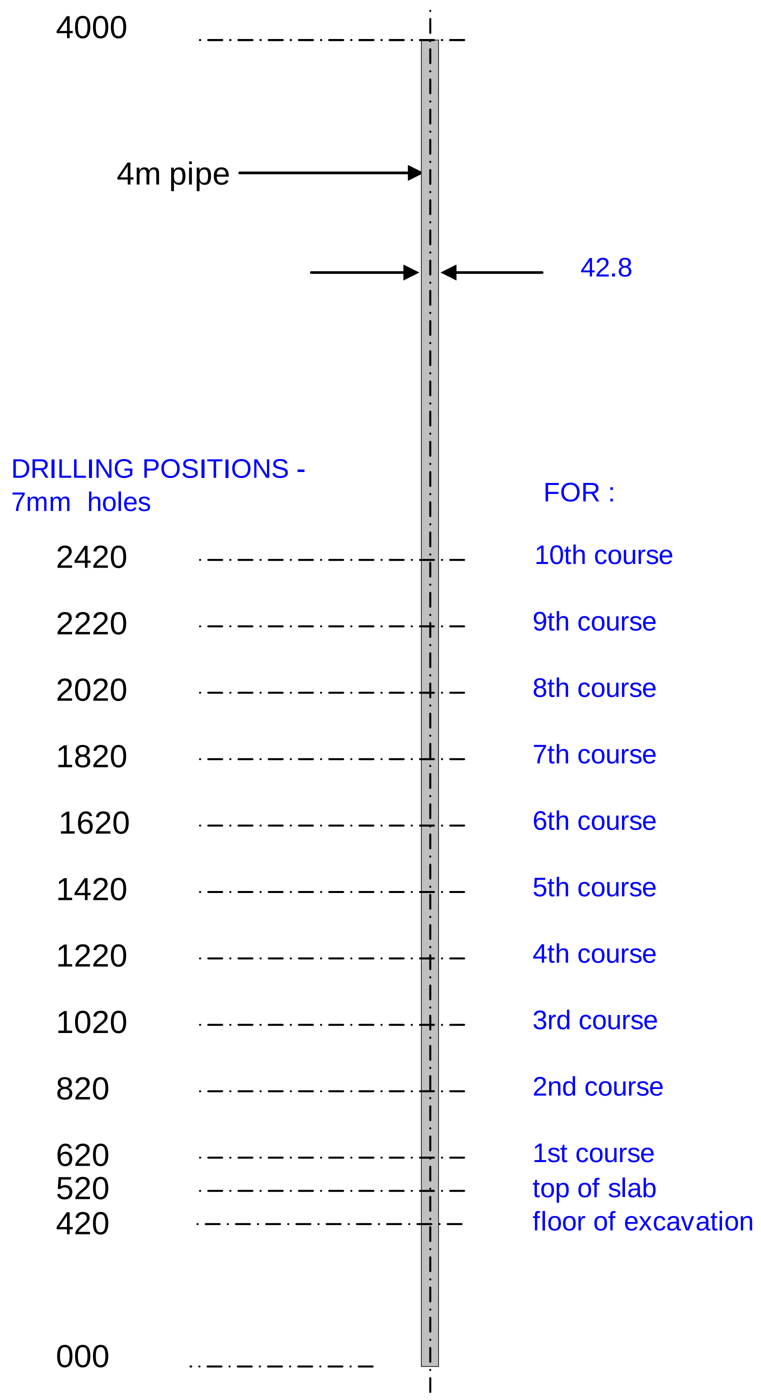




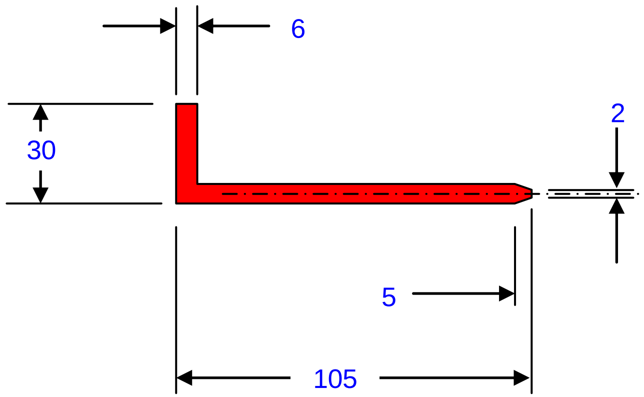
Note : The two eyes of the turnbuckle are cut off, so that the LH and RH threads can be inserted into the 20mm square tube as indicated

Drilling Positions for Central Pole

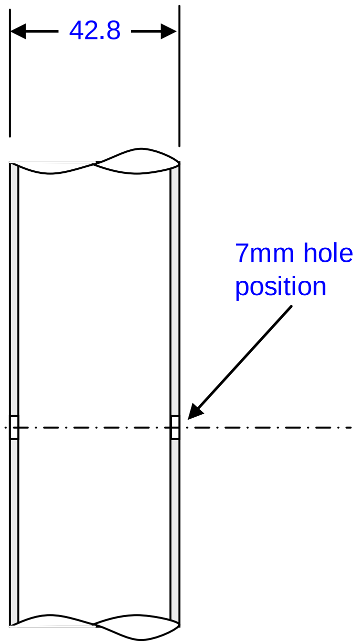
Note : A vertical module of 200mm has been assumed for the hole drilling (based on the blocks being 188mm in height on a 12mm mortar bed). Adjust drilling module as required for blocks of different height.



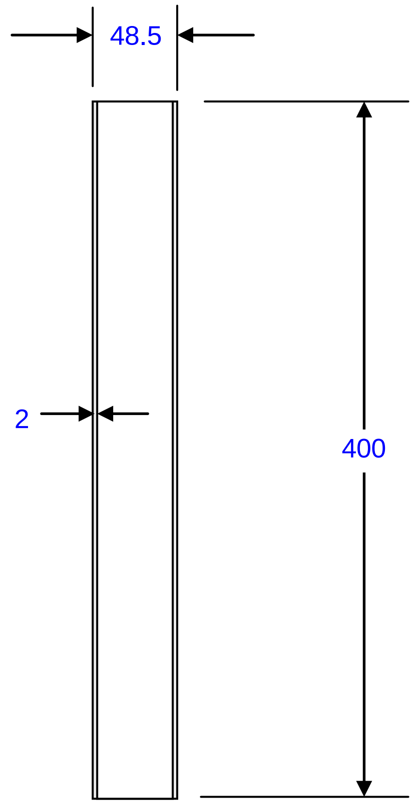
Workshop dwg for Locking Pin (2 off)



Front Elevation of locking pin (2 off)



Longitudinal Section of portion of central Pole



Longitudinal Section through Sheath Pipe (1 off per dam)

Materials List for Pole - Arm System				
Item no.	Materials	for use in …	main component	Quantity
1	48.5mm x 2mm x 875 mm steel pipe	sliding pipe	radial arm	1
2	5mm x 25mm x 35mm long steel flatbar	sliding pipe	radial arm	4
3	5mm x 25mm x 35mm long steel flatbar	horizontal member	radial arm	2
4	25mm x 25mm x 2mm x 2000mm long steel square tube	horizontal member	radial arm	1
5	20mm x 20mm x 2mm x 100mm long steel square tube	horizontal member	radial arm	1
6	6mm steel pin x 140mm long	horizontal member	radial arm	1
7	600mm long spirit level	horizontal member	radial arm	2
8	20mm x 20mm x 2mm x 2000mm long steel square tube	telescopic member	radial arm	1
9	100mm x 100mm x 10mm steel plate	telescopic member	radial arm	1
10	20mm x 20mm x 2mm x 975mm long steel square tube	diagonal member	radial arm	2
11	M16 turnbuckel	diagonal member	radial arm	1
12	M6 x 50mm bolts and nut		radial arm	3
13	42.8mm x 2.5mm x 4000mm long steel pipe		central pole	1
14	6mm steel pin x 140mm long		central pole	1
15	48.5mm x 2mm x 400 mm steel pipe		sheath pipe	1
16	M12 turnbuckle		pole stabilizer	3
17	400mm portion of 1.2m steel fence dropper		pole stabilizer	3
18	1.6mm binding wire x 5m long		pole stabilizer	3
19	6mm steel bar x 200mm long (hook at top)		pole stabilizer	3

APPENDIX F3. Standard RWH Dam: **Specifications**

1. Introduction

These specifications should be read in conjunction with:

- Appendix F1: Standard RWH Dam: **Drawings** – where the shape, size and dimensions of the dam, inlet and overflow structures are detailed in Dwgs 1 through 19
- Appendix F4: Standard RWH Dam: **Construction Manual** – where the various construction processes are described in considerable detail
- Appendix F5: Standard RWH Dam: **Step-by-step Illustrated Construction Sequence** – where the complete construction process is described in a step-by-step manner

With construction processes and design details covered adequately in the above named documents, the focus in this Appendix will be to:

- define dimensions and tolerances, in reference to Appendices F1, F4 and F5 for details;
- describe the various materials briefly, again making reference to Appendices F1, F4 and F5 for details; and
- interpret the dam, inlet and overflow structures in the light of the relevant SABS specifications.

Construction processes will only be discussed where a desired outcome is required (since these processes are adequately covered in Appendices F4 and F5).

2. Excavation

The excavation shall be cylindrical in shape with a diameter of 5 680mm ± **50mm** and a depth of 2 200mm below the datum lines (see Dwg 1 and 2 of Appendix F1). The floor shall be compacted using hand-held stampers to the extent that when maximum pressure is applied to the surface by the thumb, no noticeable depression shall be observed. The final level of the excavation's floor shall be level to a tolerance of ±15mm. (Note that the diameter of 5 680mm assumes that the wall will be made of 140mm wide blocks, and will need to be adjusted if the width of the blocks differs).

For more information, refer to steps 1 through 18 of Appendix F5. Steps 1 to 4 illustrate the setup procedures that that take place ahead of the excavation process, step 5 shows the excavation of the trial pit, while steps 6 through 16 are devoted to the setting up of a 'central pole & radial arm' in preparation for the main excavation, which is shown in steps 17 and 18. Similarly, sections I through IV in Appendix F4, describe in words the same processes illustrated in F5.

Reference may be made to Appendix F2 for detailed Dwgs of the 'central pole & radial arm'.

3. Floor

a. **Dimensions**: The diameter of the floor-slab shall match the diameter of the excavation, i.e. approximately 5 680mm, and shall be 100mm thick (see Dwg 5 of Appendix F1) with a maximum out of level tolerance of ±10mm at the surface. It shall be made of mesh reinforced concrete.

b. **Reinforcing**: The reinforcing shall be Ref. 193 mesh (5.6mm high-tensile bars with a characteristic tensile stress of 450 MPa. The bars are spaced at 200mm centers in both directions). When joining mesh pieces, the minimum overlap shall be 400mm (see Dwg 3 of Appendix F1), with an edge clearance of 40mm from the wall of the excavation. The mesh shall be positioned centrally in the slab. Refer also to steps 22 through 27 and step E of Appendix F5, and points c through e of section V in Appendix F4.

c. **Concrete**: The concrete shall have a characteristic compressive strength at 28 days of 25MPa – see Table 1 of Appendix F1 for a typical mix design.

> (The term 'characteristic strength' implies that no more than 5% of the cubes crushed according to the method prescribed in 'SANS 5863:2006 Concrete Tests – Compressive Strength of Hardened Concrete' will have a compressive strength of less than 25MPa at 28 days. It is a requirement that the cubes used in the compression testing are made in accordance with 'SANS 5861-3:2006 Concrete Tests – Making and Curing of Test Specimens'. Either 100mm or 150mm cubes are permissible).

Refer also to steps 28 & 29 of Appendix F5, and point f of section V in Appendix F4. The concrete shall be adequately compacted, and step 29 of Appendix F5 shows a 'levelling/compaction plank', which should be regarded as an essential item of equipment and is included in Appendix F6.

d. **Water**: It is a requirement that only water fit for drinking shall be used for the making of concrete, mortar or plaster.

Table 1 in Appendix F1 does not specify the amount of water to be added in the mixing process, since this will vary very substantially depending on the characteristics of the aggregates, and especially those of the sand (e.g. characteristics such as grading, particle shape, surface texture and specific gravity). See notes in point g of Appendix F4. It is the responsibility of the RIA to ensure that the mix put forward in Table 1 of Appendix F1 satisfies the required characteristic strength for the particular types of aggregates and processes used at a given site.

But, while it is not possible to specify a fixed number of litres for the mix in Table 1, it is possible to specify a slump, and for an average quality sand, a slump of 100mm will likely achieve the desired compressive strength of 25MPa. If the slump is less than 75mm, mixing should continue with more water being added. If the slump is more than 125mm, the mix should be put on one side and thoroughly blended in with a new mix where less water is used. Only mixes which have slumps varying between 75mm and 125mm are acceptable.

The correct water addition is the single most important factor affecting the quality of the mix, and each RIA should therefore ensure that all their builders are trained to do a standard 'slump-test'.

For this reason the 'slump test-cone' is included in Appendix F6 as an essential item of equipment.

e. **Cement**: All cement bags purchased for any part of the dam shall display the 'SABS' mark together with either 'CEM 1 42.5' or 'CEM 2A 42.5' or 'CEM 2B – 42.5'. These are the only cements permitted for the various floor slabs, the mortar used in the walls, and for the plaster applied to the walls. (Note that the above stated cements conform to the strength and durability requirements of

SANS 50197-1:2000 Cement. Part 1: Composition, Specifications, and Conformity Criteria for Common Cements).

f. **Finishing**: The surface of the floor shall be hand floated followed by cycles of delayed steel floating as described in step 33 of Appendix F5, and point h of section V of Appendix F4.

g. **Curing**: Finally, the floor-slab shall be ***cured*** for a period of 7 days, either by covering it with polythene plastic sheeting (see step 34 of Appendix F5), or by continuously wetting the surface.

4. Walls

a. **Dimensions**: The wall of the dam shall stand centrally on top of the floor-slab and shall be cylindrical in shape with an internal diameter of 5 200mm and a total height of 2 000mm (see Dwgs 5 and 6 of Appendix F1). The permissible variance in the dam's internal diameter and internal height shall be ± 20mm. The walls shall not be more than 20mm out of plumb at any point around the circumference. The top of the walls shall not be more than ±20mm out of level.

b. **Building units (i.e. blocks/bricks)**: The walls will normally be made of cement blocks or bricks. The minimum thickness of the wall shall be 100mm in the case of solid bricks, and 140mm in the case of hollow blocks. The SABS specification dealing with masonry units is SANS 1215:1984 – Standard Specification for Concrete Masonry Units. The relevant aspects of this specification are dimensional tolerances, compressive strength and drying shrinkage. The dimensional tolerances are given as:

- +2, -4 for length
- ±3 for width
- ±3 for height

It may be unrealistic to expect small brick yards in remote rural areas to achieve such tight tolerances, and it is possible to compensate for higher tolerances by taking various measures. These are discussed in point b of section VI in Appendix F4 under the heading of 'dimensional tolerances'.

SANS 1215 also proposes a number of strength classes for blocks/bricks. For RWH dams an average compressive strength of 8MPa (based on 5 units tested) is appropriate – this is explained in point b of section VI in Appendix F4 under the heading of 'compressive strength'.

Finally, the drying shrinkage limit shall not exceed 0.08%. This is also discussed in point b of section VI in Appendix F4, under the heading of 'drying shrinkage'.

In certain areas it may be advantageous from cost considerations to use clay bricks. But, great care must be excercised to ensure that the bricks are fully sintered and not half baked – or they will expand irreversibly and disintegrate over time. Such bricks should also meet the requirements stipulated above for cement bricks.

c. **Bedding mortar**: The ***bedding mortar*** used to lay the blocks shall be based on Table 1 of Appendix F1, and shall have the following proportioning:

- 1 x bag cement (Cem1, Cem 2A or Cem 2B)
- 3 x wheelbarrows of builders' sand (0.195m^3 loose sand)
- water should be added to render the mortar sufficiently workable to lay blocks/bricks

Any protruding mortar shall be trimmed off flush with the wall.

The quality of the bedding mortar will vary depending on the quality of the sand. A simple and useful test for determining the suitability of a mortar is to place a handful of mortar on a flat plate, and then push down on this lump with a bricklayer's trowel. If nearly all the mortar is squeezed out from beneath the trowel as pressure is being applied, then it is suitable. On the other hand, if minimal downward or lateral displacement occurs, the bricklayer will have difficulty building with it. Note that this test method is advocated by the Cement and Concrete Institute, Midrand.

d. **Hoop steel**: A closed hoop made of 6mm steel bars shall be built into the bedding mortar between courses, at a vertical spacing not exceeding 230mm. The hoop shall be centrally placed upon the wall and shall be fully encased with mortar (see Dwg 11 of Appendix F1). In order to achieve this with hollow blocks that have open cores, it will be necessary to fill the cores with soil to approximately 5mm from the top to support the mortar. Three 6m long x 6mm diameter bars shall be required for one hoop, and they should be spliced together with 1.6mm binding wire, with an overlap of 400mm (300mm minimum) – see Dwg 4 of Appendix F1. Preferably, high yield bars with a characteristic tensile strength of 450 MPa should be used, as these do not kink and are easier to form into a perfect circle/hoop.

e. **Roof-sheet anchorage wires**: Galvanised ***roof-sheet anchorage wires*** of diameter 2.5mm shall be built into the wall approximately 400mm below the top of the wall, for the subsequent anchorage of the roof sheeting (see Dwgs 9 and 11 of Appendix F1). These wires shall be cut 900mm long, bent in half, and then threaded through the hoop steel until steel-on-steel contact is made at the bend. The wires should be spaced 350mm apart all the way around the circumference, with the ends of the wires protruding radially outwards, as indicated in Dwg 4 of Appendix F1.

f. **Roof-pole anchorage wires**: Similarly, four 2m long galvanised ***roof-pole anchorage wires*** of diameter 4mm shall also be built into the wall approximately 400mm below the top off the wall, and spaced 870mm away from datum line BB, as indicated in Dwg 4 of Appendix F1, so that they are plumb below the centers of the future roof-poles (see Dwg 6 of Appendix F1). The wires are bent as an unequal U. The short leg runs 600mm along the wall, on the inside of the dam; the base of the U goes through the wall on the underside of the hoop steel (see Dwg 10 of Appendix F1) and is 150mm long; the long leg on the outside of the dam is 1 250mm long, also running along the wall. The wires are placed beneath the 6mm hoop bar – see Dwg 10 of Appendix F1. The U shape makes it convenient for the wires to lie on top of the backfill layer, parallel with the wall, and away from the activity of wheel barrows, etc.

g. **PVC pipes**: Three 110mm diameter 'SV PVC pipes' of length 300mm shall be built into the wall corresponding to the position of the inlet structure (see later), such that their invert levels are 670mm below datum line BB (see step 46 and step F in Appendix F5). Similarly, three of the same pipes shall be built into the wall for the overflow structure, usually on the opposite side of the dam, and at the same level as the inlet pipes. Only SV PVC pipes displaying the SABS mark and conforming to the SANS 967 specification for SV PVC pipes shall be used. Note that these pipes are both tough (they do not easily crack) and UV resistant. RIAs are cautioned against other types of PVC pipes, which generally are not UV resistant and become increasingly brittle with time.

h. **Plaster**: The walls shall be rendered with ***plaster*** that is struck and finished to a thickness of 15mm, made from a mix proportioned according to Table 1 of Appendix F1, as follows:

- 1 x bag cement (Cem1)
- 2 x wheelbarrows of plaster sand (0.13m^3 loose sand)
- water as required to make plaster of a 'creamy' consistency

The plaster shall be wood floated to achieve an uniform and smooth surface, followed by steel trowelling to further increase the smoothness, as well as increase the density of the surface zone. This is enhanced by applying increasing pressure on the trailing edge of the steel trowel blade as the plaster hardens.

As in the case of the concrete and mortar, the quality of the plaster will vary depending on the quality of the plaster sand. A simple and useful test for determining the suitability of a plaster made with a given sand, it to scoop up a lump on a bricklayer's trowel, and then reduce the thickness of the lump to a uniform thickness of approximately 10mm by making short but rapid sideways motions of the hand to and fro (which will result in some of the plaster falling off the sides) until the desired thickness is achieved. The trowel is now turned on its side, or even upside down, and if the plaster sticks to the trowel, then it is suitable. If, on the other hand, it falls off, the plasterer is likely to experience difficulty getting the plaster to stick to a brick/block wall. Note that this test method is advocated by the Cement and Concrete Institute, Midrand.

The various processes involved with the plastering of the dam are described in detail in points a through e of section VIII of Appendix F4, and illustrated in steps 52 through 59, and step G of Appendix F5.

5. Roof Poles

Two 5.4m long creosote treated 125/100 gum poles are built into the top course of the wall such that they lie parallel to datum line BB and at a distance of 870mm on either side (see Dwg 6 of Appendix F1). Note that when building the wall, it will be advantageous to leave out four blocks of the top course where the roof poles are to be built in. In addition, the top of the poles must be flush with the top of the wall. The poles are anchored to the wall using the 4mm pole-anchorage wires described earlier – see Dwgs 4, 6, 10 and 11 in Appendix F1.

The poles used for supporting the roof sheeting shall comply with the requirements of SANS 457 'Wooden Poles, Droppers, Guard Rails and Spacer Blocks: Part 3, Hard Wood Species (Eucalyptus). In particular, the poles shall not be more than 10mm out-of-straight for each meter of length, which translates to a maximum out-of-straightness of 54mm for a 5.4m long pole, i.e. when the pole is rolled over on a flat floor, the maximum distance between floor and pole shall not exceed 54mm. The penetration of the creosote into the pole shall not be less than 13mm (H4 category). The top end of the pole shall not be less than 100mm and not greater than 125mm. Up to four knots are permitted over a length of 150mm, but the girth of the knot shall not exceed a quarter of the circumference, and neither shall it protrude outwards by more than a quarter of the diameter at that point (e.g. where the diameter is 100mm, the knot may not protrude outwards by more than 25mm). There appears to be no strength criteria, but experience has shown that two 100/125 Eucalyptus poles have more that adequate flexural strength and stiffness to support the roof of the Standard RWH Dam, with minimal deflections experienced by construction crews working on top.

The various processes involved with the installation of the timber roof-poles, are described in detail in points a through f of section X of Appendix F4, and illustrated in steps 49, 50, F, 69 through 76, G, and H of Appendix F5.

6. Waterproofing

The walls and a 100mm strip of the floor at the wall/floor corner of the tank shall have a ***waterproof coating*** of 'Chryso L228' (supplied by Chryso). This material shall be stored, blended, and applied strictly in accordance with the manufacturer's instructions on the packaging.

The preparation, application and curing of the coating has been summarized in Appendix F4, section XII.

From reports it appears that this coating is exceptionally durable, while remaining sufficiently flexible to bridge minor cracks that may appear in the wall or at the wall/floor interface.

The various processes involved with the waterproofing of the dam are described in detail in points a through e of section XII of Appendix F4, and illustrated in steps 86 and 87 of Appendix F5.

7. Inlet Structure

The ***excavation*** and ***construction*** of the Inlet Structure is described in detail in Appendix F4, see section XI, and the associated dimensions are shown in Dwgs 12 and 13 of Appendix F1. The materials used for this structure are Ref. 193 mesh in a 25 MPa concrete floor-slab, cement blocks for the walls, which are rendered with plaster on the inside, a waterproof coating and bandage at the interface with the main dam structure, and a protective grill made from steel which is hot dip galvanized after the welding process. All these materials, along with the correct method of application (other than the steel grill), have already been specified in the foregoing sections. See Dwgs 16 through 19 in Appendix F1 for a set of 'workshop' drawings of the grill, with sufficient detail for manufacturing in an engineering works. These Dwgs also show how to install the lugs into concrete behind the crest section of the wall. These lugs form an integral part of the hinge mechanism for the protective grill.

Pieces of fine ***chicken wire mesh*** shall be rolled into a 'sausage' and inserted into the PVC pipes to act as a removable course filter, and to keep rodents and birds out of the tank. The exterior of the pipes shall then be wrapped around with plastic sheeting and fastened with 1.6mm binding wire to ensure a waterproof seal for seven days (when using Chryso L228) to allow the polymers and cementitious materials in the coating to harden sufficiently.

The various processes involved with the construction of the inlet are described in detail in points a, b, d, e, f, g and h of section XI of Appendix F4, and illustrated in steps 77 through 85, 103, 105 through 108 of Appendix F5.

8. Overflow Structure

The ***excavation*** for the overflow structure shall be 1 500mm long x 1 000mm wide, and it shall be 100mm deep with respect to the ground at the exit of the overflow (see Dwgs 14 and 15 in Appendix F1). It shall be level (see Dwg 15 of Appendix F1).

The ***floor-slab*** of the inlet structure shall have corresponding dimensions in plan and a thickness of 80mm. Ref 193 mesh reinforcing shall be centrally placed in the slab with a clearance of 40mm around the sides. The floor-slab shall be level. The absence of a gradient helps to reduce the velocity of water exiting the channel.

Two brick ***walls*** form a channel to convey water exiting the tank away from the tank. The walls butt up against the tank at the one end and have a clearance of 50mm with respect to the edge of the slab at the other end. Likewise the clearances on the sides are also 50mm (see Dwg 14). The wall is one course high for the most part, but should be two courses or more in the 'splash' region. The inside of the walls shall be plastered according to the specifications given earlier for the dam structure.

The corners and edges where the overflow structure butts up against the dam shall receive a ***flexible bandage***, as described earlier for the inlet structure.

As for the inlet structure, rolled 'sausages' of fine ***chicken wire mesh*** shall be inserted into the PVC pipes, to keep rodents and birds out of the tank.

The various processes involved with the construction of the overflow are described in detail in points a, c, d, e, f of section XI of Appendix F4, and illustrated in steps 77 through 85, 103 and 105 of Appendix F5.

9. Roof Sheeting

IBR roof sheeting is specified by stating the thickness of the sheeting material as 0.5mm for the Standard RWH Dam, the class of the corrosion protection as galvanizing class Z275, and the cover width as 686mm (not to be confused with the actual width of the sheet, which is 762mm).

According to MACSTEEL Roofing's Product Catalogue, these sheets have a span capability of 1 900mm for continuous spans and 1 650mm for simply supported spans. The Standard RWH Dam has one continuous span in the center with a span of 1 740mm, and two end spans of 1 700mm. Although the end spans are marginally more than the recommended 1 650mm for simply supported spans, this effect is mitigated by (1) one side is continuous, which will increase the spanning ability, and (2) only the sheet on the centerline spans 1 700mm; the others, on average, are less than 1 657mm (see Appendix F12.10). Finally experience on site has shown that this arrangement does not result in 'uncomfortable' deflections. It is however important not to reduce the thickness of the sheets to avoid local buckling effects when someone stands on the a ridge that is directly over a pole.

The central roof sheet shall be installed such that it bisects datum line AA (see Dwg 7 of Appendix F1). The sheets must be trimmed such that they extend over the exterior of the wall uniformly, by approximately 60mm.

The sheets shall be fastened to the roof-poles by means of 6mm x 65mm long ***sheet-fastening roof-screws***, at every second ridge of the IBR. The sheets should also be fastened to the wall on its outside circumference by means of the 2.5mm wires that were previously built into wall. The spacing of these wires is approximately 350mm.

10mm ***holes*** should be punched into the troughs of the roof sheeting, at intervals of approximately 500mm, but taking care to position the holes haphazardly so as not to create a line of weakness. A funnel effect on each hole can be achieved by drilling the hole 8mm, and then punching it through with a 10mm bar.

The outer lips of these sheets may also be turned upwards at both ends of each corrugation, to create a ***damming effect*** in rainstorms, with all the resulting rainfall entering directly into the RWH Dam via the 10mm holes.

10. Trap Door

One of the 5 400mm long IBR roof sheets should be cut short to create a ***trap door***. It should have two heavy duty brass hinges fastened to the adjacent 5 700mm sheet, and a 12mm hole drilled in the opposite outside corner, to secure the door with a brass padlock to the 4 500mm long sheet on the side of the trap door opposite to the hinges.

The various processes involved with the installation of the roof-sheeting is described in detail in points a through h of section XIII of Appendix F4, and illustrated in steps 88 through 102, as well as steps J through P of Appendix F5.

APPENDIX F4. Standard RWH Dam: **Construction Manual**

Construction Process	**Rationale of Design**
Explaining the HOW	Discussing the WHY
Summary This construction manual sets out in chronological order the various processes in building a partially sunken rainwater harvesting (RWH) reservoir (or RWH Dam), together with the ancillary inlet and overflow structures – hereafter referred to as the 'Standard RWH Dam'. The manual covers all the topics discussed in 'Appendix F3: Standard RWH Dam: **Specifications**', but in greater depth and detail, and introduces additional methods and approaches. It makes reference to Drawings 1 through 19 of 'Appendix F1: Standard RWH Dam: **Drawings**' where the main storage structure and ancillary inlet and overflow structures are detailed. The manual is entirely textual, but is closely related to 'Appendix F5: Standard RWH Dam: **Step-by-Step Illustrated Construction Sequence**', which is entirely devoted to illustrations. Reference to Appendices F1, F3 and F5 will greatly facilitate the reader as s/he continues below. The construction process is discussed hereafter and is set out in chronological order under headings that indicate the various activities.	In this column, explanations are given for recommendations made in the first column, such as why a particular type of material is specified, or why a particular construction approach or process is used.
I. SETTING OUT – DAY 1	
a. **Inspection**: Consider the three preferred positions for the RWH Dam, previously determined by the householder. Select a final position in collaboration with the household.	The household must take ownership of the RWH process as far as possible, and will have to live with the choice of RWH Dam position in their yard henceforth. Therefore the **FFP Facilitator** facilitates the households beforehand to each draw their 'helicopter plan' showing their garden layout planning, including three preferred RWH Dam positions. At the final tank siting, the **QA** confirms

	one of the household's preferred positions, unless all three are technically unsound, in which case a suitable alternative position is agreed with the household. The most important consideration for RWH Dam positioning is rainwater collection potential, while proximity and elevation relative to the garden, relation to other existing or planned structures, and ground conditions should also be taken into account.
b. **Key Pegs**: Marking pegs, ideally made from Y standards, should be used to mark the following key points: • the ***center*** peg indicates the centre of the RWH Dam – ideal peg length, 400mm. • the inlet peg marks the position where the ***inlet*** starts. This peg should be approximately 400mm long and be driven until it is flush with the ground. The top of this peg represents the ***crest*** of the inlet, and the profiles and horizontal ***datum lines***, (see later) are all referenced to this level. • the overflow peg marks the position where the ***overflow*** ends. It is also driven until it is flush with the ground and this level controls the elevation of the overflow. The length of this peg may be 300mm. The distance between the inlet peg and the centre peg is 4 390mm, while that between the overflow peg and the centre is 4 240mm (see step 2 in Appendix F5). Usually, these three pegs will all be in a straight line, and the inlet peg will always be uphill of the center peg, and the overflow peg downhill.	The 'crest' of the inlet, where the water flows into it, should clearly be the same as the surrounding ground level. If it is higher the water will dam up behind it before it can flow in; if it is lower the ground will progressively erode away until its level is the same as that of the 'crest'. Such erosion is unsightly, and the eroded material will flow into the RWH Dam requiring removal.
c. **Profiles**: Four profiles, each 4 800mm from the center peg, should be set up in a cross formation. Profiles No.1 and No.2 should be in the same line as the three key pegs, with Profile No.1 on the outside of the inlet peg, and Profile No.2 on the outside of the overflow peg. These profiles may be Y-standards of sufficient length to ensure that they are at an elevation of 600mm above the inlet peg, and also deep enough so as to be securely anchored in the ground. Similarly, 'datum BB' may be established by stringing a fish line between Profile No.3 and No.4. These steps are illustrated in	With the tops of all the profiles 600mm above the inlet peg, it is evident that the two datum lines provide a convenient horizontal reference in both directions. The datum lines are set out such that they are at right angles at the point that they

steps 2 through 4 in Appendix F5. Alternatively, conventional profiles may be established, using short timber poles as the posts and timber planks as the horizontal cross beam, which should all be 600mm above the inlet peg. A nail is used to fix datum lines AA and BB - see Dwgs 1and 2 in Appendix F1.	pass over each other, and this point is directly above the center peg. Thus, the cross-over of the datum lines maintains the center of the excavation.
II. TRIAL PIT – DAY 2	
a. **Trial Pit**: Excavate a trial pit approximately 1 500mm in diameter, at the centre of the RWH Dam, to a depth of 2 200mm below the datum line (see Step 5 in Appendix 5).	The volume associated with a diameter of 1 500mm is only 7% of the total volume that is finally excavated, based on a diameter of 5 680mm (compare step 5 with step 18 of Appendix 11). The hardness of the ground can thus be explored with a minimum of wasted effort should the ground become too hard to pick before the design level is reached (2 200mm below the datum line). In this event, an alternative position can be chosen for a second trial pit.
b. **Sheath hole**: Excavate a further hole at the base and centre of the trial pit, an additional 400mm deep and 300mm in diameter.	This hole is required to house the 'sheath pipe' that later supports the 'central pole & radial arm'. It is important that the base of the hole is at the correct depth, since this directly determines the height of the central pole, which in turn determines the height of the floor and walls.
c. **Setup pipe**: The 'setup pipe' that is 42.8mm in diameter, 2.5mm thick and 2600mm long, may conveniently be used as a gauge rod to establish the depth of the sheath hole, which, as may be expected, should be 2 600mm below the datum lines. See step 6 of Appendix F5.	
d. **Spoil**: The excavated material should not be left directly adjacent to the hole, it should be spoiled some distance away. Conveniently, wheelbarrow loads can be tipped to form two berms to direct the runoff towards the future inlet (see Appendix F8.1).	Earth dumps that are too near the hole will hinder subsequent construction activities such as pouring concrete, and building the wall and roof. These piles are also a significant safety hazard if they are left next to the excavation.
III. –SHEATH PIPE – DAY 3	
a. **Sheath Pipe**: The sheath pipe has dimensions of	The sheath pipe effectively has an internal

48.5 x 2.0 x 400mm long. Its purpose is to later support the central pole in an upright position at the center of the excavation. The setup pipe is used to align the 'sheath pipe' so that it is directly below the cross-over point of the two datum lines, as well as plumb. This is achieved by inserting the setup pipe into the sheath pipe, holding a spirit level against the protruding pole, and checking that the pipe is directly below the datum lines.	diameter of 48.5 - 2 - 2 = 44.5mm, while the central pole (and the setup pole) has an external diameter of 42.8mm. The clearance is therefore 1.7mm, which is enough to remove the central pole during and after the construction process.Note that the sheath pipe will be securely bonded to the soil:cement and cannot therefore be re-used.
b. **Backfill**: With the setup pipe plumb and in position, the sheath hole is backfilled with a soil-cement mixture, where 5 shovels of soil to one shovel of cement will suffice. The consistency of the soil-cement should be moist to facilitate compaction. Care must be taken to adequately compact the mixture after placing it in the sheath hole. See steps 6 through 10 of Appendix F5.	One of the functions of the central pole is to ensure that the walls of the main excavation are vertical, so that no more or no less than the required amount of soil is excavated by the ***digging team***. A hole that was made too large or deep means that unnecessary costs were incurred in the digging process, but it also means that additional costs and delays will be experienced when it comes to backfilling the hole later on. On the other hand, a hole that is too small means costs and delays as the ***building team*** will have to dig and trim before they can proceed.

IV. MAIN EXCAVATION – DAYS 4,5,6

a. **Setting up**: The setup pipe is now removed from the sheath pipe, and the central pole, consisting of a 42.8 x 2.5 x 4 000mm long steel pipe, is inserted in its place (see step 10 of Appendix F5). Following this, the 'radial arm' may now be attached to the central pole (see step 11). (**<u>Note</u>**: It may be simpler to first slide the central pole into the radial arm before inserting the former into the sheath pipe). Thereafter, three ***'pole stabilizers',*** each consisting of a 5m wire attached to a turnbuckle at the one end and a hook at the other end, are installed as indicated in step 12 of Appendix 5. The eye of the turnbuckle is fastened to a stake in the ground, while the hook hooks into the top of the central pole. The three stablizers are spaced 120 degrees apart in plan as may be seen in step D in Appendix F5. When tensioning the stabilizers, a spirit level is placed against the central pole to ensure that the wires are equally tensioned so that the pole remains vertical. The radius of the arm should be set to 2 840mm as indicated in step 15	The pole stabilizers are required to keep the central pole from bending excessively from the weight of the arm assembly, which acts at a substantial eccentricity. This dimension for the excavation (2 840mm) assumes a wall thickness of 140mm. If the wall thickness differs, the radial arm's radius should be adjusted accordingly.

of Appendix F5.	
b. **Digging**: Using the radial arm as a guide, the diggers excavate a near perfect cylindrical hole, until the radial arm comes to rest on the top of the '***pole-pin'*** (previously inserted into the appropriate position in the central pole – see step 17), indicating that the excavation is at the correct depth of 2 200mm below the datum lines. This method will also ensure that the excavation's floor is level and flat, and certainly within a tolerance of ±10mm, providing the 'horizontal member' of the radial arm is level – and this is achieved by adjusting the turnbuckle on the ***diagonal member*** with an eye on the ***spirit level*** (see step 16 of Appendix F5).	The radial arm will come to rest on the pole-pin, and thus the corresponding hole position in the central pole determines the depth of the excavation - see Appendix F2.8 for the various hole positions in the central pole.
c. **Compaction**: If the soil at the required depth is relatively soft, it should be compacted with hand stampers, with additional compactive effort applied where the wall is to be constructed. In this case it may be necessary to backfill and re-compact to re-establish the correct floor level as dictated by the arm assembly. The backfill should be compacted at optimum moisture content (approximately earth-moist consistency).	
V. FLOOR – DAY 7	
a. **Raise the radial arm**: With the excavation complete, remove the pole-pin from the central pole (from its 'floor-of-excavation' hole), then lift the arm slightly and re-insert the pin into the 'top of slab' hole (see steps 19 to 21 of Appendix F5).	
b. **Debonding PVC**: A strip of 110mm PVC damp proof course (DPC) is coiled five times around the pole at the point directly above the sheath pipe, with the aim of preventing the concrete that will later make up the floor-slab, from adhering to the pole (see step 21a). A piece of 1.6mm binding wire may be fastened around the outside of the PVC strip to prevent it from uncoiling.	
c. **Reinforcing mesh**: It is quicker and easier to assemble the mesh pieces into the required configuration (see step E of Appendix F5) outside the hole on a nearby piece of flat ground. All	The function of the mesh is to limit the size of any 'drying shrinkage cracks' that may occur if the RWH Dam remains empty for any length of time. The mesh tends to evenly distribute ***drying***

overlaps should be 400mm. The various pieces are tied together using 1.6mm binding wire. After this, the centre point of the assembled mesh pieces is determined, and a circle is circumscribed with a radius of 2 800mm. A bolt cutter is now used to trim the mesh assembly along this circle (see step E of Appendix F5).	***shrinkage*** effects so that crack widths are substantially smaller compared to an unreinforced slab. Small cracks up 0.3mm are not considered problematic in structural concrete from a corrosion point of view – rather it is the thickness of the cover and the cement content of the concrete that determine the concrete's ability to protect the reinforcing, and these aspects have been catered for. There is ample cover to the reinforcing and the concrete mix is relatively rich – see Table 1 of Appendix F1. The mesh also gives the concrete slab a measure of flexural strength, thus limiting the size of any ***structural*** cracks that may occur as a result of differential settlement.
d. **Mesh installation**: The assembled mesh configuration should now be opened along its middle splice (by cutting the appropriate binding wires), resulting in two halves. The separate halves are carried to the hole and lowered into position one at a time, after which the two halves are wired together again, with a 400mm overlap along the centerline as before (see steps 22 to 24 of Appendix F5).	It is necessary to install one half at a time because of the central pole.
e. **Spacer blocks**: Small spacer-blocks, 50mm thick, are now inserted beneath the mesh. They should be spaced 800mm apart in both directions. See steps 26 and 27 of Appendix F5 and Dwg 3 of Appendix F1). Ideally, these blocks should be made of 25MPa concrete, have dimensions 80 x 80 x 50mm high, with a 200mm long x 1.6mm wire that is bent into a U shape that is cast centrally in the block such that the legs protrude upwards. The base of the U is 10mm, and the two legs are of equal length.	
f. **Concrete mix**: The mix is proportioned according to 'Concrete Mix' in Table 1 of Appendix F1, and poured into the excavation. The radial arm, supported by the pole-pin, may be used to skim the surface of the concrete, thus achieving a level floor-slab of the correct thickness. During the spreading operation, compaction is achieved by tamping with a 'leveling compactor'.	The mix given in Table 1 (Appendix F1) should exceed a characteristic strength of 25 MPa for most aggregates, based on a 100mm slump.
g. **Water**: In order to achieve a characteristic compressive strength of 25MPa with the mix given	In mixing the concrete, great care should be exercised with the water dosage; too much

in Table 1 of Appendix F1 (which assumes an average quality sand with a water demand of 200 litres/m^3), the water added in the mixing process should be such that a slump of 100mm is achieved in a standard slump test. The correct water addition is the single most important factor affecting the quality of the mix, and each RIA should ensure that all their builders are trained to do a standard 'slump-test'. For this reason the 'slump-test-cone' is included in Appendix F6 as an essential item of equipment. (In this test, concrete is placed inside a standard 300mm high truncated cone, in three layers, and each layer is compacted by poking 25 times with a 20mm steel bar, after which the cone is carefully lifted and the slump measured). A 100mm slump is ideal for a hand compacted mix. Note that slumps less than 75mm run the risk of being too 'unworkable' to expel macroscopic air voids and channels, while slumps of 125mm and above will have excessive microscopic voids and capillaries. Both these cases render the concrete porous/permeable, and substantially reduce its compressive strength and abrasion resistance.	water results in 'plastic shrinkage cracks' during setting, and later ongoing 'drying shrinkage cracks' will appear if the RWH Dam remains empty for a length of time. Clearly this is most undesirable for a water retaining structure. On the other hand, too little water makes compaction difficult, leading to entrapped air, which is also very undesirable - it weakens the concrete and makes it pervious. Builders often use excessive amounts of water in the mix, as this makes it much easier to mix and compact, but this is very detrimental to the strength and permeability of the concrete. The aim is to use as little water as possible, consistent with full compaction, and generally a slump of 100mm will achieve this for hand compacted concrete, providing the stone, sand and cement are correctly proportioned as given in Table 1 of Appendix F1. Note, however, that Table 1 does not specify the amount of water to be added in the mixing process, since this will vary substantially depending on the characteristics of the aggregates, and especially those of the sand (e.g. characteristics such as grading, particle shape, surface texture and specific gravity). Concrete made with a good quality sand may only require 160 litres of water to make a cubic meter of concrete, while a poor quality sand may require as much as 250 litres/m^3. In the former case, strengths will exceed 25MPa for the proportioning given in Table 1 of Appendix F1, while in the latter case, they will be lower. It is therefore advisable to have the 'water demand' of the sand checked to see if it is capable of achieving the required characteristic compressive strength of 25MPa before using it. However, regardless of the quality of the sand eventually selected, the quality and eventual strength of the concrete made with it, is still very dependent of the quantity of water used in the mix – and this is where a slump tests plays a vital role.
h. **Finishing**: When the bleed water has evaporated, and providing the floor has reached a measure of stiffness whereby a person can walk on it without making a substantial imprint, the	After the placement of any concrete, 'bleeding' commences, whereby water gradually comes to the surface as the heavier materials tend to sink in the lighter materials. [The stone has a higher

surface should be floated off with a wood float. This agitation will bring further bleed water to the surface, and the finishing process should now be delayed to allow this water to evaporate. To reduce the waiting period, this water may also be soaked up with rags.	specific gravity (SG) than the supporting mortar and hence sinks into the mortar, the sand in the mortar has a higher SG than the supporting cement-paste and hence sinks in it, and finally the cement grains have a higher SG than the supporting water and hence sink in it. This process results in a degree of segregation of the materials, and an upward displacement of water, evidenced by a layer of water appearing on the surface].
The surface should now be steel floated, stopping when the full area has been covered in order for evaporation to once again dry out the surface. Cycles of delayed steel-floating should continue until no further bleed-water surfaces from this action. With each cycle more pressure should be exerted on the trailing edge of the blade to increase the density of the upper surface. See step 33 in Appendix F5).	This finishing technique will not only provide a dense hard surface that has a lower permeability, but also an increased abrasive resistance to withstand the effects that occur once the RWH Dam is in use when periodic cleaning of sediment takes place inside the RWH Dam.
i. **Curing**: After the steel floating operation, the surface of the concrete should be covered with a PVC cover until the next day (see step 34 of Appendix F5). Alternatively, damp sacks or moist cement bags may be used if a PVC cover is not available. Thereafter, the surface should be kept wet continuously for 7 days.	It is well established that concrete that is exposed to moist conditions until it is seven days old has less permeability and substantially more abrasion resistance relative to uncured concrete. Note that while late curing will improve concrete that was not cured in its early life, it never fully recovers from what was lost.
VI. WALL – DAYS 8,9	
a. **Dimensions**: Construct the walls with a radial setting of 2 600mm on the arm assembly (ID of wall = 5 200mm). If 188mm high blocks are used with a mortar bed height of 12mm, then there will be 10 courses to achieve a wall height of 2 000mm (see Dwg 11 of Appendix F1).	
b. **Blocks/bricks**: The walls may be built with cement blocks or bricks. Typically, hollow blocks may be 390mm long, 188mm high and 140mm thick, while cement bricks may be 220 x 106 x 73mm.	Building Units: The walls will normally be made of cement blocks or bricks. The minimum thickness of the wall shall be 100mm in the case of solid bricks, and 140mm in the case of hollow blocks. The SABS specification dealing with masonry units is 'SANS 1215:1984 Standard Specification for Concrete Masonry Units'. The most relevant aspects of this standard relate to (1) dimensional tolerances, (2) compressive strength, and (3)

	drying shrinkage. The given dimensional tolerances are given as: - +2, -4 for length - ±3 for width - ±3 for height It is doubtful that these tolerances will be met by the smaller brickyards in rural areas, but this should not be a major problem so long as the RIA makes allowances for this. Variations in ***width*** should not be too problematic, providing the builder works on the inside face, so that any variations will be unseen on the outside where the backfilling is, except for the last 500mm of the wall which protrudes out of the ground. Where widths vary significantly, particular care must be taken in the area protruding out of the ground to hide unsightly variations, e.g. bagging.
	Length variations should also not pose any great problem, so long as the builder more or less maintains a stretcher bond pattern, and this can be achieved by varying the thickness of the perps (the perpendicular joints). A more serious problem lies in the ***height***. The best thing to do here is to make an inspection of a representative sample of blocks from the supplier. Then the vertical gauge for the wall should be set to 12mm more than the highest block. It follows that in places the mortar-beds will be a thickness of 12mm plus the difference between the highest and lowest block. The RIA might decide that the variation will result in a mortar-bed that is simply too thick – mortar beds approaching 40mm should be considered on the limit, since they will require a lot of mortar on the one hand, and result in a reduction in the interlocking and cross-block shear transfer capabilities of the wall, on the other hand.
Accoring to SABS 1215, cement blocks and bricks should have an average compressive strength of 8 MPa (average of 5 blocks) with an individual minimum of 5.5 MPa.	A number of compressive strength classifications are proposed in SABS 1215: 1984 for different class structures. For RWH dams, the lowest category of average compressive strength, 4 MPa (with 3 MPa as an individual minimum), is deemed insufficient to withstand circumferential compressive stresses, which may be shown to exceed 2 MPa for a wall made of bricks

	subjected to 'earth pressure at rest' conditions of clay in a near liquified state acting on the walls when the tank is an empty state. Although 2 MPa is still less than the minimum compressive strength of 3 MPa specified for bricks, a consideration of 'limit state design' parameters shows that if the 'partial factor of safety for loads' of 1.6 is applied to the applied stress (i.e. 2 MPa x 1.6 = 3.2 MPa) and the 'partial factor of safety for materials' of 1.5 is applied to the minimum strength of 3 MPa (i.e. 3/1.5 = 2.25 MPa), it is evident that the 'ultimate' load exceeds the 'ultimate' strength. (In this analogy, the minimum strength of 3 MPa is assumed to approximate the 'characteristic' compressive strength of the blocks – a reasonable assumption). The reader is referred to SABS 0100 for a more in depth discussion of 'limit state design', 'ultimate' and 'characteristic' strength, 'partial factors of safety' for materials and applied loads. It is therefore considered prudent to specify the 8 MPa class rather than the lowest class of 4 MPa.
The requirement for drying shrinkage in SABS for pre-saturated units is 0.06% for normal shrinkage units and 0.08% for high shrinkage.	Since the walls are essentially unconstrained (except at the base) and therefore free to move and hence unlikely to crack from shrinkage movements, it is probably permissible to accept the higher 0.08% limit. On the other hand, cracks may appear at the wall/floor interface as a result of restraint against shrinkage movements imposed by the slab, but any such cracks will be masked by the flexible bandage applied in that area (a woven polypropylene membrane impregnated with 'Chryso L228' waterproof coating). Blocks made with a relatively clean river sand are unlikely to experience high shrinkage, but where blocks are made using soil-cement, shrinkage values may be much higher. Regardless of what material is being used for manufacturing the blocks, the RIA must to ensure that the blocks will not shrink beyond the prescribed limit of 0.08%.
To conclude, the RIA must submit representative samples to a certificate concrete laboratory for compression and shrinkage testing, and furthermore must take sufficient measurements of representative samples to ensure that the builders	

will not be unduly troubled by dimensional variations.	
Clay bricks are also permitted if they meet the dimensional, compressive strength and shrinkage requirements of SABS 1215. But under no circumstances may half-baked bricks be used.	If clay bricks are used in preference to cement bricks/blocks (such as cost considerations – perhaps there is a nearby clay factory), the same tests and checks apply as described above. A further precaution with clay bricks is to ensure that they are completely sintered from burning at sufficiently high temperatures – beware of half-baked clay bricks! They expand irreversibly in moist conditions, and disintegrate over time!
c. **Bedding mortar**: See Table 1 in Appendix F1 for mortar mix proportions for the bedding mortar. The builders sand that is used, should be free of organic matter such as leaves and roots, and should not have too much clay on the one hand, nor be too course, on the other.	It is important that the perps are fully filled with mortar, followed by a second process of tapping down and compacting the mortar in the perp after 10 minutes has lapsed for 'absorption shrinkage' to take place. This is important as the circumferential compressive stresses in the wall are transferred through these perp joints.
d. **Hoop steel**: Three 6m long high-yield reinforcing bars of diameter 6mm (i.e 6mm Y-bars) are spliced together with an overlap of 400mm to form a hoop, which should lie centrally on the blocks (see Dwg 4 of Appendix F1). This overlap length will automatically be achieved if 6m long bars are used on a 5.2m diameter ID dam with a 140mm wall, providing the three overlaps are equalized. For larger diameters, or where thicker blocks are used, the overlap will be less, but at no stage should it be less than 300mm, which corresponds to 50 diameters of the 6mm Y-bar.	For high-yield reinforcing bar of diameter 6mm, a minimum overlap length of 300mm will be sufficient for the transfer of tensile stresses from the one bar to the other, even for smooth bars. Note that this equates to 50 diameters, which may be considered conservative, but it must be remembered that mortar typically only has a compressive strength in the range of 5 MPa to 10 MPa, and at these low strengths, longer overlaps are advisable.
This hoop should be placed in the mortar beds of all the courses, except below the bottom course, as indicated in Dwg 11 of Appendix F1. This however, does pose a difficulty if hollow blocks are used to construct the wall of the RWH Dam, since the hoop would be unsupported where the hollow cores are. It is therefore recommended that the hollow cores are filled with earth, to about 5mm from the top of the block, which would allow the mortar bed to be spread across the full width of the block, and hence the hoop can be fully encased by mortar. There is no need to compact the earth inside the cores, as it only has to provide support for a relatively thin layer of mortar, and that only for one or two hours until the mortar has	The advantage of using high-yield bars is that they are self-straightening, and it is therefore relatively easy to achieve a smooth circular hoop with these bars. Mild steel bars on the other hand, are easily kinked in the transportation and handling process, making it troublesome to work with. (It is also possible to use two 4mm wires instead of one 6mm bar, but two wires will always be more troublesome than one 6mm bar, and furthermore, experience has shown that the 4mm wires tend to bend and kink substantially in the uncoiling process, making it difficult to create a hoop that lies centrally on the blocks). It should be noted that the advantage of the high-yield bars is limited to their self-straightening

gained sufficient strength to span the width of the blocks and adhere to the walls.	ability, and their superior bonding capability. Their high-yield strength does not improve their structural performance in this case, since the level of stress in the steel should not exceed 130N/mm^2 (if crack widths in the wall are to be limited to 0.2mm as recommended in BS8007 for water retaining structures) and these stress levels are well within the capability of mild steel bars.
	It should also be noted that if the backfill is well compacted, the tensile stresses will be low or even zero, and in this case there would be no cracks even without hoop steel – thus the hoop steel is there chiefly as insurance in event of substandard backfilling.
	On the other hand, if the backfilling is poorly done, crack widths will increase substantially as the wall moves outwards, and the steel is likely to yield before sufficient passive pressure is generated by the backfill. In such cases, the flexibility of the waterproof coat is the only thing that will save the RWH Dam from leaking. In extreme cases, where for example no backfilling is done, it is possible for the dam's wall to burst open.
	In normal circumstances, where backfilling is correctly done, the hoop bars higher up in the structure where hydraulic pressures are reduced may seem to be redundant. But, for the sake of preventing errors related to forgetting to put in the hoop bars, it was decided to include them in all the mortarbeds (see Dwg 11 of Appendix F1).
	But note that the hoop steel in the courses above ground level are useful for anchoring the wires that are used to tie the timber roof-poles, as well as those used to tie down the roof sheeting. During high winds, when the roof tends to lift off the walls, the top layers of hoop steel will make the top section of the wall act as a reinforced concrete beam, this preventing local pull-out effects where the poles are anchored, and allowing a larger number of the blocks lying in the zone between the poles and above the critical hoop bar (that anchors the pole tie wires) to be used in the stability calculation.

e. **Construction**:	
-**Radial Arm**: The radial arm is used to establish the correct height of each block in each course, the radial arm simply being pushed along as the block layer works. Once again, the turnbuckle in the diagonal member can be adjusted to ensure that the arm revolves in a horizontal plane.	In effect, the radial arm serves the same functions as a builder's line on a straight wall.
-**Steel hoop**: Prior to the placement of the mortar on a given bed, a steel hoop is placed centrally on the wall, made up of high-yield deformed bars of diameter 6mm. This was discussed in more detail in point d above.	See notes in point d.
-**PVC pipes**: The 110mm x 300mm PVC inlet and overflow pipes are built into the wall such that their invert levels are at a height of 670mm below datum line AA (see step 46 in Appendix F5) . There are three pipes for the inlet, and three for the overflow (see Dwg 4 of Appendix F1).	Three 110mm pipes will allow substantial inflows into the RWH Dam, to maximise inflows during storms which may be of a very short duration. From standard hydraulic equations [V = sqrt(2gh); Q = v.A; time to fill = dam capacity / Q], it may be shown that if the level of incoming water reaches the top of the inlet pipes (which may be assumed to have an internal diameter of 100mm), then the RWH Dam can go from empty to full in just 21 minutes (ignoring the relatively minor energy losses). It may therefore be seen that three 110mm pipes are a very effective means of getting water into the RWH Dam quickly.
-**Pole anchorage wires**: 4mm galvanised wires should be built into the wall at a height of approximately 1 600mm above the floor level. Their function is to tie down the timber roof poles to the wall. The wires are 2m long and there are four in total, one for each end of each pole (see Dwgs 4, 5 and 6 of Appendix F1).	Calculations made on uplift forces from strong winds acting on the roof, indicate that one loop of a 4mm galvanised wire for each end of each pole is sufficient to withstand these forces.
-**Sheet anchorage wires**: The sheeting is anchored by 2.5mm galvanised wires (each 900mm long) spaced at approximately 350mm around the circumference. The wires are bent in half, and threaded through the hoop steel with the two legs sticking radially outwards. Later, these wires are twisted to other wires that are fed through the sheeting from the top. (Consult Dwgs 4 and 11 of Appendix F1).	2.5mm wires spaced at 350mm are more than strong enough to resist the uplift forces on individual sheets, but thinner wires are too easily vandalised. Also, thinner wires may cut into the 0.5mm thick roof sheeting more easily, especially during the twisting/tightening operation. Note that the spacing of 350mm is approximately half the cover width of an IBR sheet, and allows every second ridge to be tied down.
In the final course of blocks, four blocks are left out	The spacing of 870mm corresponds to a pole-to-

to create openings for the roof poles – to be built in later. These openings should be s 870mm away from datum line BB (see Dwg 6 in Appendix F1). This opening is later closed off with bricks and mortar once the pole is in position.	pole spacing of 1 740mm. This spacing was determined by dividing the internal diameter of the dam by three, i.e. 5 200/3 = 1 733mm. (Note that the maximum permissible span of continuously spanning 0.5mm IBR sheeting is 1 900mm, and experience at Tshikonelo, where six experimental dams were constructed, confirmed that 1 740mm does not result in excessive deflections).

VII. BACK FILL – DAYS 9,10

a. **100mm layers**: The digging team must backfill the space between the excavation and the outside of the wall in horizontal layers not exceeding 100mm and thoroughly compact these layers with hand stampers up to ground level – see Dwg 5 and 11 of Appendix F1.	If backfilling is done correctly, there will be minimal build-up of circumferential tensile stresses in the wall, and the wall will remain crack free. The backfilled layers should simulate closed horizontal rings that exert a positive pressure on the walls, resulting in the wall going into a state of circumferential compression. If the backfilling is not done in closed rings, but rather just on the one side, this may result in the displacement or collapse of the section of wall adjacent to the backfilling.
b. **Moist consistency**: The backfill material must be of a moist consistency (but not wet). This will probably require a degree of wetting and mixing.	The degree of compaction is substantially improved if the correct moisture content is achieved.
c. **Delay period**: Only that part of the wall that was built on Day 8 may it be backfilled and compacted on Day 9.	Clearly, if backfilling and compaction is attempted before the mortar has developed a measure of strength, then blocks will be displaced during the stamping process. For this reason, backfilling should not be done in a violent fashion – moderate compaction using hand stampers is adequate.
d. **Embankment**: If the ground surface on the one side of the RWH Dam is higher than the other, an embankment against the dam's wall should be created on the low side using some of the excavated material. This material should also be placed and compacted in closed horizontal rings, which means that the embankment must be built up at the same rate as the rest of the backfilling, again in layers not exceeding 100mm.	To prevent circumferential tensile stresses from developing in the wall, it is most important to equalise the final height of the backfill, and this can only be done by creating an embankment against the RWH Dam wall on the downhill side.
d. **Final height**: The final height of the backfill should be approximately 500mm below the top of	Having the ground level and/or backfill at least 500mm below the roof level will help prevent

the wall.	animals and small children from getting onto the roof and falling into the RWH Dam, particularly if the trap door is carelessly left open.

VIII. –PLASTER – DAY 10

a. **Thickness**: Plaster the wall in a single application to a total thickness exceeding 15mm.	A total thickness of 25mm, done in two applications of 15mm and 10mm would provide increased, but not guaranteed waterproofing capability. Therefore it has been decided to go for just one layer of 15mm, and then make reliance on a waterproofing coat on top of the plaster. Note also that two applications would increase the cost of the plaster without giving the necessary guarantees of water tightness.
b. **Radial arm**: Use the radial arm at a setting of 2 585mm to trim off excess plaster to achieve a uniform thickness (see steps 55 through 59 of Appendix F5). The leading edge of the 'arm-plate' may be fitted with a steel float to ensure a good cutting action, or alternatively the arm plate may be beveled at an angle of 45 degrees to provide this action (see Appendix F2.6). However, if the latter approach is used, the leading edge will require regular sharpening with an angle grinder.	
c. **Wood float**: Float the plaster's surface with a wood float to achieve increased compaction, and increased smoothness and uniformity – see step 60 of Appendix F5.	Arguably the most important function of the plaster is to achieve a relatively smooth surface over the wall, especially where blocks are used that are relatively course. This will make the waterproof coat go substantially further, and also reduce the incidence of 'pin holing' in the waterproof coating.
d. **Steel float**: Applying pressure to the trailing edge of a steel float will increase the density and smoothness of the surface – see step 60 of Appendix F5.	A denser surface makes the plaster less permeable (as a backup to the waterproof coat). A smoother surface makes the relatively expensive waterproof coat go further.
e. **Mix proportions**: See Table 1 in Appendix F1 for the plaster's mix proportions.	Note that the cement proportioning reflected in Table 1 is relatively high, since this reduces its permeability.

IX. PLUG HOLE – DAY 10

With the plastering complete, the 'central pole & radial arm' will have completed their purpose and may be removed. The pole stabilizers are disconnected, the central pole is pulled out of the sheath pipe, and together with the radial arm is removed from the dam's interior, and taken to the next site (see step 61 through 65 of Appendix F5).	
Next, the PVC sheath is pulled out from the hole. It may even come out with the pole, uncoiling in the process, and it may now be cleaned and made ready for reuse at the next site (see step 66 of Appendix F5).	
A sand:cement mix may now be made (4 to 1 by volume), adding just enough water to make it moist (see step 67 of Appendix F5).	
The mix is poured into the sheath/pipe, 50mm at a time, and compacted with a 20mm diameter steel rod. This process is continued until the sheath pipe and central hole are completely filled up - see step 68 of Appendix F5.	It is necessary to plug the central hole so that water does not escape via the sheath pipe.

X. INSTALL ROOF POLES – DAY 10, 11

a. **General**: As soon as the central pole is removed, the roofing team may install the roof poles. (see Dwgs 4, 10 and 11 in Appendix F1).	
b. **Place roof-poles**: The timber roof-poles are placed in the spaces that were left open in the top course, directly above the pole-anchorage wires – see step 69 of Appendix F5. The poles should stick out the same amount on both sides of the RWH Dam. If the poles are not perfectly straight, they should be rotated about their own axes to maximise the arch effect.	Note that most gum poles are not perfectly straight, and therefore an arch effect can be created by simply turning the pole and observing the point of maximum upwards arch at the center. An arch has more load carrying capacity than a straight pole, resulting in a roof structure with increased stiffness.
c. **Channels**: Two steel channels (e.g. 100x50mm) are placed along the top of the wall, one on either side of the RWH Dam, with their webs at the bottom, to span the openings where the poles are now lying – see step 70 of Appendix F5. Each	The channels achieve two important purposes: Firstly, the channels ensure that the poles will be at the correct distance apart from one another, i.e. 1 740mm. Note that the spacing of 1 740mm is within the recommended limit of 1 900mm for

channel has two 7mm holes spaced 1 740mm apart from each other, to ensure the correct spacing of the poles. The poles are lifted and screwed up against the underside of the channels - use the M6 x 65mm roof sheeting screws – see step 71 of Appendix F5. This done, the openings in the wall may now be closed up with brick and mortar – see step 72 of Appendix F5.	continuously spanning 0.5mm IBR sheeting. Experimental dams built at Tshikonelo, Limpopo, confirmed that this span is acceptable, and deflections at midspan from walking were slight. Secondly, the channels ensure that the upper edge of the pole is flush with the top of the wall.
d. The next day the screws are removed and the channels taken to the next site – see step 74 of Appendix F5.	
e. Tie the pole down using the 4mm pole anchorage wires that were built into the wall for this purpose – see step 75 of Appendix F5.	
f. Plaster the wall in the region of the poles, i.e. plaster over the bricks used to support the poles – see step 76 of Appendix F5.	

XI. INLET AND OVERFLOW – DAYS 11, 12, 13, 14

Detailed dimensions of the inlet and overflow structures are shown in Dwgs 12 through 19 of Appendix F1, where a list of the materials required is included in Table 2 of Appendix F1.	
a. **Excavations**: On Day 11, the digging team makes the necessary excavations for the inlet and overflow structures – see step 77 of Appendix F5. For the inlet the excavation will be 1 650mm long, 1 200mm wide (see Dwg 12 of Appendix F1), and 880mm below datum line AA (see step 77 of Appendix F5); while for the overflow it will be 1 500mm long, 1 000mm wide, and 100mm deep - see Dwgs 14 and 15 of Appendix F1. It is recommended that the digging team first excavate the overflow, as this requires minimal digging, and thus the building team will not be unduly delayed.	
b. **Inlet Structure**: In its simplest form, the inlet may consist of a U shaped wall standing on a mesh reinforced concrete slab (see Dwgs 12 and 13 of Appendix F1). The open ends of the U will butt up against the wall of the RWH Dam, and at this end the wall will have two courses (assuming 188mm	The inlet structure has a two-fold function: (1) It collects the water at a finite distance away from the RWH Dam, typically 1 600mm, so that water does not saturate the ground in the immediate vicinity of the dam, which could lead

high blocks) to retain the soil of the raised berm, with the remainder having one course as indicated in the drawings. If the slab is 80mm thick, then based on the configuration in Dwg 13 of Appendix F1, a ***sediment pit*** 130mm deep will be constituted below the invert level of the pipe. The slab is reinforced centrally by Ref. 193 mesh.	to differential settlement of its slab and walls; and (2) It acts as a sediment trap.
c. **Overflow structure**: This structure is essentially a channel that butts up against the RWH Dam. It consists of two parallel brick walls standing on a 80mm thick mesh reinforced concrete slab – see Dwg 14 and 15 of Appendix F1. Only one course is required for the channel, although it may be advisable to have two courses or more in the splash zone, depending on how much splash there is. This will depend on how far the water drops before it reaches the channel's floor-slab, and this is a function of the local topography.	The overflow has a number of functions: Firstly, it acts as a channel that conveys water a safe distance away from the RWH Dam. This prevents the ground in the immediate vicinity of the dam from becoming soaked, thus reducing the risk of differential settlement, for example between the walls and floor. Secondly, the hard concrete floor-slab of the overflow prevents erosion in the near vicinity of the RWH Dam, and particularly near the PVC pipes. It is advisable that the height of the channel be increased in this 'splash' zone to keep the surrounding ground from becoming wet from the splashing action. Thirdly, it breaks the energy of the water before it exits the channel. In areas where the natural fall of the ground is not excessive, this can be achieved simply by making the floor-slab horizontal, so that the energy of the water leaving the PVC pipes will be substantially dissipated on landing on the horizontal floor-slab; thereafter the zero slope of the channel is not conducive to unwanted acceleration as the water flows along the channel. In steeply falling terrain there will a significant embankment on the lower side of the RWH Dam, making the solution described above problematic. In such instances, it is more practical for the channel to go over the embankment, with protruding rocks to slow down the rate of flow all the way along the channel, but especially at the exit point.
d. **Plaster**: On Day 12, the blocks and bricks should be plastered on the side which will be exposed to water (i.e. on their inside faces) – see step 85 of Appendix F5.	Plastering the blocks on the side of the sediment pit will reduce water from seeping out and softening the surrounding ground.
e. **Flexible 'bandage'**: On Day 13, a 200mm strip of	The supporting slab of the inlet and overflow

'ABE fabric' impregnated with 'Chryso L228' must be applied to create a flexible bandage where the inlet and overflow butt up against the RWH Dam – see step 13 of Appendix F5.	structures are at a substantially higher level relative to the dam's slab. Swelling or settlement of the ground in the intermediate zone will therefore cause the higher structures to move relative to the RWH Dam, resulting in the formation of an open joint/crack at the interface. Thus the flexible bandage allows such movement while preventing water from entering the joint/crack – which would further aggravate any settlement or heave effects.
f. **Chicken mesh**: A coil of fine chicken mesh may now be inserted into all six PVC pipes – see step 105 of Appendix F5.	This precaution prevents rodents, birds and frogs from entering the RWH Dam. The coils should be cleaned regularly and especially after each rain event.
g. **Plastic seals**: The PVC pipes are closed off on the outside with plastic sheeting for seven days (a good quality plastic bag will also suffice). The bags are fastened to the pipes by using 1.6mm binding wire, which should be twisted relatively tightly to ensure a good temporary seal – see step 106 of Appendix F5.	'Chryso L228' requires one week to stiffen sufficiently for no re-emulsification to occur on contact with water. Therefore it is important to prevent any inflows into the RWH Dam for seven days after the waterproofing is applied.
h. **Cover grill**: Finally, a hinged grill is installed to cover the inlet to prevent small children from drowning (see Dwgs 16 to 19 in Appendix F1). The grill hinges on lugs that protrude out of the concrete. The hinge points are behind the the front wall of the inlet structure, i.e. behind the 'crest section'. The lugs are anchored to fill-in concrete in this area as indicated in the drawings.	
i. **Construction time**: The excavations, slabs and block laying can all be completed on Day 11. Note that it is permissible to build one or two courses of blocks/bricks on the slabs once they are 4 hours old, but the plastering of the blocks/bricks should wait until the next day, Day 12. On Day 13, the plaster will be hard enough to apply the flexible bandage. Then the chicken wire coils are fitted, the plastic pipes are closed off with plastic covers, and the grill is fitted to the inlet.	This kind of multi-tasking in a single day is justified by the smallness of the task, and the fact that the RWH Dam is almost complete.

XII. WATERPROOF COAT – DAY 12

a. **Preparation**: The following sequence should be followed and is most important if good adhesion is	'Chryso L228' is a cementitious/polymer based product and is imported from France by Chryso.

to be achieved between the waterproof coat and substrate: -Make sure that all wall surfaces are clean, and slightly damp. -In the region near the wall, the concrete floor surface must be scrubbed with a wire brush to remove laitance (the thin layer on the surface of concrete that is weak as a result of bleed water). -Flush with water to remove all dust. -Brush away all standing water. -Allow surfaces to dry to a damp but not dry state.	Chryso have branches in Johannesburg, Cape Town, Durban and Port Elizabeth. 'Chryso L228' is sufficiently flexible to accommodate slight movements at joints and minor post-construction cracking in the substrate. Preliminary investigations by the writer have indicated that 'Chryso L228' is the best performing product available on the market, requiring no maintenance for the life of the structure, and capable of performing in hydraulic heads of up to 100m, and backpressures of 30m for properly prepared substrates.
b. **Application**: Apply a waterproof coat ('Chryso L228') to the plaster on the wall per the manufacturer's instructions on the packaging. Two kits (each consisting of 10 litres of polymer and 18kg of sand-cement) are required to apply the mandatory two coats. Mixing should ideally be done using a 12mm T-bar inserted into an electric drill. Experience has shown that a block brush is the best way to apply the material – see Dwg 11 of Appendix F1 and step 86 of Appendix F5. The first coat should be slightly diluted as per the instructions on the packaging. It is essential that the surface is fully covered with no bare spots or even pin holes left uncovered.	
c. **Corner membrane**: Reinforce the corners where the wall meets the floor with a 200mm ABE membrane - fully impregnate with the coating (see Dwg 11 of Appendix F1 and step 87 of Appendix F5). The corners and edges where the inlet and overflow structures butt up against the dams should be similarly treated.	This measure makes allowance for possible movement between the wall and the floor-slab. Such movements may occur as a result of the floor drying out and shrinking more than the walls, and this could result in a crack developing in the first mortar bed. Similar actions may occur as a result of thermal movements in the slab relative to the wall. It is also possible that there may be some differential settlement, whereby the floor-slab subsides relative to the wall, again resulting in a crack in the mortar bed. Note that it is by virtue of the L-shape of the corner membrane that it can accommodate both downward or horizontal movements without developing leaks. For ***downward movements*** the contact between the bandage and the substrate will first be lost in the immediate corner – for perhaps a distance of 10mm along the x-axis

	and the y-axis, but there will still be 90mm left that does not tear away, so that the overall sealing action is not compromised. The 10mm portion that tears away (both horizontally and vertically) now assumes an angle of 45 degrees instead of its previous horizontal/upright position. The polypropylene fibres of the bandage have sufficient tensile strength to break the adhesion between substrate and waterproof coating, while the impregnated coating has sufficient flexibility to accommodate the miniscule bending and stretching movements that occur between and around the fibres of the bandage in this process. For ***lateral movements*** as a result of drying shrinkage or thermal movement similar actions take place.
d. **Floor**: It should not be necessary to coat the floor as this should be relatively impermeable if the guidelines for delayed wood and steel floating given under "Day 7 – Floor" were adhered to.	Any treatment of the floor with a coating will be subject to abrasive actions when the sediment is periodically removed from the RWH Dam – and with care a well compacted and impervious concrete floor is achievable.
e. **Curing**: Allow one week for the 'Chryso L228' to cure before filling the RWH Dam.	'Chryso L228' requires one week to stiffen sufficiently for no re-emulsification to occur on contact with water. The precaution of closing off the inlet pipes as described in 'Inlet and Overflow' point g, is thus necessary.
XIII. ROOF SHEETING – DAY 13	
a. **General**: With the completion of the waterproofing inside the RWH Dam on Day 12, the roofing team may install the roof sheeting on Day 13 - see Dwgs 7, 9 and 11 of Appendix F1.	
b. **Specifications**: Use IBR sheeting with a minimum thickness of 0.5mm. The galvanizing specification shall be 'Z275'.	A thickness of 0.5mm should be considered as a minimum. Experienced at Tshikonelo showed that even at this thickness there were occasional instances of 'local buckling' of the ridges. This generally occurs if a heavy person walks on the IBR directly over the beam. In this instance there is no possibility for the load to be spread, and hence one or both sides of the ridge buckles under the concentrated load. Thinner classes of galvanizing, such as Z160 or even Z120, will corrode substantially sooner than

	the Z275, which is likely to last 20 to 40 years depending on local humidity.
c. **Laying**: the first 5.7m long sheet is laid such that its central ridge is directly below and parallel to datum line AA (see step J of Appendix F5). Thereafter the other sheets are sequentially lipped in, with the sheets getting progressively shorter the further they are from the datum line – see step K of Appendix F5. The sheets should protrude equally over both edges.	
d. **Fastening**: Beginning at the central sheet, and working progressively outwards, a hole is drilled and then immediately fastened to the timber pole below, using a sheet-fastening wood-screw. These operations may either be done using hand tools, or power tools. Every alternate ridge is fastened (see Dwg 11 of Appendix F1). A roof washer should be used with each fastener to prevent 'pull through'.	It is important to finish fastening off one screw before drilling the next hole, as the fastening action has a tendency to spread the sheets laterally, so that holes that may have matched initially will not necessarily match later when the fastening is done, if the two operations (drilling and fastening) were not done consecutively on a hole-by-hole basis.
e. **Trap door**: A trap door can be made by cutting off a piece of the 4 500mm long sheet. The cut should be made about 200mm beyond the supporting pole. The cut-off section is then moved up by 60mm for overlap and support. Next, two medium duty brass hinges are installed along the side nearest datum line AA, to create a hinged lid-type door that allows access into the RWH Dam as indicated in Dwg 7 of Appendix F1. A detailed sequence for making the trap door is shown in Appendix F5, steps 93 through 95, as well as steps N and O.	The trap door so formed is comfortably large and user friendly. The person drawing water is able to sit on the wall in the process. The opening is also large enough to make shoveling out of sediment a simple matter. When open, it lets ample light into the interior if at a later day a new application of a waterproof coating is required.
f. **Trimming**: The sheeting is trimmed with an angle grinder (9" works better than 4") to a radius of 2 800mm – see step 96 and P in Appendix F5. The sheets should protrude approximately 60mm over the wall.	
g. **Sheet Anchorage Wires**: At the zone where the roof overlaps the dam's walls, two 3mm holes are drilled in the upper ridge of the IBR sheeting. Typically these holes may be 30 mm apart. A U-shaped 2.5mm galvanised wire (total length 900mm), is inserted through these holes. It follows that the base of the U is 30mm long to correspond with the hole positions. Thereafter, each leg of the	This method of fastening, where both legs of a U shaped wire pushed in from the top is fastened to two wires coming up from the anchorage point lower down, is much simpler than if one of the lower anchorage wires were to be made long enough to thread through the holes in the top ridge and then tightened by twisting with the wire of the lower leg. The loop through the top also

U is tied off with the corresponding wire that was previously built into the wall (see Dwgs 9 and 11 of Appendix F1, and steps 98 through 101 of Appendix F5).	tends to be loose and untidy, and also causes tearing of the sheet in the threading process.
h. **Padlock**: To secure the trap-door, a good quality brass padlock should be used, as the lock will be exposed to the elements. A 12mm diameter hole is drilled through the trap door in the outer corner on the opposite side to the hinges, and a corresponding hole through the fixed sheet. (See steps 97 and Q of Appendix F5).	The lock to the trap door is a precaution against children opening the trap door unsupervised and falling in.
XIV. BAGGING – DAY 13	
The section of the wall protruding out of the ground on the outside is 'bagged'. The ground around the wall should be raked away to a depth of approximately 100mm, to allow the bagging to start some way below the surface (see Dwg 11 of Appendix F1), in case there is some settlement or erosion later on.	This action adds aesthetic value to the RWH Dam and is not a time consuming or costly exercise.
Essentially, bagging involves the application of a relatively thin layer of sand-cement slurry to the wall – applied with a block brush. The mix proportion for 'plaster' given in Table 1 of Appendix F1 will suffice, but it may be necessary to increase the quantity of cement if the sand is relatively coarse. Add water until a slurry-like consistency is achieved – similar to a PVA paint.	
XV. LANDSCAPING AND CLEANUP – DAY 13	
The type of landscaping that is adopted will depend on factors such as the general topography, the position of the RWH Dam in relation to the garden, the elevation of the tank out of the gound, etc. Consult Appendix F8 for various options. In the following points a through c, it has been assumed that the various factors affecting the landscaping make the layout described in Appendix F8.1 the most suitable.	
a. **Berm**: The two berms are in effect mini	The function of the berm is to divert the runoff into

embankments made up of the excavated material, and their function is to channel the water towards the inlet. The crest of the earth berm should be horizontal – and say 300mm below the roof of the RWH Dam.	the RWH Dam. When the runoff is slight, the berms merely divert the water towards the inlet. But when runoff is much greater, for example at the height of a storm, it is possible that the inflow into the inlet will exceed the flow capacity of the three inlet pipes, and at such times the berms becomes mini 'surge-dams'. The advantage of a surge dam is that less water bypasses the RWH Dam. Clearly, the greater the length and height of the berms, the greater the temporary storage of the 'surge dam'.
b. **Spillways**: These should be created on either side of the berm as 'by-passes' for potentially destructive inflows during unusually large storms. These may simply consist of grassed or stone-packed surfaces that may be 3m wide. Sufficient width is required to minimize the depth of flow. The contours of the spillway should always be 90 degrees to the direction of the intended flow.	
c. **Embankments**: In steep terrain, the excavated material not used to construct the berm, should be spoiled on the low side of the RWH Dam to create an earth embankment, such that the final crest around the dam is horizontal and approximately 500mm below roof level.	This action is extremely important from a structural point of view. The hoop steel is not sufficient to resist the tensile stresses that will develop if the RWH Dam is not surrounded by compacted backfill/embankment. See comments made under the 'Backfilling' and 'Wall' sections.
e. **Cleanup**: All builders' rubble and rubbish is to be removed from site. This includes such items as cement bags, tins, loose aggregate, loose stones, piles of soil, etc. Hard areas where mixing was done are to be broken up, with all cement/concrete residues being disposed of. (Note that this material can conveniently be used in the berms or for backfill). Finally, the site is to be raked to create a tidy and uniform appearance.	

APPENDIX F5. Standard RWH Dam:
Step-by-step Illustrated Construction Sequence

[This Appendix consists of 110 sheets with detailed step-by-step sketches of the construction sequence. Please see these on the enclosed CD: Excel Worksheet: Appendix F5_Step-by-step Construction Sketches.xls]

APPENDIX F6. Standard RWH Dam: Construction Tools & Equipment needed

Appendix F6

Construction Tools and Equipment

In this Appendix, the various tools that are required for the construction of a RWH dam are shown. A number of options are given based on the RIA's attitude towards using power tools, versus hand tools, or mechanical devices such as the 'central pole & radial arm', versus working without this aid. Finally, a few tools are suggested for a simple field workshop, but clearly this list is very short and each RIA will decide to what extent it should be expanded.

Whatever approach is used, the list serves as a useful checklist for RIAs getting ready to start up a new site.

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Appendix F6 - Construction Tools and Equipment

Item	total	siting	hole	floor mesh	floor	block wall	backfill	plaster	plug hole	roof poles	inlet & overflow	water-proofing	roof sheeting	workshop equipment
Essential Items														
4 lb hammer	1	1	1			1				1	1			
5m tape	1	1	1	1	1	1		1		1	1			
1200mm spirit level	1	1	1								1			
600mm spirit level	1										1			
builders square	1	1								1	1			
wheelbarrows	3		2		3	2	2	2			1			
shovels	5		3		5	3	3	3	1		3	1		
10 litre bucket	3		1		3	1	2	2	1		1	3		
picks	3		3								2			
5l watering can	2		2				2							
200 litre dums	2		2		2	2	2	2						
Hose pipe and fittings	1		1		1	1	1	1			1			
2m ladder	1		1	1	1	1		1	1	1		1		
10mm x 300mm long fish line pegs	4		4										1	
chisel	1		1							1	1			
steel stampers	3		3				3				2			
3m aluminum straight edge	1		1		1			1						
1.5m aluminum straight edge	1		1		1			1			1			
300mm high slump test cone incl plate and poker	1				1									
Levelling / compacting plank cw handles	1				1									
fencing pliers	3			3		1				2	1		3	
bolt cutter	1			1							1			
steel rake	1				1						1			
wood floats	2				2			2	1	1	1			
steel floats	2				2			2	1	1	1			
hack saw	1												1	1
pvc curing cover	1				1									
bastard file	1												1	
bricklayers trowel	2					2					2			
20mm steel rod x 800mm long	1								1					
block brush	3										2	3		
steel brush	2											2		
2 lb hammer	2												2	
centre punch	1												1	
10mm socket for turning screws	1												1	
Additional Items for Hand Approach														
hook-on-line level	1	1												
hand drill	2												2	
hack saw	1												1	
Additional Items for Mechanical Approach														
dumpy-tripod-stand or hook-on-line level	1	1												
setup pole (2.6m)	1		1		1	1		1						
central pole (4m)	1		1		1	1		1						
radial arm	1		1		1	1		1						
pole-pin	1		1		1	1		1						
arm-pin	1		1		1	1		1						
pole stabilizers	3		3		3	3		3						
600mm spirit level	1		1		1	1		1						
1m x 110mm pvc dpc	1				1	1		1						
adjustable builders scaffold	1		1											
228mm x 38 mm x 3000mm scaffold planks	3		3					3						
100 x 50mm steel channel by 2.5m long	2									2				
Additional Items for Power Approach														
concrete mixer	1				1						1			
power drill	2												2	
9" angle grinder	1												1	
electric generator	1												1	
night lamps	2				2									
30m extension cords	2												2	
Recommended Workshop Items														
Steel Table with Vice	1													1
welding machine	1													1
welding electrodes 1kg	1													1
set screw drivers	1													1
set spanners and sockets	1													1
lockable trunk	1													1
pop riveter	1													1

APPENDIX F7. Standard RWH Dam
List of Consumable Items needed

Appendix F7

List of Consumable Items

In this Appendix, the various 'consumable items' are listed. A consumable item may be described as a simple tool or piece of equipment, or accessory to a piece of equipment, that is consumed in the course of building a RWH Dam. It is not claSsified as a 'raw material' since, generally speaking, it does not become part of the structure, and for this reason it does not appear in Table 2 of appendix F1 where all the raw materials are listed. Neither do these items belong to Appendix F6, which lists the items of equipment - which are not consumed and may therefore be used over and over.

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Appendix F7 - List of Consumable Items **(required to build a Standard RWH Dam)**

Item	total	siting	excavation	floor concrete	inlet & overflow	roof sheeting
Essential Items						
Y standard x 1200mm (setting out profiles)	4	4				
Y standard x 400mm (marking pegs)	3	1				
Y standard x 300mm long level pegs (floorslab)	9			7	2	
50m fishline	1	1	1	1	1	1
concrete spacers for supporting mesh	41			33	8	
1m x 110mm pvc dpc	1			1		
permanent marking pen	1					1
3" nails	20	20				
4" nails	4					4
Additional Items for Mechanical/Power Approach						
400mm sheath pipe	1		1			
3mm drill bits (holes for roof-sheet anchorage wires)	3					3
5mm drill bits (holes for roof-screws)	3					3
8mm drill bit (drainage holes in roof-sheets)	2					2
9" steel cutting disc	1					1
30m extension cords	2					2
roll pvc tape (to fasten level to radial arm)	1		1	1		

APPENDIX F8. Rainwater Harvesting Layout: examples

Appendix F8.1 - Earthworks to direct run-off and to stabilise the RWH Dam walls

Appendix F8.2 - Steep terrain

Appendix F8.3 - Large uphill catchment (e.g. field, road)

Appendix F8.4 - Main catchment a large roof

Appendix F8

RWH Layout Examples

In this Appendix, a number of examples are given for the positioning of a RWH Dam relative to an intensified garden. Factors such as the steepness of the terrain, the size of the uphill catchment area, or the presence of an elevated catchment such as a large roof, will influence (1) the position of the tank relative to the garden, and (2) the elevation of the tank. In addition, structures for dealing with potentially large and destructive inflows are also considered, and the essential provision of an embankment on the downhill side of the dam is amply illustrated.

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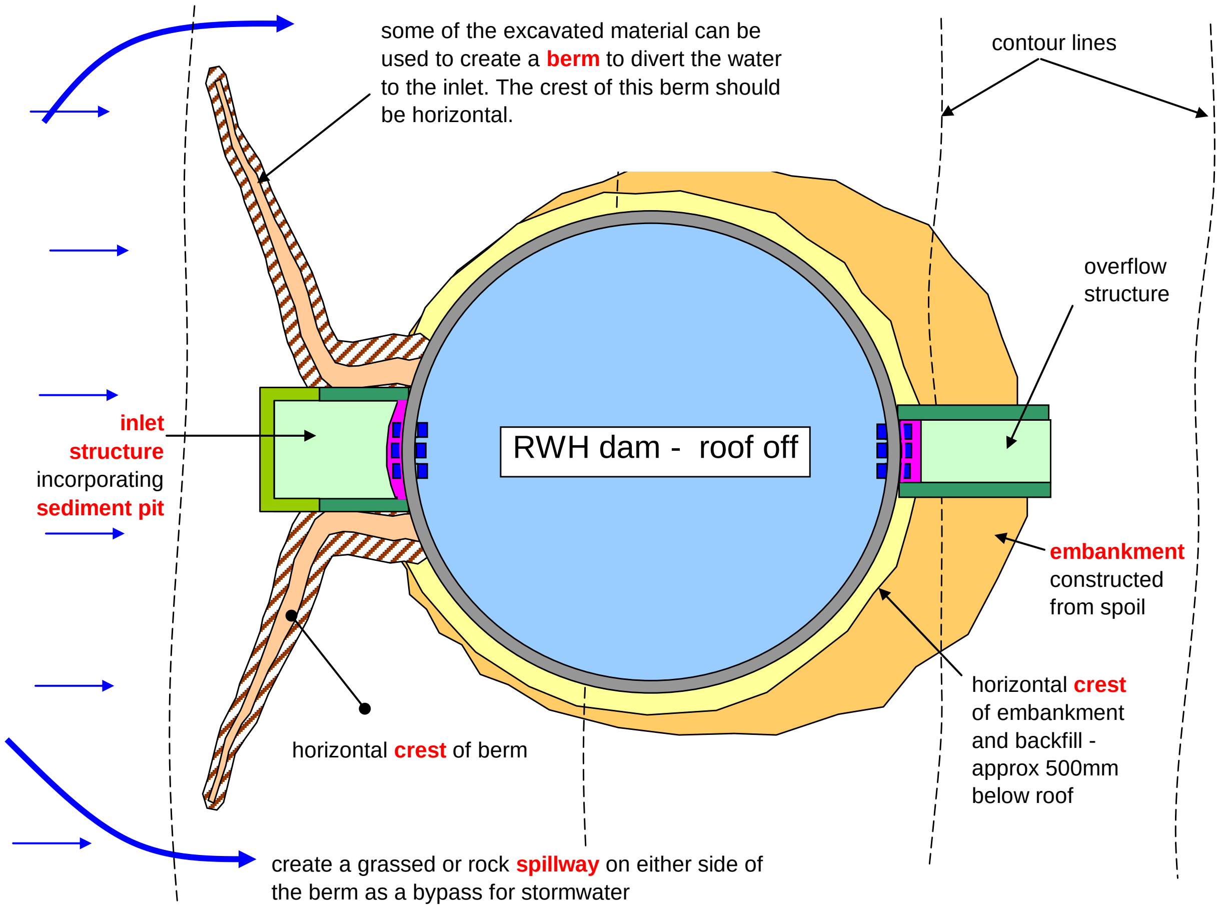
Appendix F8.1 - Earthworks to direct run-off and to stabilise the RWH Dam walls



Notes:

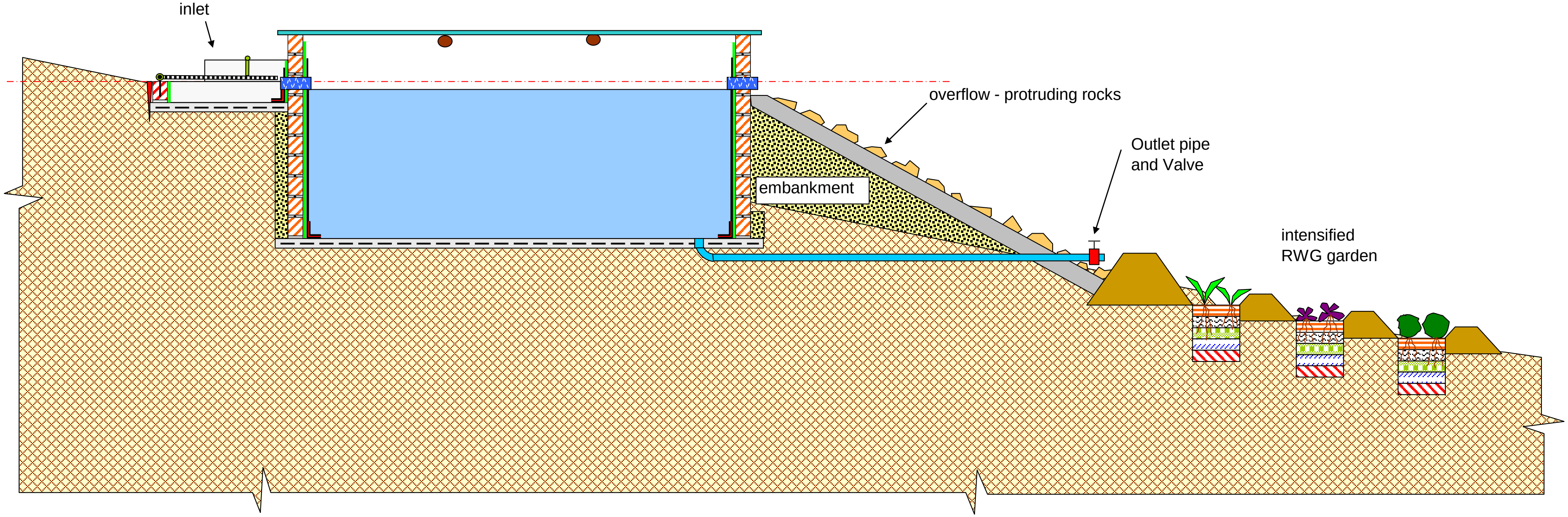
When the garden is downhill of the dam, it will normally be advantageous to construct **berms** to divert the rainwater runoff into the dam. When the runoff is slight, the berm merely diverts the water towards the **inlet**. But when runoff is much greater, for example at the height of a storm, it is possible that the inflow into the inlet will exceed the flow capacity of the three PVC inlet pipes, and at such times the berms act as a mini 'surge-dam'. The advantage of a surge dam is that less water bypasses the tank, and more ends up in the tank. Clearly the greater the length and height of the berms the more effective this is. The **crest** of the earth berms should be horizontal - and say 200mm below the roof of the tank. The **sediment pit** forms part of the inlet, and reduces the coarse sand and grit that enters the dam. The floor of the pit is approximately 130mm below the invert level of the 110mm PVC pipes.

Spillways should be created on either side of the berms as by-passes for potentially destructive inflows during unusually large storms. These may simply consist of grassed surfaces of sufficient width to minimise the flow velocity. The contours of the spillway should always be 90 degrees to the direction of the intended flow.

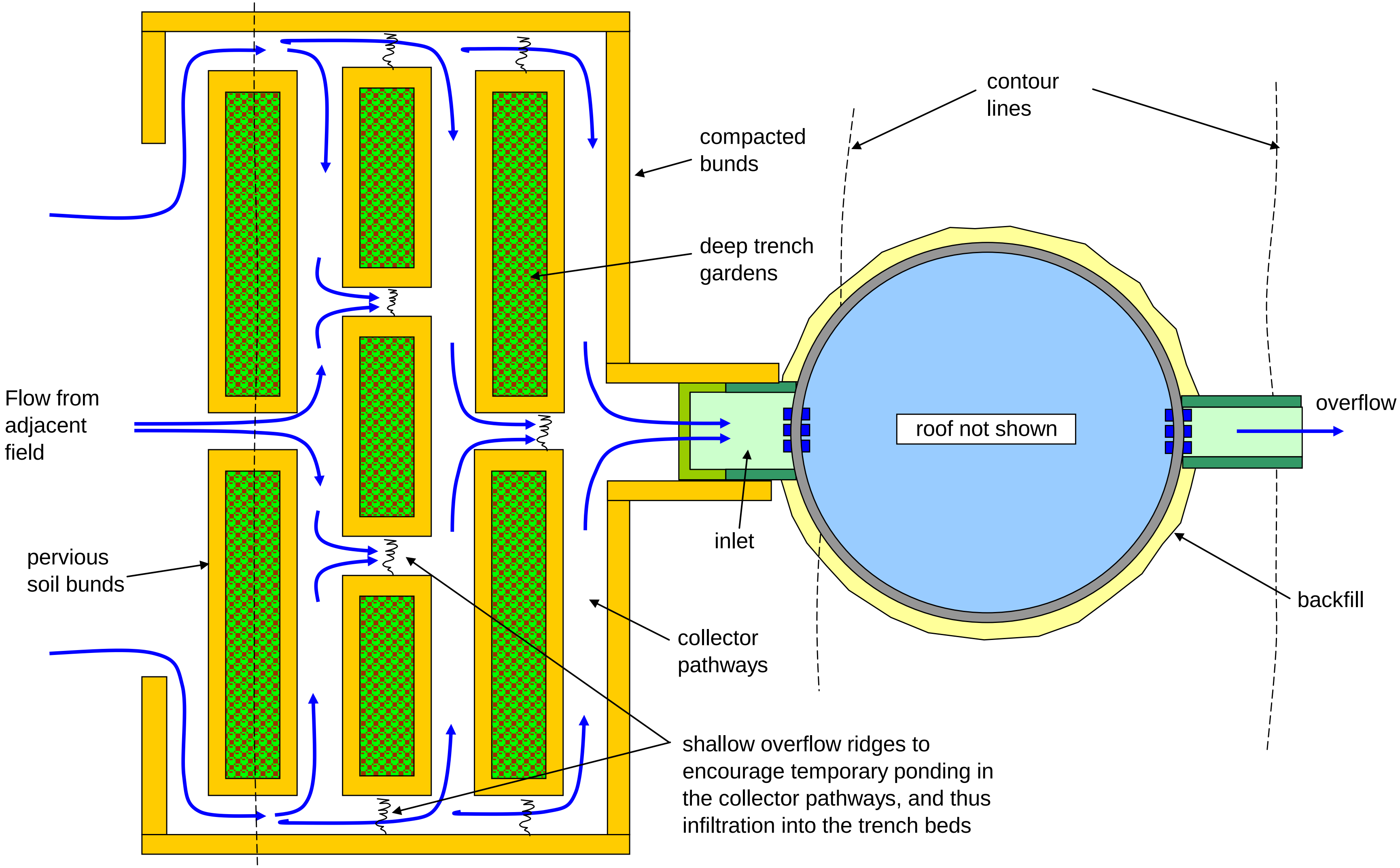
The excavated material should also be spoiled on the low side of the dam (in addition to using it for constructing the berms) to create an **embankment**, and this is structurally important where the terrain is steep. The top of the embankment and the final **crest** all around the tank should be horizontal and approximately 500 mm below roof level.

Any backfilling done near the tank should be placed and thoroughly compacted in horizontal layers not exceeding 100mm. This will equalize the earth pressure all around the tank - and hence minimise circumferential tensile stresses in the wall.

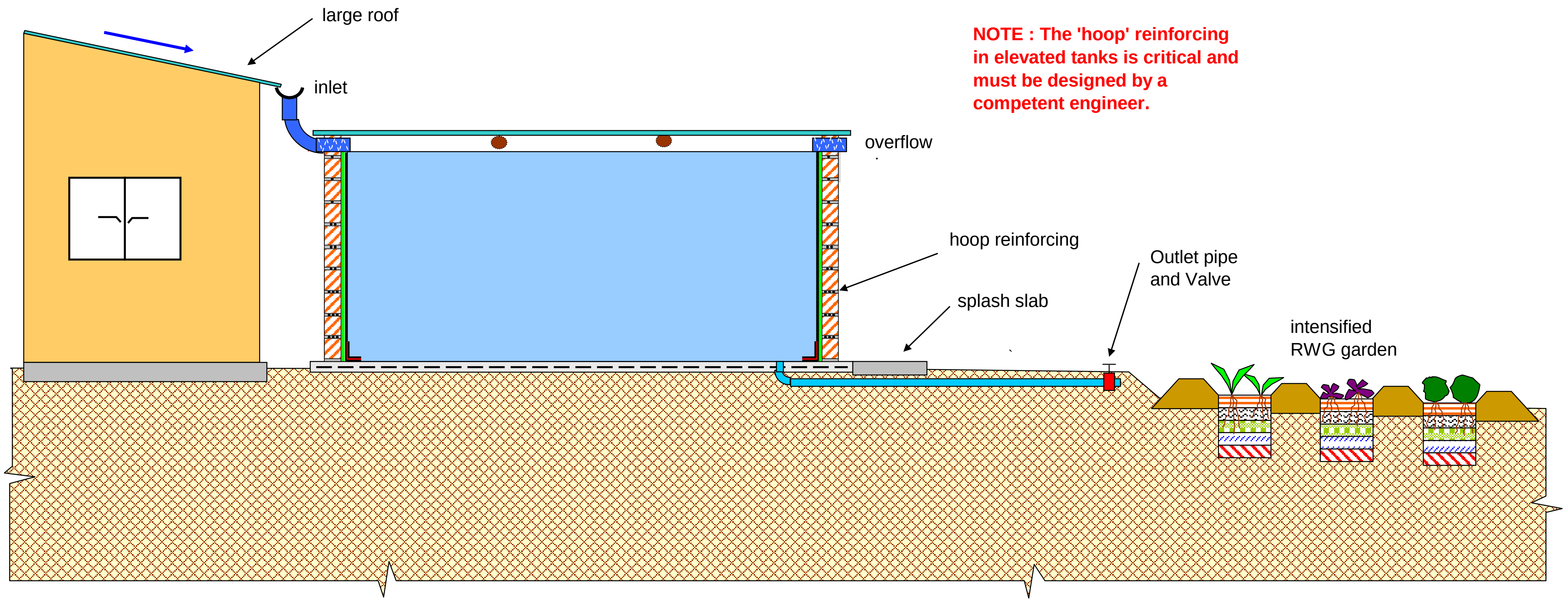
Appendix F8.2 - Steep terrain
Situate the garden downhill of the RWH Dam, and provide an outlet and valve for gravity flow to the garden



Appendix F8.3 - Large uphill catchment (e.g. field, road)
In this case, the intensive trench garden can be situated below the uphill catchment, but above the RWH Dam.
Once rainfall run-off has saturated the garden trenches, the overflow would fill the RWH Dam.
The RWH Dam should be close to the garden trenches, to facilitate irrigation by bucket or treadle/manual pump.



Appendix F8.4 - Main catchment a large roof
Situate the garden downhill of the RWH Dam, and provide an outlet and valve for gravity flow to the garden



APPENDIX F9. Excavation considerations

Appendix F9

Excavation Considerations

In this Appendix, problems associated with building a RWH Dam in difficult ground conditions or a high water table are considered, and various solutions are proposed.

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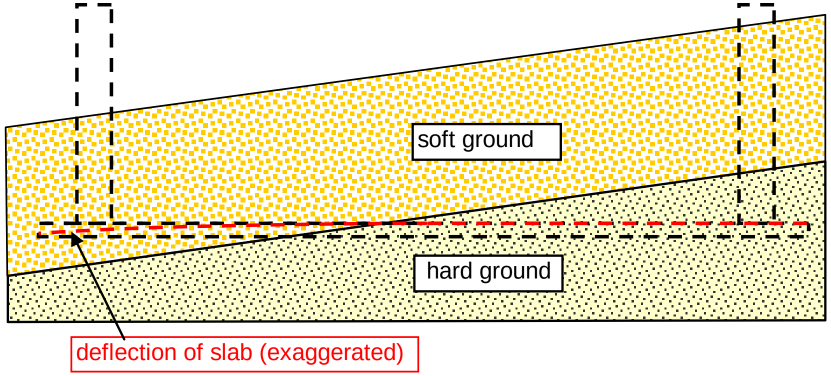
Appendix F9.1 - How to deal with variation in ground hardness

Statement of the Problem:

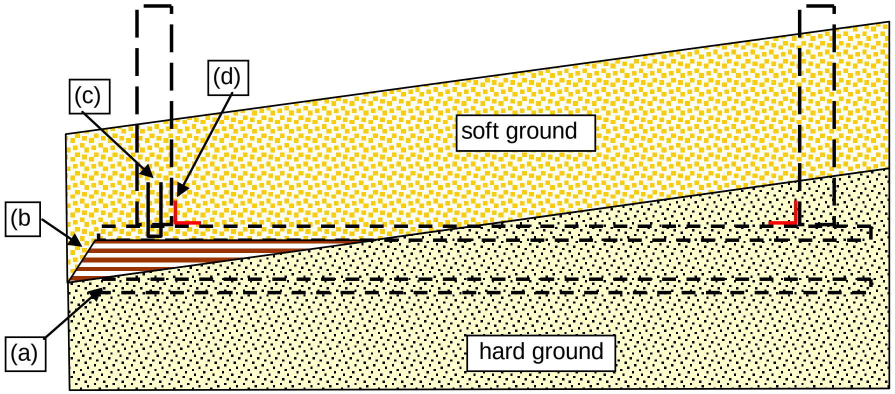
In steeply sloping terrain, coupled with a variation in the hardness of the ground layers, the RWH Dam's horizontal floorslab could be in harder ground on the uphill side relative to the downhill side (see sketch). The softer ground would consolidate more easily, particularly under full dam conditions, which would mean less support for the slab in that zone. With no reduction in load from the full dam, the slab would be pushed downwards until equilibrium is re-established. Thus the softer ground would continue to consolidate and the slab would continue to deflect downwards until it cracks. The nominal reinforcing in the standard slab mainly controls drying shrinkage, and would be insufficient to prevent the slab from bending and cracking under the conditions decribed above. It is also unlikely that the minimal tensile bond between slab and wall would be able to prevent a crack developing here, and water would begin to leak out. This leak would further soften the ground in this area, leading to more consolidation and hence larger cracks/leaks developing. This effect would be especially troublesome if there is a sudden transition in ground hardness along or near the centreline of the floor-slab.

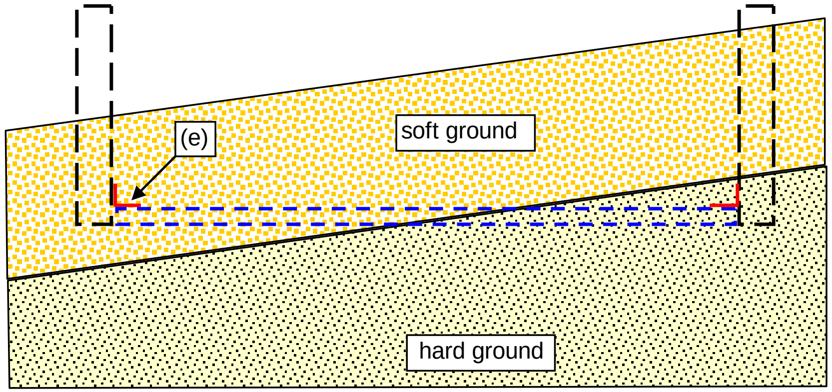


Five possible solutions:

(a) dig a deeper excavation so that the entire floor slab is supported by hard ground
(b) remove the soft ground and bring in suitable ground, spread in layers of 100mm, and thoroughly compact at optimum moisture content with hand stampers, or preferably mechanical compactors if obtainable
(c) use steel reinforcing bars to tie the floor into the wall (note that the wall is much stiffer than the floor and will not as easily bend downward, particularly if it has reinforcing between the courses
(d) use a high quality flexible bandage in the corner to prevent leakage through the crack. The bandage should go all the way around the circumference
(e) cast the reinforced concrete slab between the walls rather than under the wall, again with a flexible bandage all the way around the circumference to accommodate the movement in the slab as it flexes. The slab is likely to flex less (and hence not crack) as it is free to move, while the flexible bandage will accommodate any movements at the corner.

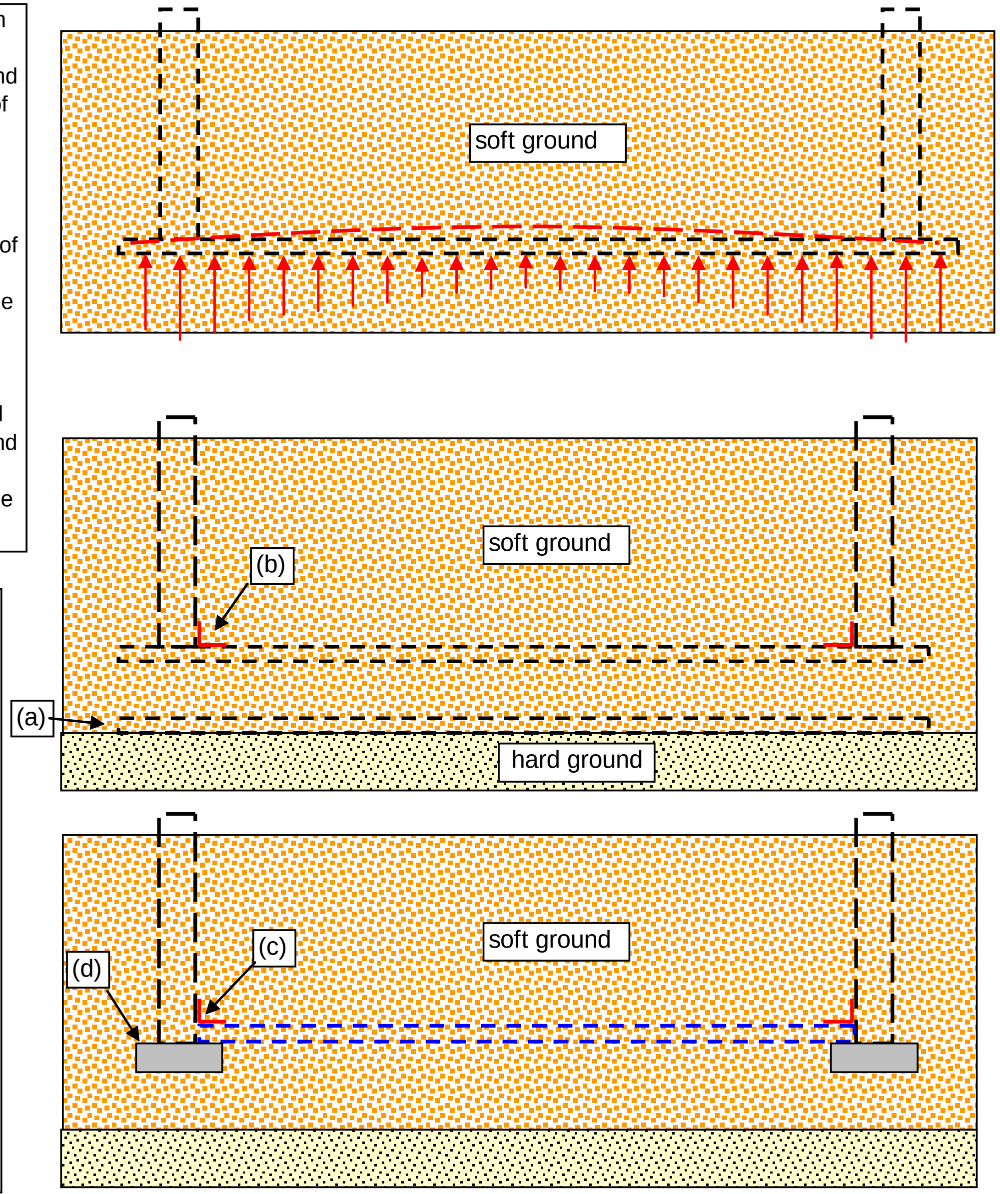
Solutions (a) and (b) may be regarded as best practice as they prevent bending effects in the slab.





Appendix F9.2 - How to deal with soft ground

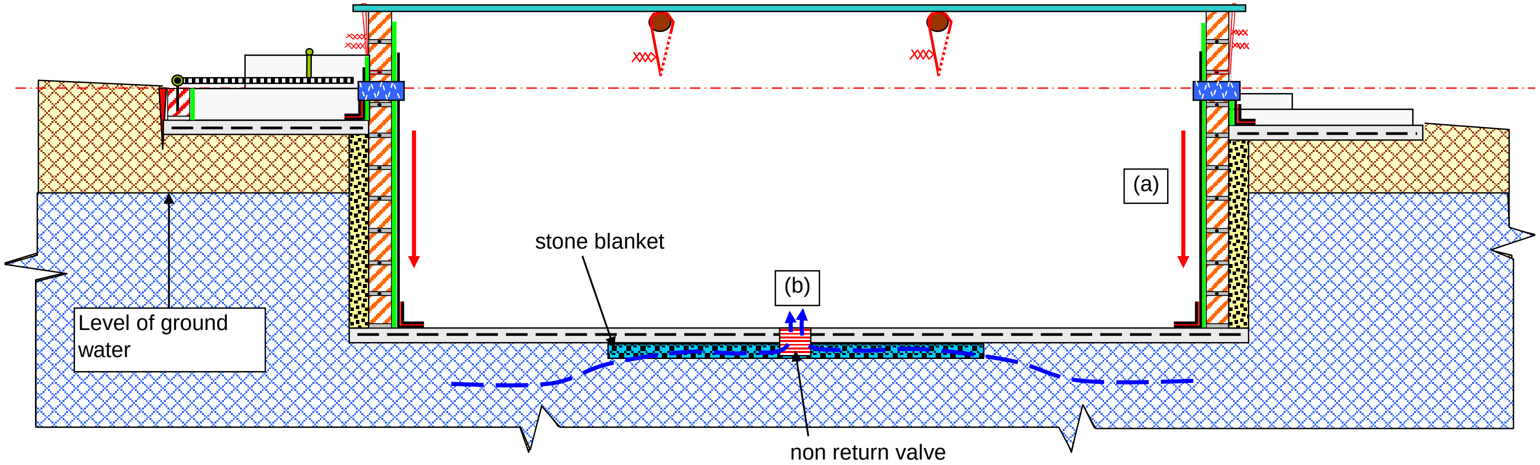
Statement of the Problem: Soft ground will consolidate in time from the pressure applied by the weight of the tank. However, there will always be more pressure applied to the rigid zone beneath the wall and less pressure applied at the middle of the floor slab - firstly because of the additional weight of the walls, and secondly because the flexibility of the floor-slab has the effect of lessening the pressure in the middle zones. (Note that the floor slab derives its flexibility primarily from being thin, typically 100mm, and secondly from being lightly rather than heavily reinforced, typically ref 193 mesh). When the tank is full of water, this pressure differential will be relatively minor, but when it is empty the pressure below the wall will be significantly more than at the centre of the slab - leading to substantially different rates of consolidation over time. The settlement of the structure (possibly 10mm in soft ground) is generally of no concern where the ground is uniformly soft over the full area of the floor slab, unless there are rigid plastic pipes exiting the reservoir that may shear off. On the other hand the deflection of the floor-slab as indicated in the sketch will be accompanied by a rotation at the region below the walls, leading to the possible formation of cracks and leaks.

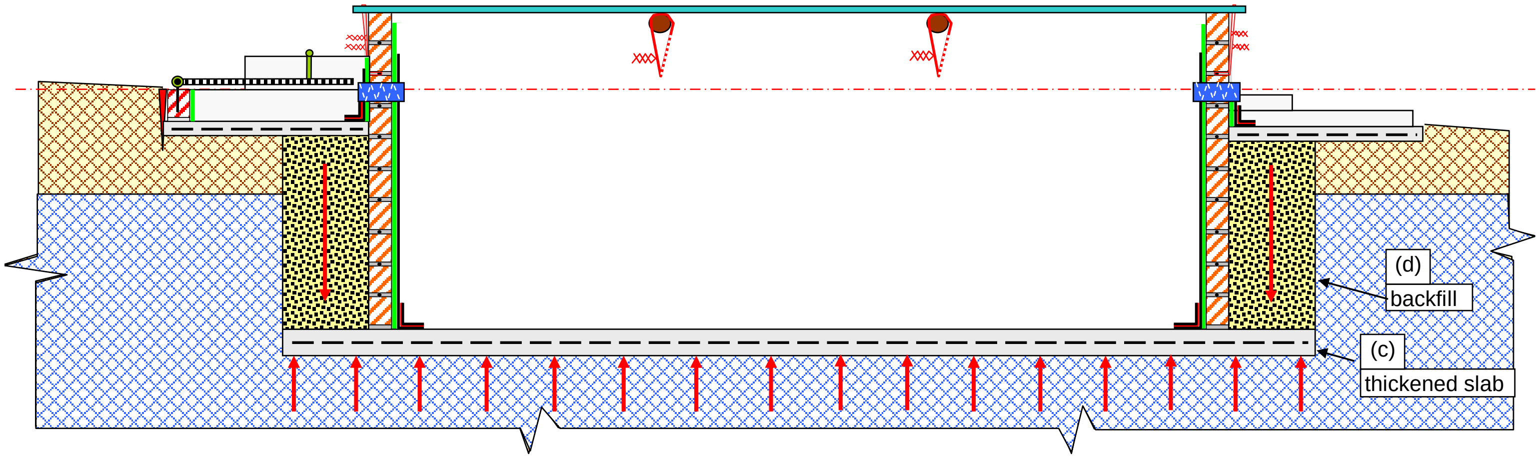


Three possible solutions:
(a) dig a deeper excavation so that the entire floor slab is supported by hard ground
(b) use a flexible bandage in the corner to prevent leakage through the crack
(c) place the reinforced concrete slab between the walls, with a flexible bandage all around the circumference to prevent leakage at the corner. In this case the floor slab 'floats' on the supporting ground and the pressure below the floor slab will be uniform over the full area of the floor, and there will therefore be minimal flexing of the slab.
(d) same as (c) but as a further precaution a foundation is provided to limit settlement of the walls, especially where there are pipes that may shear.

Solutions (a) and (d) may be regarded as best practice as they prevent/limit bending effects and differential consolidation. However, they are also more costly, and providing settlement is likely to be excessive, options (b) or (c), where provision is made for settlement, may be quite acceptable.

Appendix F9.3 - How to design for a high water table





Statement of Problem :

Where a high water table occurs, followed by rapid emptying of the reservoir, substantial uplift pressures will act on the underside of the slab, and if the resultant uplift exceeds the combined weight of the tank, then it is possible that the tank may float out of the ground, or at least be partially displaced.

Solutions :

(a) Ensure that the walls of the tank stand on top of the floor-slab (a floorslab that is built between the walls will be displaced upwards from uplift pressures far more easily than one that has the wall built on top of it).
(b) Before the slab is cast, a compacted stone blanket may be installed together with a non-return valve. The valve provides a channel for water that migrates into the blanket to exit upwards into the empty tank, and this action prevents the build up of any significant pressures.
(c) Increase the thickness of the slab, and hence its total weight.
(d) If the slab is made to extend further out from the walls, then it will carry a significant weight of backfill.

Note that it is relatively simple to determine the uplift forces if the height of the water table is known. However, all the solutions discussed here need to be built in at the time of construction. It is therefore important that high water tables be identified at

APPENDIX F10.
RWH Dam Safety & Maintenance Manual

Introduction

All structures require maintenance if they are to last for many decades and continue to operate at an optimal level, and RWH Dams are no exception.

There are principally three types of safety and maintenance actions that are discussed in this Appendix.

F10.1 deals with safety issues associated with the daily operation of the RWH Dam, in addition to the issues related to post-rain safety measures discussed in F10.2, and the annual maintenance and safety inspection discussed in F10.3.

F10.2 deals with the maintenance and safety inspection that must be carried out after each and every rainfall where the runoff was sufficient for water to enter into the RWH Dam via its inlet. The checks and associated tasks are relatively simple, but these must be done on many occasions in a year, after each significant rainfall event.

F10.3 deals with the maintenance and safety inspection that must be carried out annually. The first step in this checkup is the removal of all sediment that had accummulated in the RWH Dam over the past year, followed by an inspection of the various infrastructural components of the RWH Dam. This checkup will usually be done towards the end of the dry season when the water in the RWH Dam is depleted.

Several of the maintenance tasks discussed in F10.2 and F10.3 are especially important in that they render the RWH Dam and surrounds '**unsafe**' if not attended to – with the possible loss of life and limb!

The tables in F10.2 and F10.3 are arranged in four columns. The 1st is the number of the point under consideration, the 2nd refers to the part (or component) of the RWH Dam under scrutiny, the 3rd is a statement of one or more problems that may be noticed during the inspection process, while the 4th proposes one or more solutions, but also cautions how '**unsafe**' the RWH Dam will be if nothing is done about the problem.

It is the responsibility of the RIAs to impart the necessary level of understanding to the householders before handing their RWH Dams over to them. It is suggested that training sessions are conducted in groups of 10 householders at a time, where the RIA's technical officer goes through the various steps in F10.1, F10.2 and F10.3. Most important is that a local builder who has been involved in the building process, and who is willing to undertake some of the more technical procedures on behalf of the householder, should also be present at these sessions, so that he is sufficiently knowledgeable to apply the Proposed Solution if 'Problems' arise at a later date. Finally, each householder should be handed a complete copy of this Appendix F10, with steps 109 through 117 of Appendix F5 attached to it.

Some of the 'Proposed Solutions' associated with Appendix F10.3 require 'repair kits' of 'Chryso L228'. Because this material is only available from Chryso's regional centres based in Johannesburg, Cape Town, Durban and Port Elizabeth, it is essential that the RIA gives each householder a repair kit to repair any accidental damage to the waterproofing coat when the RWH Dam is cleaned annually (e.g. see F10.3.2). The repair is very simple to do, but if the householder is not sufficiently confident to do it, the builder may be called upon to assist, but some compensation will naturally be involved. It is recommended that each repair kit consist of 500 ml of the polymer, with the companion cementious/sand component being 900grams. These two components should be kept in sealed plastic containers (e.g. 800 gram peanut butter type plastic bottles are ideal and will keep their contents in a good state for many years). The supplier's preparation, blending, mixing, and application instructions should also be included in this repair kit. Finally, the repair kit should also contain 1m of ABE membrane (a 200mm wide 'bandage' made from woven polypropylene fibres). At current prices the repair kit would cost under R30, but allow an additional R10 to R20 for packaging the materials. It is likely that if Chryso are approached to assist with this matter, they will be quite willing to do the packaging of the 'repair kits'.

If for whatever reason the RWH Dam's floor or walls are not watertight to the extent that a major re-sealing repair is required (e.g. F10.3.7 and F10.3.9), this clearly would call for one or more *full* (standard) kits of 'Chryso L228'. The RIA must secure an assurance from the main local supplier involved in the supply of the building materials in a given area that they will assist in obtaining one or more kits from Chryso on behalf of the householders in such cases.

Note that Appendices F10.1 through F10.3 make reference to various physical components that are detailed in Appendix F1 and F8, to construction procedures that are detailed in Appendix F4, and finally to illustrations of maintenance and safety procedures shown in Appendix F5.

After the RIA has given all the essential training regarding maintenance and safety, it is the ongoing responsibility of the householders to ensure that their RWH Dams are operated in a safe manner at all times.

F10.1 Daily operational Safety Measures for a RWH Dam

The focus in this Appendix relates to safety measures to be implemented on a day-by-day basis, relating to daily usage of the RWH Dam, as opposed to post-rain safety issues discussed in F10.2 or annual safety issues considered F10.3.		
	Possible Problem/s	Proposed Solution/s
1	The trap door is not closed and locked after opening it to draw water for irrigation.	The RIA must make a sign printed on a 0.8mm thick stainless steel plate, warning of the dangers of leaving the trap door open. This sign is to be pop riveted on the roof-sheet next to the trap-door. Before handing over the tank to the householder, the RIA must impress upon the householder that it is **unsafe** to leave the trap door unlocked.
2	The water is used for drinking purposes.	The RIA must also include on the sign printed in 1 above, incorporating a skull and crossbones, the dangers of drinking the water from the RWH Dam. As in 1 above the RIA must impress upon the householder that it is **unsafe** to drink the water from the RWH Dam.
3	There is water in the sediment pit	Following a rain event, water must first be taken from the sediment pit to empty it - as an additional safety precaution.
4	The inlet's protective cover is open	The inlet's protective cover/grill must be kept closed at all times, except when the sediment pit is being emptied as described in 3 above.

F10.2 Post-rain Safety & Maintenance Inspection for a RWH Dam

After every significant rain event that results in water flowing into the RWH Dam, there are certain checks that should be carried out if the RWH Dam is to function at its best and serve as a safe and useful water storage facility for gardening. The various checks that should be carried out are listed under the headings 'Inspection', 'Possible Problems', and 'Proposed Solutions'.			
	Inspection	Possible Problem/s	Proposed Solution/s
1	Inspect the inlet	Leaves and rubbish cover the inlet's protective grill	Remove the leaves and rubbish and throw it away. The organic material may be left on a compost heap, or placed in a trench for enriching the soil for an the intensive garden.
2	Inspect the sediment pit	Sediment and water are left in the sediment pit after the rain.	Open the protective grill, and scoop up the water into a bucket. Pour it out over the vegetables in the garden, then scoop up the sediment and throw it away, or mix it with organic waste so that it may be used for intensive gardening. See steps 110, and 111 in Appendix F5. Note that it is '**unsafe**' not to remove the water and sediment immediately after the rain, as this represents both a drowning hazard and a breeding ground for mosquitoes. It is further '**unsafe**' not to close the inlet's protective cover after cleaning the sediment out, even if it is empty following the cleaning operation. The cover must always be closed except during times of cleaning out sediment in readiness for its protective function following the next rains.
3	Inspect the chicken mesh 'sausages' inside the inlet and outlet PVC pipes.	The chicken mesh 'sausages' in the PVC pipes become blocked with leaves and rubbish – this will mainly occur on the inlet pipes, but the overflow pipes may also become blocked from time to time and should always be checked at the same time.	Remove the 'sausages' in the inlet and overflows, clean them with water, and re-insert then into the pipes. See steps 112 and 113. Clogged or blocked 'sausages' will prevent water from entering the tank, which defeats the whole purpose of having a tank in the first place!
4	Inspect the surface of the roof	Dust and leaves accumulate on the roof, and block the	This material must be swept off the roof – use a simple broom. When working on the roof, only stand in the troughs, not on the ridges, to prevent localised

		10mm drainage holes in the roofsheeting – see step 102 in Appendix F5 for a view of a typical hole.	buckling in the webs. It may be possible to use this wind swept material to enrich the soil in an intensive garden.
5	Check the functionality of the padlock.	The brass pad lock becomes unlubricated as a result of the rain, making it difficult to open. Furthermore, the padlock may be lost, or its key may be lost.	Apply a few drops of oil to the lock after the rain. A lost or non-functional padlock must be replaced immediately. It is **unsafe** to operate a RWH Dam without being able to secure the trapdoor, as clearly this can lead to people drowning, especially small children.
6	Inspect the berms	The berms are breached, or too low.	The function of the berms (based on the general configuration shown in Appendix F8.1) is (1) to divert incoming rain-water runoff to the RWH Dam's inlet structure, and (2) to divert excessive runoff to the spillways so that it safely by-passes the RWH Dam, and thus keep water away from all other parts of the RWH Dam's perimeter, and (3) to create a surge dam to capture some of the peak runoff at the height of the storm when the inlet's PVC pipes are unable to cope with the inflow. Breached berms must be repaired with earth, which should be mildly compacted, and vegetation should be encouraged to grow at these places to prevent future erosion of the berm. Berms must be high enough to safely divert excessive storm water around the RWH Dam, and to act as mini-surge dams.
7	Inspect the earth embankments	The embankments are eroded or not at the correct elevation.	The function of the embankments, especially in steeply sloping terrain, is to ensure that the earth is at the same elevation all the way around the circumference (see example in Appendix F8.2). This is a structural requirement for the stability of the structure and especially the walls. Therefore eroded embankments must be repaired, and grass established. Note that it is **unsafe** to operate a RWH Dam that has a variation in backfill elevation – in extreme cases this may lead to the RWH Dam bursting, cracking, or collapsing, possibly resulting in severe injury or death.
8	Inspect the	The spillways are	Generally there will be two spillways in a RWH Dam –

	spillways	eroded or too narrow or not normal to the intended direction of flow	based on the general configuration shown in Appendix F8.1 – and accepting that there are other configurations for other requirements. The eroded areas in spillways must be filled in with soil and planted over with grass. Eroded spillways are **unsafe**, as they may concentrate the flow of water during peak run-off, and this may result in drowning of small children. Therefore spillways must be well maintained and relatively wide, say 3m, to limit the depth and velocity of the water, and to meet this requirement they must also be landscaped such that their contours are 90 degrees to the direction of the intended flow for the water.
9	Inspect the ground profile around the RWH Dam.	The ground level slopes radially *inwards* towards the RWH Dam, resulting in standing pools around the wall of the dam, which will soften the ground, increase earth pressures against the RWH Dam's wall, and likely result in unwanted differential settlement.	Landscape the ground in contact with the wall of the RWH Dam so that it is approximately 500mm below roof level, and so that it slopes radially *outwards* away from the dam, for a distance of approximately 1m away from the wall. Thereafter the ground should be landscaped to lead the water evenly in a downhill direction.
10	Inspect the overflow	There is erosion at the end of the overflow, where it meets the ground.	Erosion at the end of the overflow must be repaired by placing ground in any washed away areas, and then planting grass. Rocks may also be used to slow the water down if erosion takes place downhill of the overflow.

F10.3 Annual Safety & Maintenance Inspection for a RWH Dam

Once a year the RWH Dam should be emptied (ideally at the end of the dry season) and a thorough check should be made of the various components that make up the RWH Dam and the ancillary inlet and overflow structures. As for F10.2 the approach adopted here for each 'inspection', will be to list the potential 'problems' that may arise/accumulate in the course of the year, and then recommended a 'solution'.			
	Inspection	Possible Problem/s	Proposed Solution/s
1	Look inside tank to see if there is a build up of sediment.	Sediment accumulates inside the RWH Dam, consisting mainly of very fine silt and clay particles, but some fine organic matter will inevitably also make its way past the chicken mesh 'sausages' (inside the PVC inlet and overflow pipes) and into the RWH Dam.	Towards the end of the dry season it is likely that all the water in the RWH Dam will be used up. The sediment will also soon dry up, and at this point entry should be gained into the dam via the trap door and the sediment scraped up off the floor with a spade, and tossed outside the RWH Dam. This sediment may be enriched with additional organic waste or compost, and used in an intensive garden. Alternatively it may be disposed of. See step 115 of Appendix F5 for an illustration of sediment being removed from a RWH Dam. It is important to work carefully when approaching the perimeter of the RWH Dam in the region of the flexible bandage – making sure not to pierce it with the spade. From a drowning perspective, it is **unsafe** to have a tank that is empty in regard to the water being removed, but still with muddy sediment, and the trap door must remain locked in the absence of responsible supervision until all the sediment has been removed. No drowning can occur in a clean dry dam!
2	Inspect all the flexible bandages at the wall floor interfaces	Sediment covers and dirties the flexible bandage making it difficult to inspect the condition of the bandage.	Carefully scrape excessive sediment off the bandage using a wooden plank. Then scrub the bandage using a nylon brush until it is clean, so that it may be inspected.
3	Inspect all the cleaned flexible bandages. This applies to the bandage inside the RWH Dam at the wall/floor	A hole or crack is discovered	Carefully scrub the area around the hole with soap and water to remove all traces of mud and sediment. Use a fine sand paper to slightly roughen the outermost skin of the 'Chyso L228' in this region. This action will also remove any oxidised molecules in this region. (Do not remove more than 0.1mm). Mix the ingredients of a 'repair kit', following the instructions on the packaging, and brush it on to

	interface, but applies equally to the bandage at the interface of the inlet and the dam, and the bandage at the interface of the overflow and dam.		the prepared surface. Apply a small piece of abe membrane to this area. Paint over the membrane until it is fully covered. Leave RWH Dam empty for a few days to let the patch cure and harden.
4	Inspect the 'Chryso 228' coating on the walls, especially in the region of the trap door	Holes/ cracks/ abrasions are discovered.	Same as in point 3.
5	Inspect the wall's plaster	The plaster has fallen off the wall, or is no longer bonded to the blocks	Tap the plaster to determine where the loose area ends. Chisel out a neat perimeter at this juncture. Replaster the section and follow this up two days later with a two coat block brush application of 'Chryso L228'. One or more repair kits may be required. Leave the tank empty for a few days until the coat has cured. It is evident that the repair described here will required the input of a local builder.
6	Inspect the shape and geometry of the wall	The wall is bulging inwards or outwards	This means that the walls have either been pushed out by the water, or pushed in by earth pressure. This situation is **unsafe** as the possibility for overturning and collapse exists. An engineer should be called in to assess the situation. The engineer will assess whether the walls need to be demolished, or if some other corrective action is possible.
7	Look for brown stained horizontal cracks corresponding to the position of the mortarbeds.	The steel bars in the RWH Dam's wall are corroding.	A temporary solution, which may be good for 10 years, is to apply a new coat of 'Chryso L228' to the wall. This will prevent leakage, and either stop or slow down the rate of corrosion. Take care to prepare the existing surface as described in point 3, prior to applying the coating. [Note that when steel oxidizes it will occupy nine times more space relative to its initial volume – and this is the reason for the appearance of horizontal cracking. This type of cracking is probably an indication the waterproof coating was not correctly done in the first instance – which allowed oxygen and water to

			get to the steel hoops].
8	Check the blocks around the top of the RWH Dam, the inlet and the overflow.	The blocks are cracked or loose.	Remove cracked/loose blocks, clean away the old mortar beds and perps, and relay the loose blocks, patching the plaster where necessary. It may be necessary remove some of the roof-sheeting to effect this repair – the repair should be done by a local builder. Loose blocks at the top are **unsafe**, as they may eventually fall on people, and weaken the integrity of the structure, especially in regard to their role in providing mass against wind uplift.
9	Inspect the floor for cracks.	The floor is cracked.	Cracking in the floor is normally an indication of drying shrinkage. Try first sealing the cracks with a 'repair' kit. If this proves unsuccessful, the seal the entire floorslab. This will require a full kit of the water proof coat, 'Chryso L228', consisting of 10 litres of the polymer and 18 kg of the sand/cement pakage. Follow the preparation, proportioning, mixing and application instructions on the packaging, and the procedures set out in sections a. and b. of section XII of Appendix F4. Furthermore, a new 200mm wide flexible bandage must be placed around the perimeter as prescribe in point c. of section XII of Appendix F4. If the cracks are open cracks, the problem is serious, and may be the result of either heave of settlement. In this case, cast a new 100mm floor on top of the old floor, doubling up on the normal quantity of mesh (use 2 x ref 193 mesh pieces). Once again install a new flexible bandage around the perimeter. [Note that the new slab will be less prone to cracking as it is not constrained by the walls, and can therefore accommodate movements more readily without cracking].
10	Inspect the floor for perviousness. A good way to check for this is to flood the floor with about 5 to 10mm of water. Then come back when the slab starts drying. Areas that remain moist	There are poorly compacted areas, honeycombed areas, or pervious areas that may be the cause of leaking.	If the problem is localised apply two coats of 'Chryso L228' to these areas, using a repair kit. If the problem is extensive use a full repair kit to waterproof the entire floor surface, following the procedures set out in sections a. and b. of section XII of Appendix F4.

	have a higher rate of absorption than areas that dry out quickly.		
11	Inspect the concrete in and around the central sheath-pipe. It should be dense, hard, sound, and not come away when scratched with a nail.	There is evidence of poorly compacted and pervious concrete. This should also manifest in the flood test described in 10 above.	Apply 'Chryso L228' waterproof coat, following the procedures set out in sections a. and b. of section XII of Appendix F4.
12	Check all four roof-pole anchorage wires (4mm).	One or more of the wires are broken or loose	Follow the same procedure as described below in 13, but with a 4mm link wire. Clearly if the roof can blow off this is **unsafe** for people living in huts/houses nearby.
13	Check all the 2.5mm roof-sheet anchorage wires around the circumference.	Some of the wires are broken or loose.	Tighten loose wires by additional twisting at the splice. Reconnect snapped wires by supplying a link to connect them. (Wires snap from too much twisting when tightening). Simply cut out a section of the wire where the break is and splice in a short link wire (another piece of 2.5mm wire) twisting the wires together to tighten them in the usual way. It is **unsafe** to have broken wires, as this increases the possibility of these sheets from being blown off the roof making them dangerous projectiles.
14	Check all M6 x 65mm roof-sheet fastening screws.	There are missing or loose screws.	If loose or missing screws are detected, dip two matchsticks in 'Alcholin Cold Glue' and insert them in the hole, then re-screw a M6 x 65mm wood-screw into the hole. It is **unsafe** to have loose or missing roof-sheet wood screws, as this increases the possibility of these sheets from being blown off the roof making them dangerous projectiles – same danger as in 13.
15	Inspect timber roof-poles.	There are signs of rot, termite activity, cracks and excessive sagging.	A double application of creosote paint, on an annual basis, will be required to stop minor termite activity if untreated poles were incorrectly used for the roof. Creosote paint should also stop minor rotting. However, if these problems are well advanced, and/or the roof sags noticeably when someone walks on top directly along a pole, the

			roof-sheeting should be removed, and new poles should be installed. Clearly it is **unsafe** to have a roof where the supporting beam-poles are in danger of collapsing – this may result in drowning, or broken limbs if the RWH Dam is empty.
16	Inspect IBR sheeting, inside and outside.	There are signs of corrosion.	Scrub the inside and outside surface of the roof with soap and clean water, and then rinse thoroughly with clean water, then wipe dry with a clean towel. After the roof has baked dry and is slightly hot from the sun, paint the roof with a galvanizing paint. Pay special attention to the edges where the sheeting was cut at the time of installation, and to the 10mm funnel holes in the troughs of the roof-sheets, since the cutting and drilling operations would have removed the galvanizing from these areas and they are therefore susceptible to corrosion. Note that it is **unsafe** to allow roof-sheeting to corrode. Eventually the sheeting will be so thin that it may collapse when a person walks on top, resulting in a possible drowning, or broken limbs if the RWH Dam is empty.
17	Inspect the gutter bolts of the trap door.	Some bolts are missing or loose.	Replace missing M5 x 20mm gutter bolts and nuts that fasten the trap door to the roof-sheeting. Tighten loose nuts. Note that it is **unsafe** to operate a trapdoor with missing bolts and nuts, as this may result in the door being blown away or stolen, making the RWH Dam a drowning hazard.
18	Inspect the brass hinges of the trap door.	The brass hinges may get lost if (1) the gutter bolts came loose, (2) the hinges are bent or too tight, which both result in tearing effects. Lost hinges result in an unsecured trap door, which may eventually be blown away or stolen.	The two hinges should last indefinitely if they were heavy duty brass hinges. But if light duty brass hinges, or if steel hinges were installed, then the hinges may bend, tear, break, corrode etc. In this event replace the hinges with heavy duty brass hinges. Note that unauthorised entry can be gained into a RWH Dam if the trap door no longer has functional hinges and is secured only with a few rocks. Clearly this is **unsafe** as children may remove the rocks, fall in and drown.
19	Inspect the 12mm hole in the trap door and corresponding anchor sheet.	The 12mm hole is much enlarged and is in danger of becoming an open slot, and will soon no longer able to secure	Pop rivet a piece of sheet metal over the 'torn-hole' area, and re-drill the hole. Clearly it is **unsafe** to operate a trapdoor that is not lockable – drownings can occur.

		the padlock or trapdoor.	

APPENDIX F11. Alternative RWH Dam Designs

Appendix F11

Alternative RWH Dam Designs

In this Appendix, a number of alternative designs are considered, all of which were constructed in one or another form during the experimental phase by one or more RIAs. The various advantages and difficulties of the alternative designs, set out in F11.2 through F11.5 hereafter, may be compared with the Standard RWH Dam shown in F11.1. While these alternative designs are viewed as a departure from the preferred standard design, there will be circumstances when a variation is justified.

June 2007

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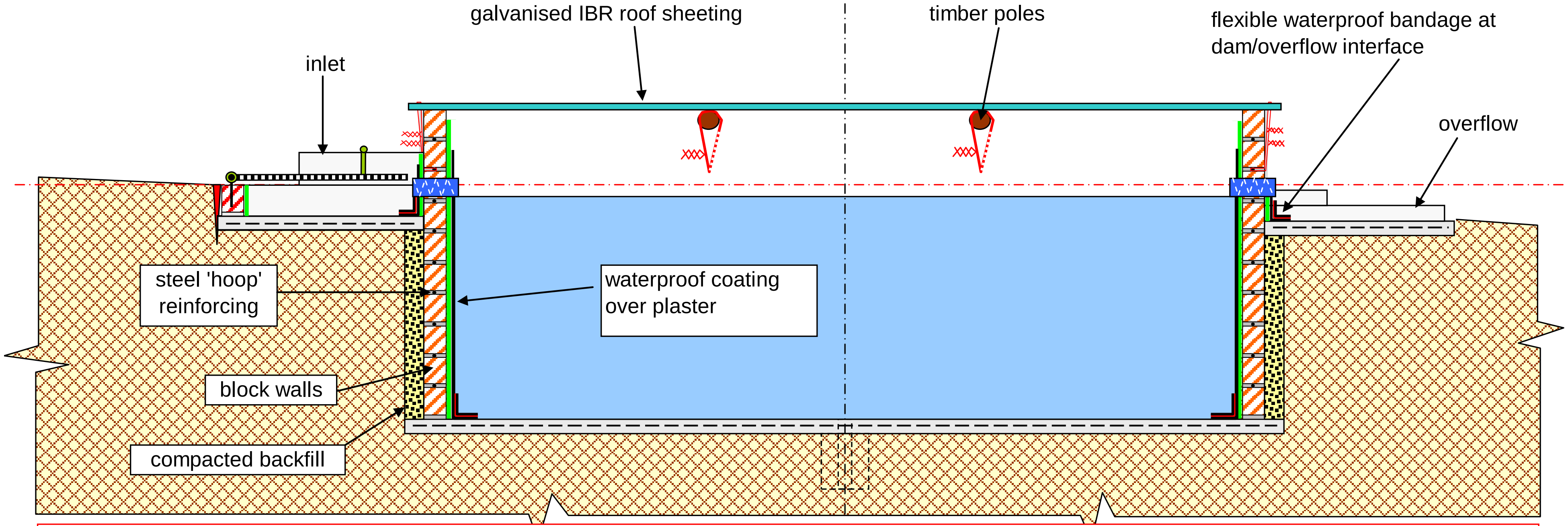
Appendix F11.1 - Standard RWH Dam: cylindrical block walls on a mesh reinforced concrete slab



Advantages

(1) Application : This method of construction has application where blocks/bricks are locally manufactured and reasonably priced. Generally this is the case for most parts of the country. Even in remote rural areas cement blocks can be obtained at relatively low cost owing to cheap labour and the availability of 'free' river sand from rivers.

(2) Shape : The cylindrical walls go into compression when backfilling is correctly done, thus cancelling tensile stresses that would otherwise develop and possibly lead to cracks. Nevertheless, a nominal amount of 'insurance' reinforcing is included in the standard design, in the event of sub-standard backfilling. (Square and rectangular shapes require substantially more reinforcing, and the placement is also much more complex).

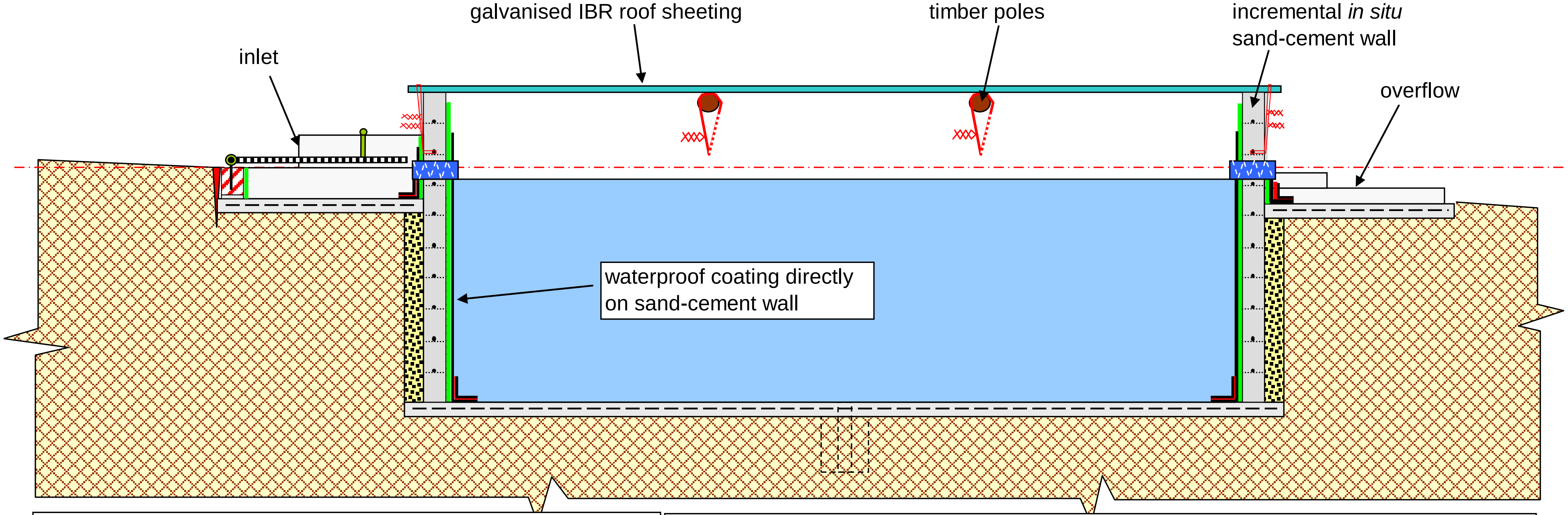
(3) Skills : The level of skill for the construction of the standard RWH Dam is readily within the experience of local builders. Tasks include: mixing and placing of concrete, laying blocks, plastering, waterproofing with block-brushes, roofsheeting on treated poles, etc.

(4) Pole-Arm : Various construction processes can be substantially simplified and accelerated by installing a 'central pole & radial arm' (see Appendix F2). This simplifies the excavation, the floor-slab, the walls, and the plastering.

(5) Cost : Assuming materials are locally available, the Standard RWH Dam has a relatively low cost structure.

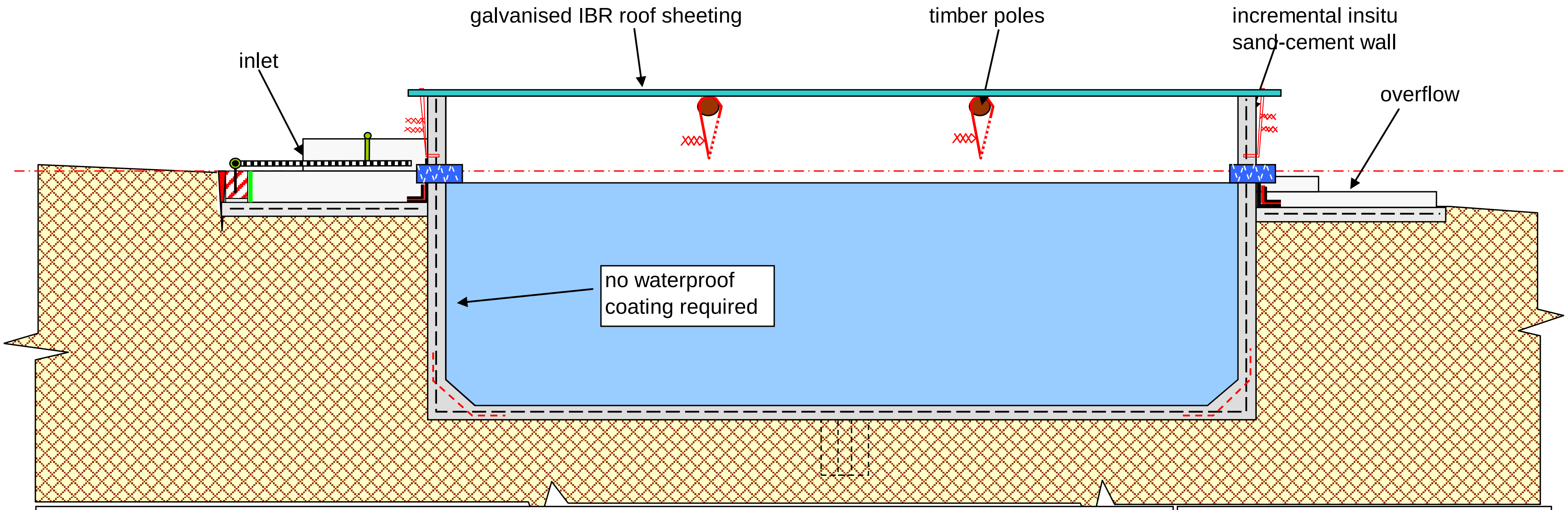
(6) Time : A well organised site can complete a 'Standard RWH Dam' in 13 days - including excavation time, and including the inlet and overflow structures.

Appendix F11.2 - Finnbuilder RWH Dam: incremental *in situ* sand-cement walls



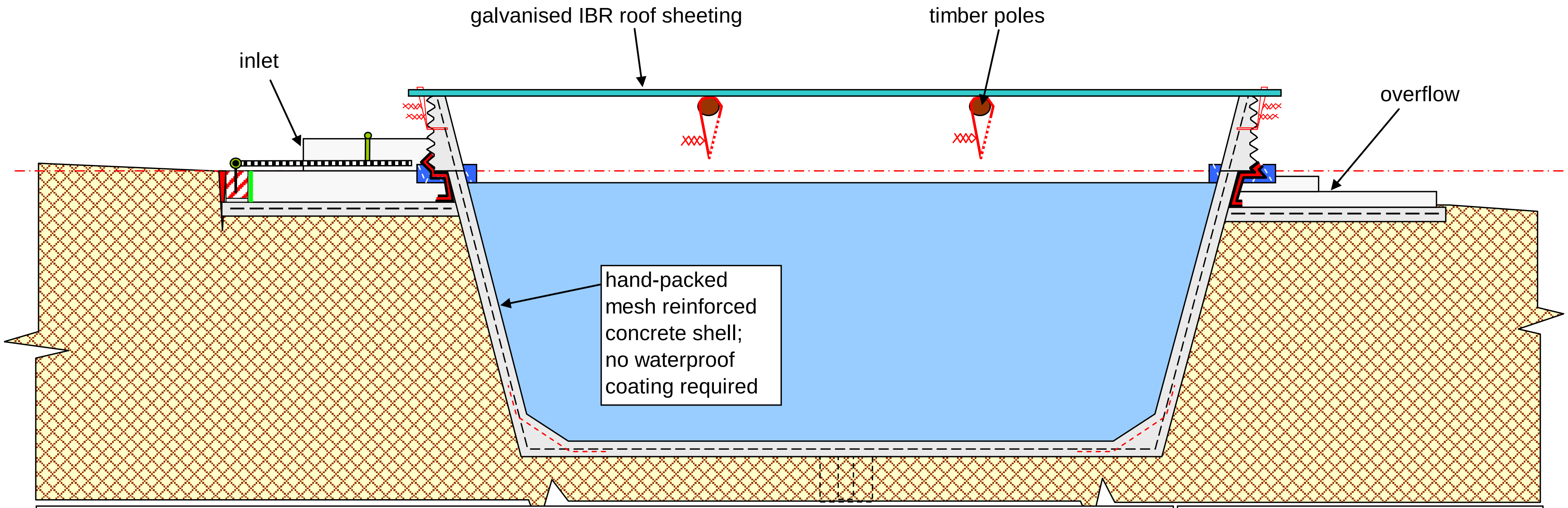
Advantages	**Difficulties**
(1) Application : This method of construction has application where course aggregate is very expensive, while a source of fine aggregate (e.g. river sand) is available at low cost. The only difference relative to the 'Standard RWH dam' is that the walls are constructed *in situ* by making use of a travelling mould such a 'Finnbuilder', whereby a semi-dry sand-cement mixture is used and tamped in position before the mould is moved to the next position a few minutes later. (2) Shape : Being of the same size and shape as the 'Standard RWH Dam' it has all the advantages of that design. (3) Pole-Arm : The wall building process is easily adapted to the 'central pole & radial arm' system. Accordingly, the new position for the travelling mould is quickly and accurately obtained every time the mould is moved. (4) No Plaster : Unlike a 'block and mortar' wall, these walls are relatively smooth if the water content in the mixture is correct and if correctly tamped. It is therefore possible to proceed with the wood and steel floating operation soon after the mould is moved to a new position.	(1) Unknown : The method of construction is not generally known and builders will require training. (2) Special Equipment : It requires specialist equipment (i.e. a travelling mould such as a Finnbuilder), but since the mould is robust and can be reused many times over, it adds minimally to the cost of the RWH Dam where many dams are to be constructed. (3) Sensitive : This method of building is relatively sensitive to the water dosage. Too much water results in the walls slumping, while too dry a mix lacks plasticity resulting in 'brittleness', causing cracking at the slightest bump when the mould is moved to the next position. (4) Slow : The construction process is at least 50% slower than that of a conventional block wall. This is because the 'block' has to be 'manufactured' in position, and while this does away with a separate laying operation (as in a 'mortar and block' wall), this saving in time is completely overrun by the slower 'manufacturing' process of filling and stamping *in situ* . Where labour is expensive, this additional time is clearly a difficulty. (5) Shrinkage : The wall is more prone to shrinkage cracks developing, since the wall is not 'pre-shrunk' as is the case with a wall made from conventional precast blocks that have been cured for 7 days and then left to 'dry-and-shrink' till they are 28 days old.

Appendix F11.3 - Gunite RWH Dam: cylindrical mesh reinforced concrete shell



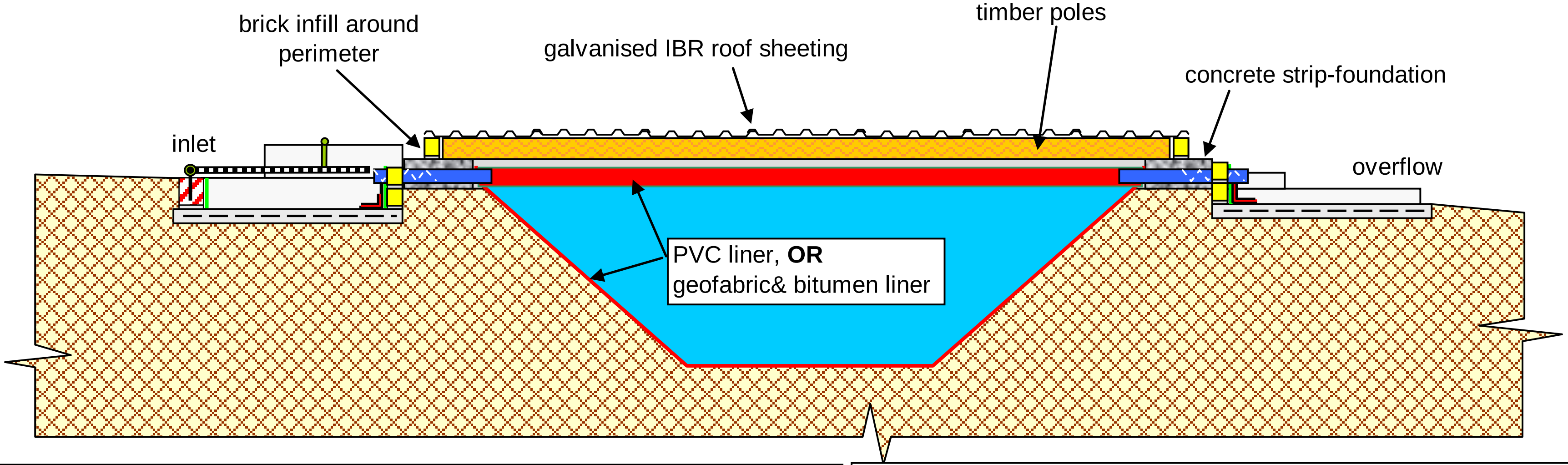
Advantages	Difficulties
(1) Application : This method of construction has application where the implementation agent is already equipped to do shot-basting ('guniting'), whereby a sand-cement mixture is pneumatically applied to the shell (floor and wall). The method further lends itself to places where course aggregate is very expensive, while a source of fine aggregate (e.g. river sand) is available at low cost. (2) Fast : The shotblasting operation, complete with the finishing process, can comfortably be completed in a single day. This allows substantially more dams to be constructed in a given timespan, with associated savings in labour, supervision, overheads, etc. (3) Shape : Being of the same size and shape as the 'Standard RWH Dam' it has all the advantages of that design. (4) Pole-Arm : The excavation, floor, and wall building processes are easily adapted to the 'central pole & radial arm' system, achieving accurate final dimensions as a result. (5) No Plaster : Unlike a 'block and mortar' wall, the wood and steel floating operation is done on the same day as the pneumatic process, with no separate plastering process required. (6) No Waterproofing : Shotcrete that is correctly proportioned, placed and finished, is substantially impermeable and does not require a waterproof coat. Furthermore, since the shell is cast integrally with no construction joint at the wall/floor interface, no 'bandage' is required in this zone. (7) Durability : This type of structure is virtually unrivalled in terms of strength and durability (only surpassed by the spherical tank).	(1) Unknown : The method of construction is foreign to most implementing agents and local builders. On the other hand most of the production tasks can be quickly learned by local labour, other than that of the 'nozzleman', where specialist skill and experience is required. (2) Special Equipment : Some items of equipment are very costly - e.g. large compressor, blender. (3) Sensitive : This method of building is relatively sensitive to the water dosage (hence a skilled 'nozzleman') and the correct type of sand.

Appendix F11.4 - Hand-packed RWH Dam: conical mesh reinforced concrete shell



Advantages	**Difficulties**
(1) Application : This method of construction has application where there are large rocks in the wall or floor areas, since the mesh can be shaped around such. The method further lends itself to places where course aggregate is very expensive, while a source of fine aggregate (e.g. river sand) is available at low cost. (2) Shape : The inclined walls of this dam allow the walls to hand packed - using a combination of shovels and wood floats to place and finish the sand-cement mixture. (3) Skills : The level of skill required for this type of construction are readily transferable to local builders. (4) Pole-Arm : The excavation, floor, and wall building processes can be done with a 'central pole& radial arm' system, achieving accurate final dimensions as a result. (5) No Plaster : Unlike a 'block and mortar' wall, the wood and steel floating operation is done on the same day as the pneumatic process, with no separate plastering process required. (6) No Waterproofing : Sand-cement that is correctly proportioned, placed and finished is substantially impermeable and does not require a waterproof coat. Furthermore, since the shell is cast integrally with no construction joint at the wall/floor interface, no 'bandage' is required in this zone. (6) Durability : This type of structure is virtually unrivalled in terms of strength and durability (only surpassed by the spherical tank).	(1) Depth : The inclined walls reduce the capacity of the dam, and thus for a given footprint the depth needs to be increased to achieve parity. (2) Pole-Arm : The pole-arm assembly requires an increased level of sophistication to cater for the inclined walls. (3) Sensitive : This method of building is relatively sensitive to the water dosage and type of sand. (4) Sheeting : Profiled corrugated sheeting is required as a mould for the section of the wall that is above the ground.

Appendix F11.5 - Membrane RWH Dam: trapezoidal earth dam, lined with membrane



Advantages

Accessibility : This design has application in inaccessible areas where materials have to be carried by donkey, as there are a minimum of heavy materials.

Flexibility : The liner is flexible and will accommodate settlement and differential settlement. The liner is approx 1mm thick and has substantial tensile strength to resist tearing.

Impermeability : No seepage will occur in PVC and bitumised geofabric lined dams - but special skills and materials are required to lay and seal the material.

Roof : The rectangular shape means all the poles and sheets can be the same length

Maintenance : A PVC liner can be repaired by gluing on a patch. Geofabric/bitumen liner may be repaired by the home owner by applying a patch of geofabric painted over with bitumen.

Difficulties

Complexity : Specialist contractors are required to weld the PVC liner together. Achieving the correct excavated shape is relatively complex. On the other hand a geofabric/bitumen liner may be installed by local builders - after some training.

Footprint : The dam has a relatively large footprint owing to the inclined sides of the trapezoid. In *loose* ground, inclinations less than 45 degrees are required for stability against shear failure (slides) and this substantially increases the footprint.

Durability : The liners are not as durable as concrete floors or block walls. The geofabric/bitumen option will require resurfacing within five to ten years, while the PVC guarantee only extends for 10 years.

Scooping : The inclined angle makes it more difficult to scoop water with buckets, and increases the likelihood of damage to the liner during scooping actions.

APPENDIX F12. RWH Dam Design Routines

Please see CD: "Appendix F12 – RWH Dam Design Routines.xls"

An Excel document on the enclosed CD contains the Design Routines for the Standard RWH Dam. These routines may be used to recalculate the parameters for a RWH Dam when the need arises, for instance where topographical conditions require a shallower, and thus larger diameter RWH Dam to be built. These routines recalculate the RWH Dam dimensions and design quantities through to Bill of Materials and thus enables costing for the chosen parameters.

These Design Routines are meant to be used by a competent engineer who would be able to interpret the consequences of design decisions.

DISCLAIMER:

The Department of Water Affairs and Forestry takes no responsibility for any mistakes that may exist in these design routines. Adjustments to the standard designs supplied by the Department may be made only with written permission from the Department, and the consequences of such adjustments will remain the professional responsibility of the RIA.

The RIA is also reminded of the following requirement:

IMPORTANT NOTE:

In instances where deviations from the Standard RWH Dam are necessary, the RIA must report these instances to DWAF for monitoring purposes, but may proceed with the construction of an alternative design approved by a professional engineer recognized by DWAF as having the necessary level of experience in this field. These structures must also be inspected and signed off by the engineer prior to handover. The structure may not exceed the accepted cost of the Standard RWH Dam without specific written approval from DWAF.