Smart rainwater harvesting for traditional housing in Malaysia using BIM

by

Afifah Nur Dina Binti Mohd Raihan

Dissertation submitted in partial fulfilment of

the requirement for the

Bachelor of Engineering (Hons)

(Civil Engineering)

SEPTEMBER 2022

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

32610 Seri Iskandar

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

…………………….

(Prof. Dr Nasir Shafiq)

UNIVERSITI TEKNOLOGI PETRONAS

SERI ISKANDAR, PERAK

September 2022

CERTIFICATE OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and the acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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AFIFAH NUR DINA BINTI MOHD RAIHAN

ABSTRACT

Flooding in Malaysia is considered an annual disaster that happens usually from November to January. Most of the people affected from the disaster are people from rural regions. As such having traditional houses and lack of stormwater and rainwater system to combat the flooding adds the difficulties to maintain their secondary income from the crops that are planted on the land that takes out more land than enough to build an on the ground onsite stormwater detention (OSD) and rainwater harvesting tank. This study deals with the problems that arise within these conditions at Batu Pahat, Johor as it is one of the states that experience the annual flooding events. It aims to provide one of many solutions for these problems. The solution that is provided in the study is having an underground OSD tank and rainwater harvesting tank that can be used for storing rainwater and to be used as storage during off season which uses SMART Tunnel as reference. The rainwater that accumulated can be used for various purposes such as watering crops and washing vehicles. This project intervened the problem by using Building Information Modelling such as ReVit to model the house to be used as reference. The reference of the house is a traditional and modern fusion of a detached house that are commonly around the rural area. The houses incorporate concrete as material that is better than wood that is used more in traditional houses. The drawing of the house is then used as references for the calculation for the underground OSD tank and rainwater harvesting tank. Results from this project are expected to contribute to answering the question that lingers from having detached houses that continue to have floods that will destroy properties annually.

ACKNOWLEDGEMENT

In the name of Allah, the most Gracious and the Most Merciful

First and foremost, I would like to praise God the Almighty for His Guidance. Though difficulties occurred, His guidance gave me the chance to still complete this challenging project successfully. Here, I would like to use this special opportunity to express my heartfelt gratitude to everyone that has contributed to the completing of my Final Year Project (FYP).

My deepest appreciation goes to my supervisor, Prof Dr Nasir Shafiq who advised and guided me with moral support throughout this project. I really acknowledge all the precious words from him and hope the moment working with him remain as valuable experience for my future undertakings. Obviously, without his cooperation and motivation I would not be able to fulfil the project requirements, as it needs a lot of commitment towards it.

My highest gratitude's' to all the lecturers of UTP especially lecturers from Civil department for their support that helps to keeps me up, my beloved family members for giving me the strength to finish my project, and all my that gave me feedback's and helped a lot through their useful ideas and advice.

Finally, for all the people that had given me their cooperation directly or indirectly, thank you all for being with me, for lending me a hand when I was in dire need of finding help for completing our project.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Malaysia has been having rough and critical these previous years with flooding and an excessive number of heavy downpours that cause many to have lost their home and lives. The lack of preparations and lack of consideration in the design of the house is one of the many reasons that brought about these problems.

When strolling down in the neighbourhood, we can see that Malaysia have many traditional houses standing and lack proper drainage or even a stormwater system for the area is not properly addressed. A substantial number of houses in Malaysia are either detached houses whether it is in traditional or modern houses. Since it is harder to accommodate each and one of the neighbourhood's demands and the need to build accommodate drainage and stormwater management, it is easier to build a personal stormwater harvesting tank along with rainwater within each boundary. This can improve the drainage and stormwater system uniquely for each house without prying much into the united system for each neighbourhood. It is also an issue that most of the flood water is wasted, whereas fresh water supply is also getting short and in future, it will be challenging to provide fresh water to the increasing population.

Housing areas have limited spaces. For a traditional house in Malaysia, the soil above is usually found with farms and gardens which are the small source of income for many. In that regard, the drainage and stormwater system are likely to be poor or very traditional looking without any proper calculation regarding the annual rainfall. For a small garden, it is also highly likely the garden to have no drainage and just soil bedding that accommodates the vegetable that is planted there. Then there is the recent year's heavy rainfall that keeps pouring day after day which makes this small ecosystem collapse. The small income and food staple for these families are ruined by the sudden large amount of water that did not have any place to go. Plants are not the only ones that are affected by these sudden big bodies of water. The property also suffers losses since they are built to withstand the former data of annual rainfall. These can be seen from all media outlets when the news break that the house collapsed leaving the family with only themselves on their own without shelter. That proper litigation has occurred to help these families, but then, we can only prepare for the next flooding without any proper preparation from the former side.

To combat the monstrous rain without having to do much prying into the united drainage and stormwater system and indirectly save space, the idea of having privately owned rainwater storage is welcoming. Simple rainwater collection and storage have been done since the old ages when people use any container that can be used to store water during rain and use it for daily necessity such as water the plants and bathing. The common idea is using water barrel with any filter to filter the water so that water left without any impurities. There are also options to store the water above the ground or underground.

In this study a procedure of calculation for the rainfall measurement using Building Information Modelling (BIM) for assessing and drawing the house for stormwater storage solution is proposed. The calculation of the rainwater demand is to measure the amount of rainfall and be used as a control variable for the size of the harvesting tank. The model of the drawing also refers from SMART Tunnel which implements the idea of space saving and reduces the likelihood of having flash flood in big city like Kuala Lumpur.

1.2 Problem Statement

Heavy rainfall and flooding are almost annual events in Malaysia. It is unavoidable for most detached houses to experience flooding and find that the drainage and stormwater system are made for a simple flood. To have an absolute resolution to this problem is a hard question to answer but having a private stormwater system that helps to direct the water away from the crops and live stocks is admirable. The increasing freshwater demand requires the enhancement of new water resources.

The proposed idea is to refer to the SMART tunnel concept to mitigate the stormwater issues in the housing areas by harvesting tank that uses both functionalities to save space and water. The tank is proposed to be built underground to lessen the space with two levels. The first level, which is the first level below ground, is for storing stormwater and the garage for instance while the lower-level function as a rainwater harvesting tank.

This proposed study will allow the understanding of BIM that is applied throughout the cycle and transform the collected data and information that are visualized and analysed by using the rainwater runoff calculation to prevent waterlogging.

1.3 Objectives

The objectives of the study are to:

1. To estimate and assess the rainwater demand and analyse the Malaysian housing sector with a pinpoint at Batu Pahat, Johor.
2. To create a BIM model of the rainwater harvesting tank using the idea of a SMART tunnel.

1.4 Scope of Study

In this project, determining the rainwater demand and the size of the underground tank for the traditional house is Malaysia the main topic. The design of the underground tank picks the idea of having two chambers instead of one. The first and the second chamber uses the annual rainwater demand equation that is provided by the MSMA. The parameters obtained from the equations will be used to compute a BIM drawing of an underground rainwater harvesting tank with the indulgence of traditional house design in Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of the literature review was to identify the issues and challenges in dealing with floodwater management within the housing sector in Malaysia. It also refers to the available solutions to mitigate floodwater issues. The most important mitigation done in Malaysia is the SMART tunnel, which is reviewed for adoption in mitigating the floodwater solution within the housing areas.

2.2 SMART Tunnel

To combat the constant flash flooding that occurs in Kuala Lumpur, it is proposed that stormwater management needed an update. SMART which is an acronym for Stormwater Management and Road Tunnel, is a solution to counter the flash flood that frequently happen and solve the congestion that happens from constant traffic problems that occur daily.

Figure 2.1: Entrance to SMART Tunnel, Kuala Lumpur, Malaysia (Sourced by:freemalaysiatoday.com)

The SMART Tunnel can be operated under four modes. The first mode or the normal mode are when the system is not filled with water due to the absence of storm and flood water. The flood water is diverted into the bypass tunnel underneath the motorway tunnel during second mode while the tunnel still allows traffic to go through it. The third mode is in operation when automated water-tight gates is opened after all the vehicle exited the motorway to make way for the flood waters to pass through. During this operation, the motorway will be closed to all traffic. The fourth mode is similar third as it is used when stormwater continues to flow in up until nearing its full capacity. After the flood has ended, the tunnel is verified and cleaned via pressure washing, and the motorway will be reopened to traffic within 48 hours of closure.

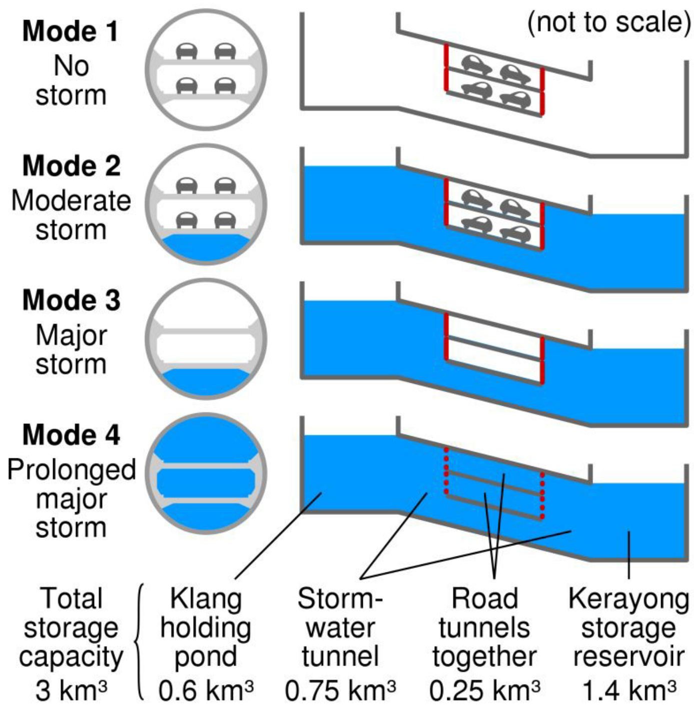

Figure 2.2: The modes and capacity of SMART Tunnel, Kuala Lumpur, Malaysia by Wikipedia

The tunnel diameter is 13.2m provide a stormwater bypass tunnel with a length of 9.7km. The tunnel also includes a 4km dual-deck motorway within the stormwater tunnel. Light vehicle can reduces the travel time down to four minutes between the Jalan Istana Interchange and Kampung Pandan by having this facility available.

Sources by Wikipedia and https://smarttunnel.com.my

2.3 Floods and Flash Flood

Floods and flash floods in Malaysia often happen when experiencing prolonged heavy rainfalls. Throughout the years, Malaysia is prepared to be having simple or small flooding in some regions within the country.

Figure 2.3: People wade through a flooded road outside Kuala Lumpur on 19 December by Vincent Thian

Records for flooding peaks before in 1967 where heavy rain during monsoon hit the states in Peninsular Malaysia excluding Negeri Sembilan and Melaka. It was recorded that to more than 250,000 people in both urban and rural areas have been affected by floods recorded as the biggest flood to occur in West Malaysia. Then a similar event occurs which the heavy non-stop rainfall that continues for several days resulting in flooding most states of Malaysia happen in December 2014. The flooding even recorded the highest number of rainfalls is for duration 10 days is at Gunung Gagau Station about 1898 mm, while the lowest value of accumulated rainfall during the flood event is at Lojing station about 476 mm (Buslima et al., 2018). While the east coast experience floods following the monsoon seasons, flash floods are disaster frequent in developing big cities such as Kuala Lumpur and Klang Valley.

Figures 2.4 : Parts of George Town hit by flash floods after two-hour downpour by The Star

Since flash floods can be shoulder on shoulder with rapid development, they are also distinguished by ascend in water level, high velocity, and enormous amounts of debris. The increasing number of vegetation removal, paving and impermeable surfaces have resulting in less soil to absorb the water which increase runoff mm (Buslima et al., 2018). It is a severe problem when the intensity and duration of rainfall as well as the steepness of watershed and stream gradients rises. Hydrologically, flood and flash flood can be differed by the duration for the river level to dwindle back to its normal level. This can be proved when floods or monsoon floods takes a longer term such as a weeks' time to recede to the normal water flow while flash flood takes only few hours. Floods can have such negative impacts to the social and economy (Buslima et al., 2018). The social impacts can include emotional distress such as anxiety, depression, and grief as well as behavioural effects. The people that experience flooding go through stages of housing. From emergency shelter, temporary shelter, temporary housing and permanent housing, the traumatic experience to went from being comfort in their own house to be forcibly lives in unsafe and uncomfortable surrounding can caused harm to them mentally. Floods can also affect the economy by people such as farmers and breeders would lose a source of income for several months until the crops or livestock can be recovered. The plantations are counted as fully destroyed most of the times and live stocks were either missing or dead as results of flooding. Tourism also taken a fall as flooding damages the premises and touristic attractions that are supported by the subsectors of tourism that are unable bounce back at lightning speed after flooding.

2.4 Rainwater Harvesting using BIM

Water is one of the basic needs of survival. In recent years, water dearth has become a crucial problem for countries, resulting in declining water supply and creating a need to find alternative solutions (Maqsoom et al., 2021). Rainwater harvesting that poses as a potential solution is which allows rainwater to be stored for human needs (Maqsoom et al., 2021). Rainwater harvesting can be done by the simplest method by using a jar and let it during the rain which the rainwater collected will be used for any intended use. Most urban buildings and housing have started make use of the concept of rainwater harvesting in their daily lifestyle. Most of the rainwater collected are used for water the garden and daily necessities. Having to use direct and calculations without playing it safe sometimes have their backfire. With the recent technology, people can assess out the model within the software and precise calculation done by computer which is called BIM. Building Information System (BIM) is a technology of transforming drawing into digitally information throughout it cycle process.

The process of using BIM can also be shown by rainwater harvesting and reuse system. For example, BIM can be use as tool to conduct dynamical monitoring of annual precipitation in the area where the building is where rainwater harvesting is located (Liu et al., 2019). The results show that by dynamic monitoring, the simulation and prediction of the largest non-traditional water of the project can be achieved through BIM technologies and the guidelines for the regulation and storage facilities can be formulated which conclude that rainwater is able to be collected and utilized more reasonably and the difference between the dry season and the rainy season can be balanced (Liu et al., 2019).

A study points general rainwater collection and utilization system that stems from the roof and road rainwater runoff which then intercepted into a sewage. The rainwater will later be filtrated using filtration system into rainwater storage tank then terminal water point (Jie & Zhang, 2019). The application of BIM in rainwater harvesting begins when rainwater collection and utilization system database established which in this study uses Geographic Information System (GIS) as input. GIS acts as specialized system that collects, stores, manages, calculates, analyses, displays and describes the geographic distribution data whether whole or part of the earth's surface expanse (Jie & Zhang, 2019). The study was done for BIM-based urban rainwater harvesting are operated and maintained by the management platform that accoutre with 3d browsing and positioning, information query, intelligent detection, intelligent analysis, and other functions (Jie & Zhang, 2019). It was concluded and proven that BIM are proven to be helpful and maintain the capability to improve the well-organized operation and management department, and realize information and data sharing among dissimilar stages, platforms, and subjects, to improve the comprehensiveness and accuracy of operation and maintenance information data (Jie & Zhang, 2019).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The overall methodology is described in Figure 3.1 as the methodology flow diagram. It explains the main steps taken to design the system. The details of each box are given in the following sections.

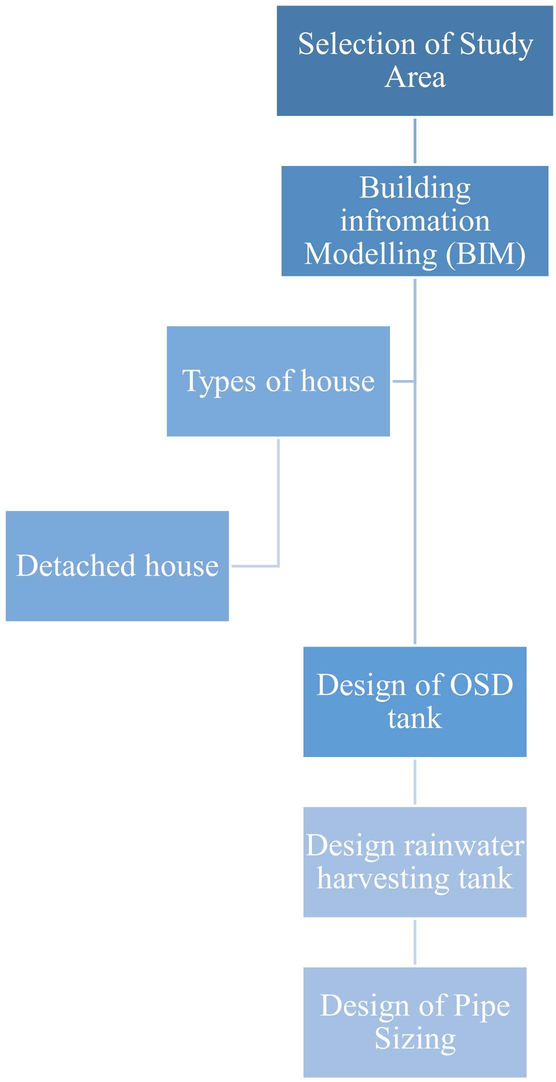

Figure 3.1: Methodology Flow Diagram

3.2 Study Area

Malaysia experiences moist weather throughout the year with having the average temperature throughout Malaysia from as low as 21°C to a 32°C daily. The Malaysian climate generally is influenced by the winds blowing from the Indian Ocean (Southwest Monsoon - May to September) and the South China Sea (North-Eastern Monsoon - November to March). Its yearly rainfall is 80 per cent a year which is between 2000mm to 2500mm.

Batu Pahat is chosen as the area of study which is a district in the state of Johor, Malaysia. The capital of the district is Bandar Penggaram and next nearest town is Muar which is 50 km (30 miles) northwest of Batu Pahat. Batu Pahat total area is 1,872.58 km^2 with population of 495,338 and density of population is 240 per km^2. Batu Pahat temperature hovers over 32ºC during the day and at night it gets as low as 24ºC. Batu Pahat gets 226.73mm of rain and can reach approximately 13 to 15 rainy days in the month. Batu Pahat humidity can approximately 79% throughout the year. There are some parts in Batu Pahat experience flooding especially during rainy seasons like December.

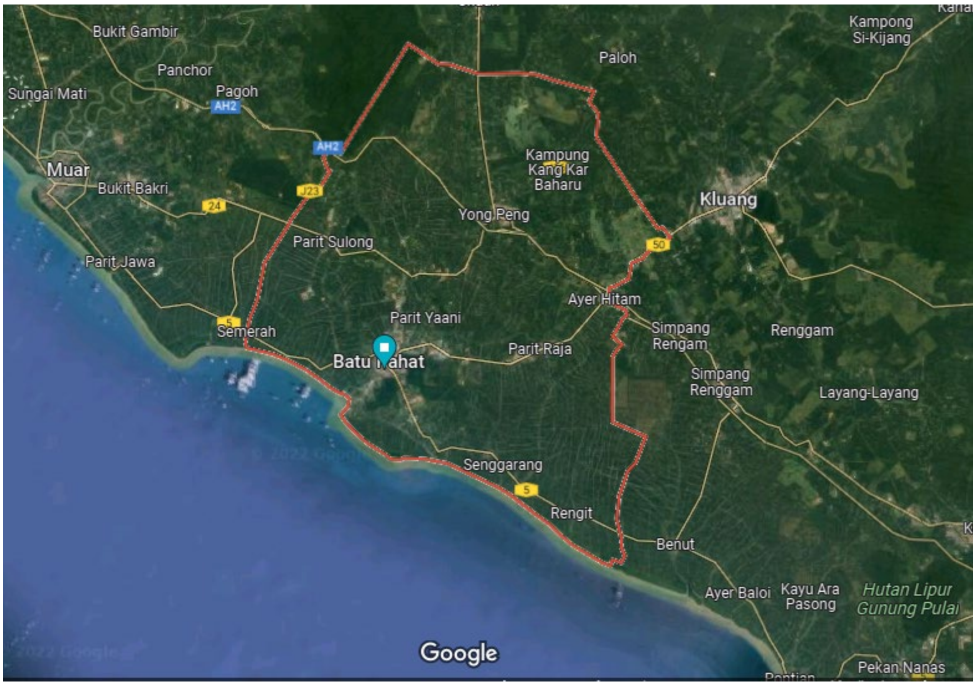

Figure 3.2: Topography map of District Batu Pahat, Johor (Source by: https://www.google.com/maps)

Figure 3.3: Topography map of Batu Pahat (Source by: https://www.google.com/maps)

3.3 Building information Modelling (BIM)

BIM is the process of generating and managing project information throughout the whole cycle of the infrastructure. It describes an activity and therefore much more than a single technology or (e.g. Revit). For this study, it is proposed to recreate a traditional and modern fusion detached house that are widely popular in many rural parts of Malaysia. The figure below shows a traditional house which only uses wood as component of construction. While modern and traditional fusion house uses the idea of traditional house and use mostly concrete with addition of wood as construction material.

Figure 3.4: A photo of a traditional Malay house in Malaysia (https://media.istockphoto.com)

Figure 3.5: A photo of a modern fusion with traditional house in Malaysia(https://www.pinterest.com)

3.3.1 Procedure for detached modern and traditional fusion house using BIM (Revit)

1. Assign the grids and elevations.
   Grid = 1000 for vertical and horizontal grid,
   elevation = 5 (level -2, level, -1, level 0, level 1, level 2) each level is 4000
2. Construct exterior wall from the plan view in level 0. Choose a suitable wall (exterior show wall) from the architecture tab from the ribbon. Assign the height to from level 0 to level 2. Insert the required properties such as insulators, etc. By using the grid, sketch the wall according to the desired length. (45000mm x 45000mm).
3. Construct interior wall for each level according to design required. Choose a suitable wall (basic interior wall) from the architecture tab from the ribbon. Assign the height to from level 0 to level 2. Insert the required properties such as insulators, etc. By using the grid, sketch the wall according to the desired
   level 0 = land and kitchen
   level 1 = house area
   level 2 = roof
4. Repeat step 2 and step for level -1 and level -2 for the under-water tank.
   By using the grid, sketch the wall according to the desired length. (45000mm x 45000mm).
   By using the grid, sketch the wall according to the desired
   level -1 = rainwater harvesting tank & garage/storage
   level -2 = OSD tank
5. Insert the families for each room and assign room name.
6. Assign the floor slab, roof, and ceiling. Choose the requirement in the properties (type of slab, attachment to base, thickness etc.
7. Insert supporting structures such as columns, steels, etc.
8. Assigned systems, heat load, air exchange rates, lines, affiliation to control/ supply circuits, maintenance information to each room.

3.4 On-Site detention

Rainwater can be divided into two categories in this study; rainwater where the water falls on the roof and stormwater where the water flows and land on the ground. As for rainwater for the first category, it can be stored into a retention tank so that it unable to make any contact with the ground. This type of rainwater, after being treated, is safe for drinking as it contains less impurities such as oil residues, soil, chemical fertilisers and debris. It can also be purpose to wash clothes, washing cars and filling up swimming pools. The second category is stormwater where mostly the water comes from roads, gardens, footpaths, driveways, gutters, down pipes, runoffs and lawns. As such, this water is not safe for drinking and is typically used for low-risk uses such as watering gardens and for flushing toilets. Stormwater can also be treated and be used for other uses such as filling up backyard swimming pools.

3.4.1 Below-ground Tank

While houses like traditional house in Malaysia have triangular shape roof, it is almost impossible to add roof tank. Flat roofs used for detention can have a considerable live load portion. As to save more soil space, underground tank is proposed. The proposed below-ground tank is used for OSD and utilised in combination with storage provided for rainwater harvesting.

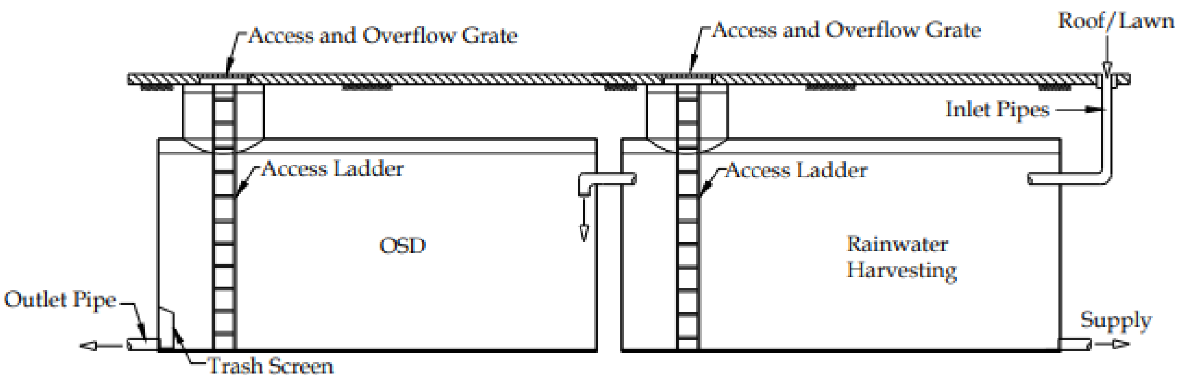

Figure 3.6: Below-ground Storage Tank - Combined with Rainwater Harvesting

3.4.2 Procedure of for designing storage system of OSD

1. Determine the type of storage that is to be used within the site; below- ground storage.
2. Pinpoint the region of the detention site from Appendix 2.
3. Discern the catchment characteristics such as terrain type and percentage of impervious area.
4. Calculate Permissible Site Discharge (PSD) per hectares (PSD/ha) from Appendix 2. Then multiply with project area to determine PSD.
5. Calculate Site Storage Requirement (SSR) per hectares (SSR/ha) from Appendix 2. Then multiply with project area to determine SSR.
6. Establish the major town of the detention site (Batu Pahat) in Appendix 3 and determine inlet flow per hectares from Appendix 3. Then multiply with project area to determine inlet flow.
7. Calculate PSD per hectares (PSD/ha) from Appendix 4. Then multiply with detention area to determine PSD.
8. Calculate SSR per hectares (SSR/ha) from Appendix 4. Then multiply with detention area to determine SSR.
9. Juxtapose the value of PSD from Step 4 and Step 7. The smaller PSD value is adopted for subsequent sizing of outlet pipe.
10. Emulate the value of SSR from Step 5 and Step 8. The larger SSR value is adopted for Selected Design Value.
11. Calculate the Inlet Pipe diameter from Appendix 5. Step 12:
12. Calculate the Outlet Pipe diameter from Appendix 5.
13. Calculate the Inlet Pipe diameter from Appendix 6 by using the Inlet Flow value from Step 6 as discharge.
14. Calculate the Outlet Pipe diameter from Appendix 6 by using the PSD value from Step 9 as discharge.
15. Emulate the value of Inlet Pipe diameter and from Step 11 and Step 13. The smaller Inlet Pipe diameter is adopted for Selected Design Value.
16. Emulate the value of Outlet Pipe diameter and from Step 12 and Step 14. The smaller Outlet Pipe diameter is adopted for Selected Design Value.

3.4.3 Procedure for designing rainwater harvesting tank

1. Quantify the annual rainwater demand (m^3) from Appendix 7.
2. From the rooftop catchment, determine the tank size. Use the equation below for the tank size calculation.

   $S_t = 0.01A_r$

   where,

   S_t = Tank Size (m^3); and

   A_r = Rooftop Catchment Area (m^2).
3. Calculate Average Annual Rainwater Yield (m^3) (refer to Appendix 8).
4. Calculate percentage of water yield over rainwater demand.
5. Calculate annual domestic water demand (m^3)
6. Calculate percentage of water yield over domestic water demand.

3.4.4 Procedure for Pipe Sizing

1. Calculate the loading rating per unit appliance.(refer Appendix 9).
2. Calculate the flow rate. (Refer Appendix 7).
3. Calculate the effective length of pipe.
4. Calculate headloss in pipe due to frictional resistance.
5. Calculate headloss in pipe due fitting of stop valve.
6. Compute total headloss.
7. Compute residual head (must be larger than 0).
8. Compute the required pipe size using Thomas-Box Equation

$$q = \sqrt{\frac{d^5 \times H}{25 \times L \times 10^5}}$$

where,

q = Discharge through the pipe (L/s)

d = Diameter of pipe (mm)

H = Head of water (m)

L = Total length of pipe (m).

CHAPTER 4

RESULTS AND DISCUSSION

The results are divided into Four (4) parts, which are: development of drawings using BIM REVIT of detached modern and traditional fusion house, OSD tank, and rainwater harvesting tank, and finally, pipe sizing. It is then followed by a discussion regarding the results of the study.

4.1 Results and Discussion of BIM drawing using REVIT of detached modern and traditional fusion house

The figures below show the outcome of the BIM drawing of the house using REVIT. The house is used to ease the calculations for OSD tank and rainwater harvesting for reference. The size of underground levels is for estimation only.

The specification of the house drawing are as follows:

1) The elevation is 4000 = 4m
2) The gridlines are 1000 = 1m (both vertical and horizontal)

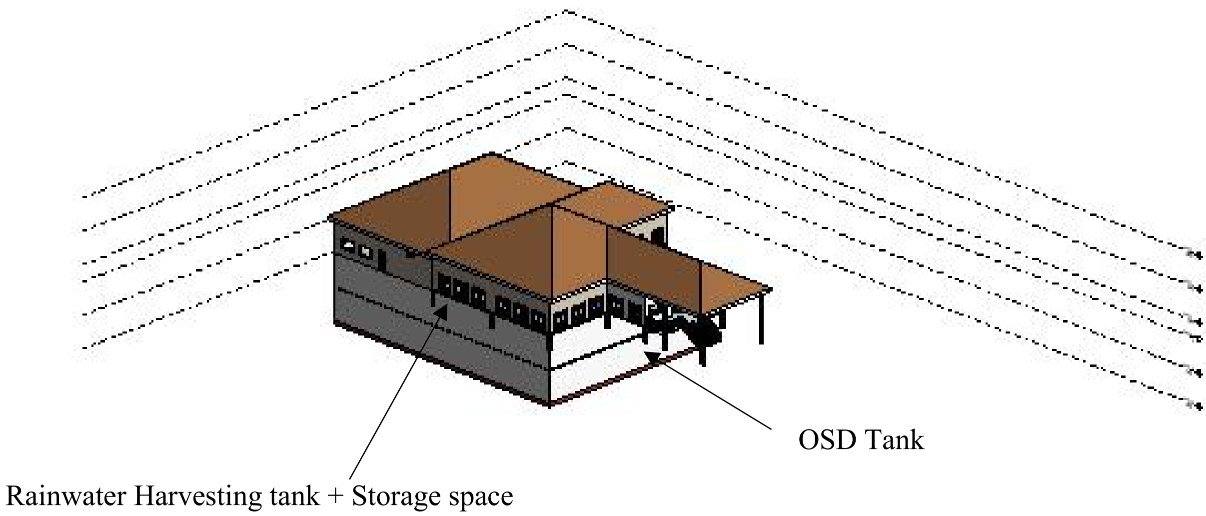

Figure 4.1: 3D View - {3D}

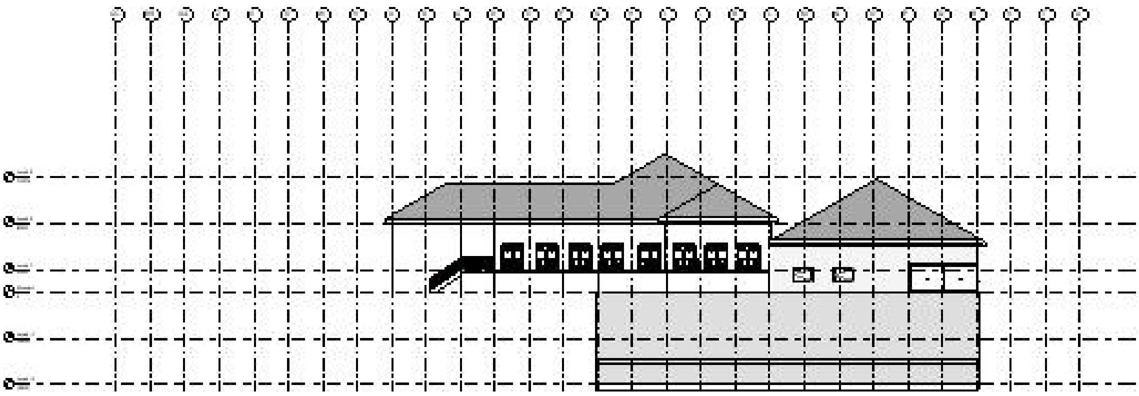

Figure 4.2: Elevation – East

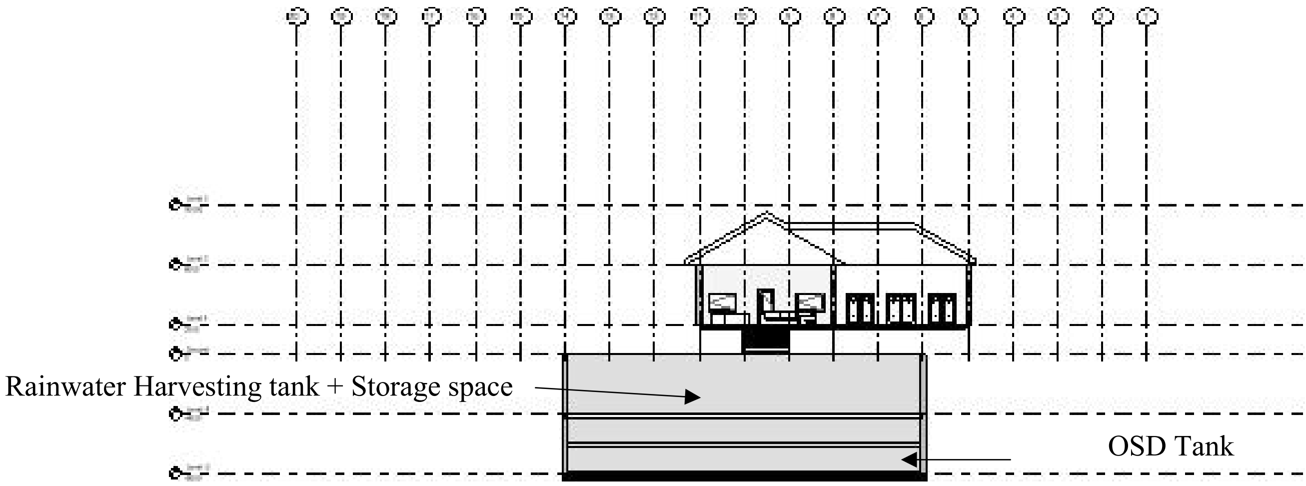

Figure 4.3 : Elevation – North

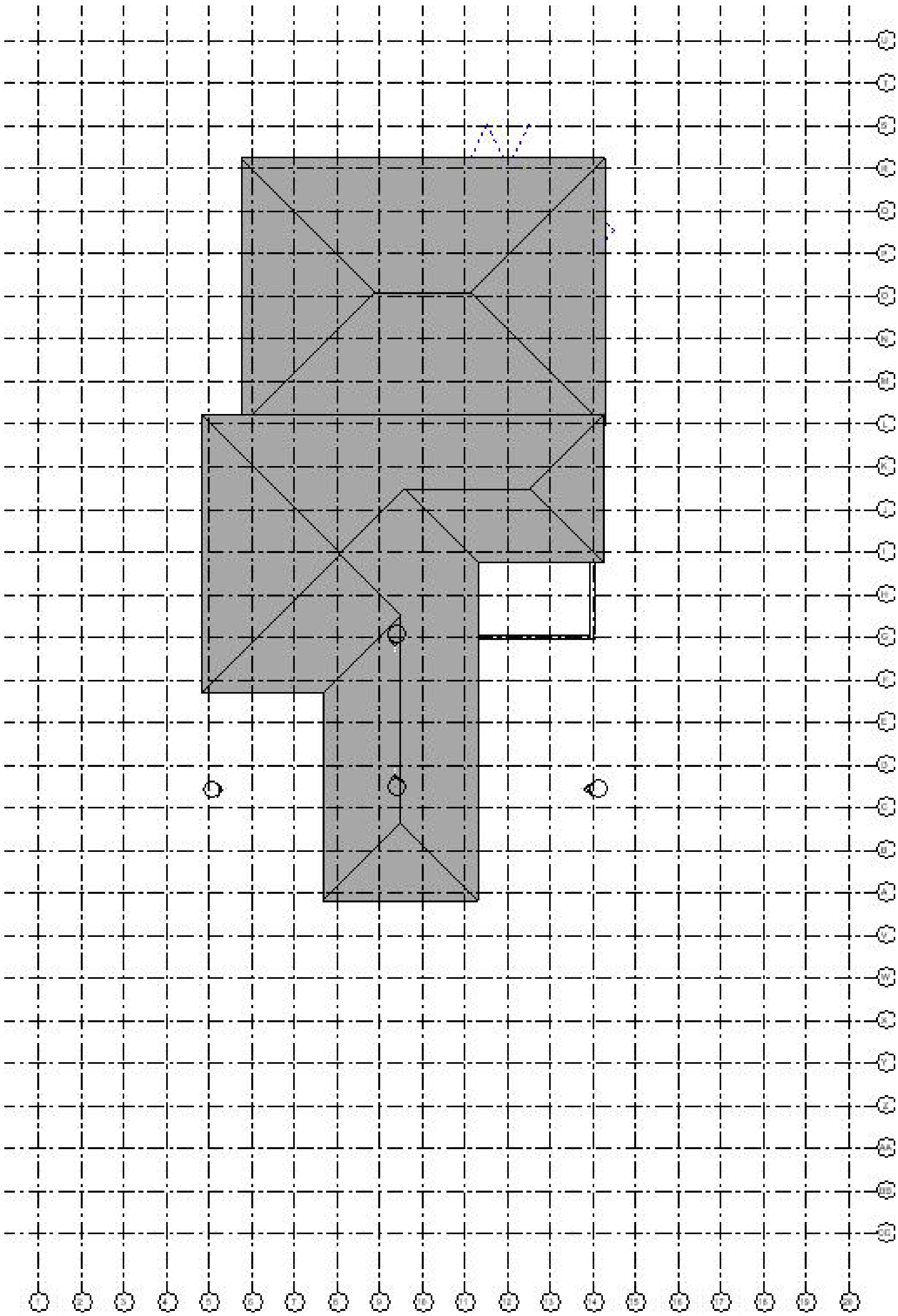

Figure 4.4: Floor Plan – Site

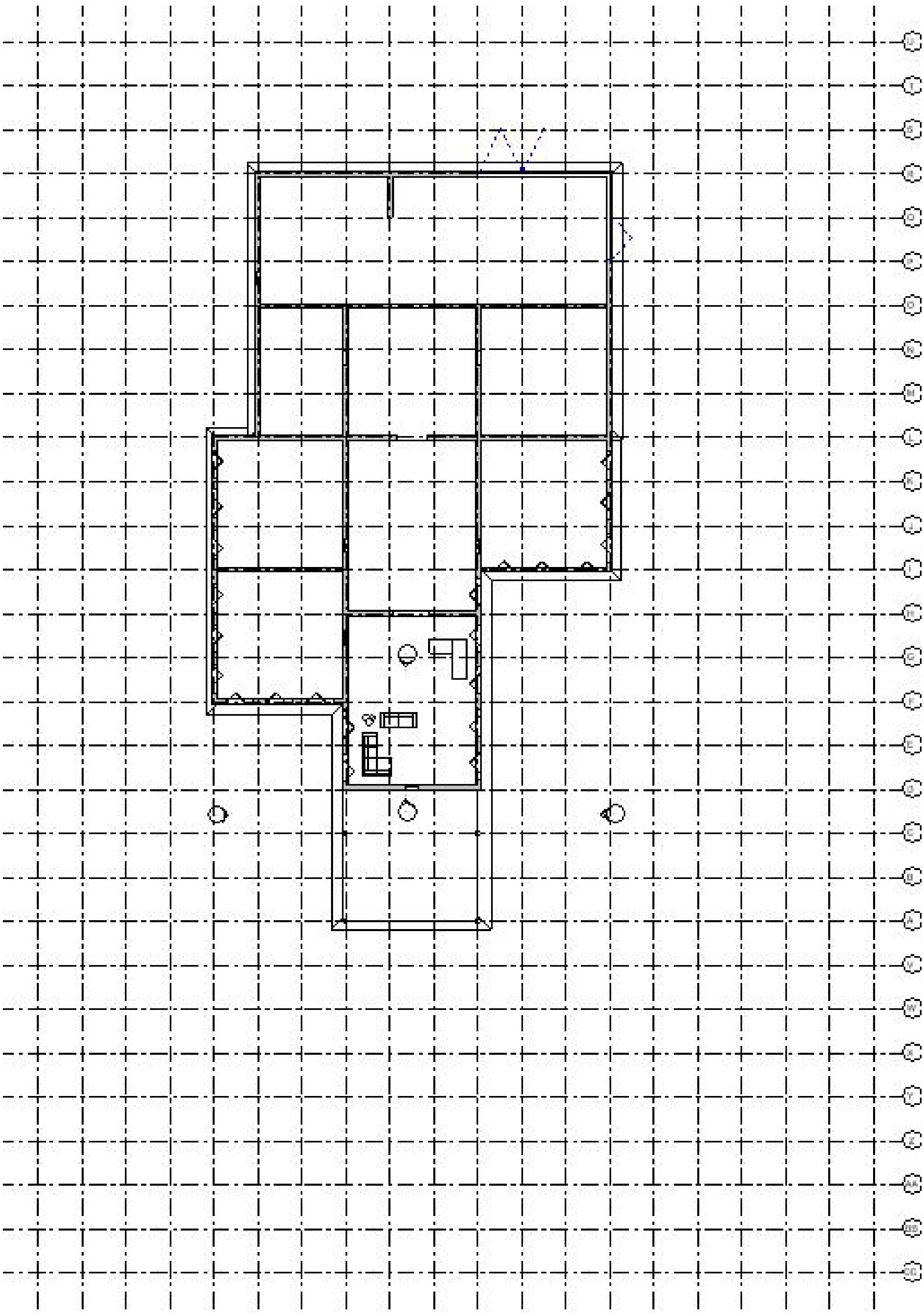

Figure 4.5: Reflected Ceiling Plan – Ground

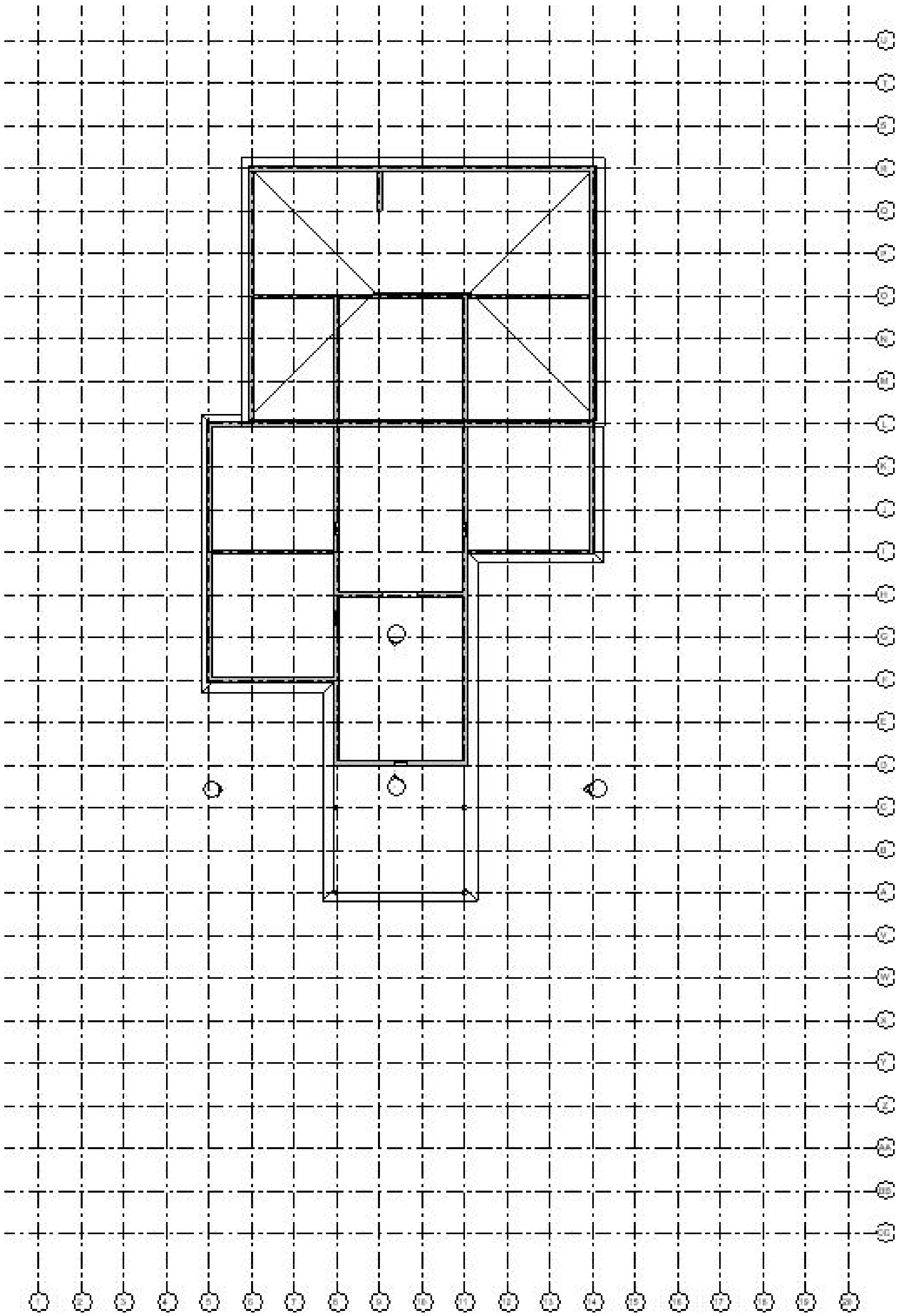

Figure 4.6: Reflected Ceiling Plan - Level 1

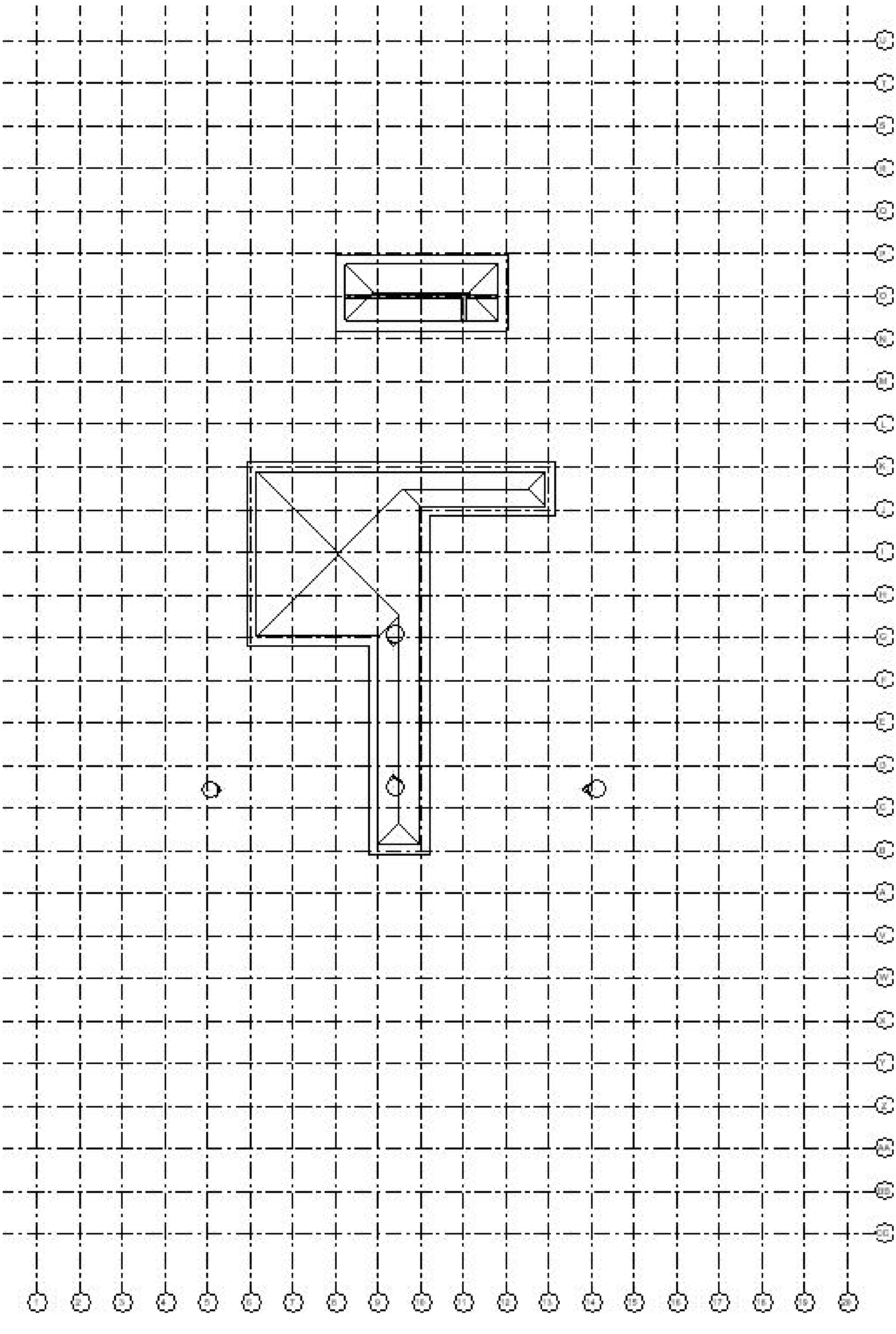

Figure 4.7: Reflected Ceiling Plan - Level 2

The results from the ReVit BIM model of the house and tanks will be used as reference for the rainwater harvesting tank and OSD. The 3D and elevations drawing shows how SMART Tunnel used as a reference for the idea by having both tanks stacked on top of each other. Reflected Ceiling Plans will help to calculate the area of roof top that will be used for the Rainwater Harvesting Tank calculations. The Floor Plan – Site drawing will be used to assist the calculation of OSD Tank. This shows that the level of contribution of BIM in this project is BIM level 2 which partial contribution.

4.2 Results and Discussion for OSD Tank

Below is the drawing of the drainage system and the ARI according to the site investigation

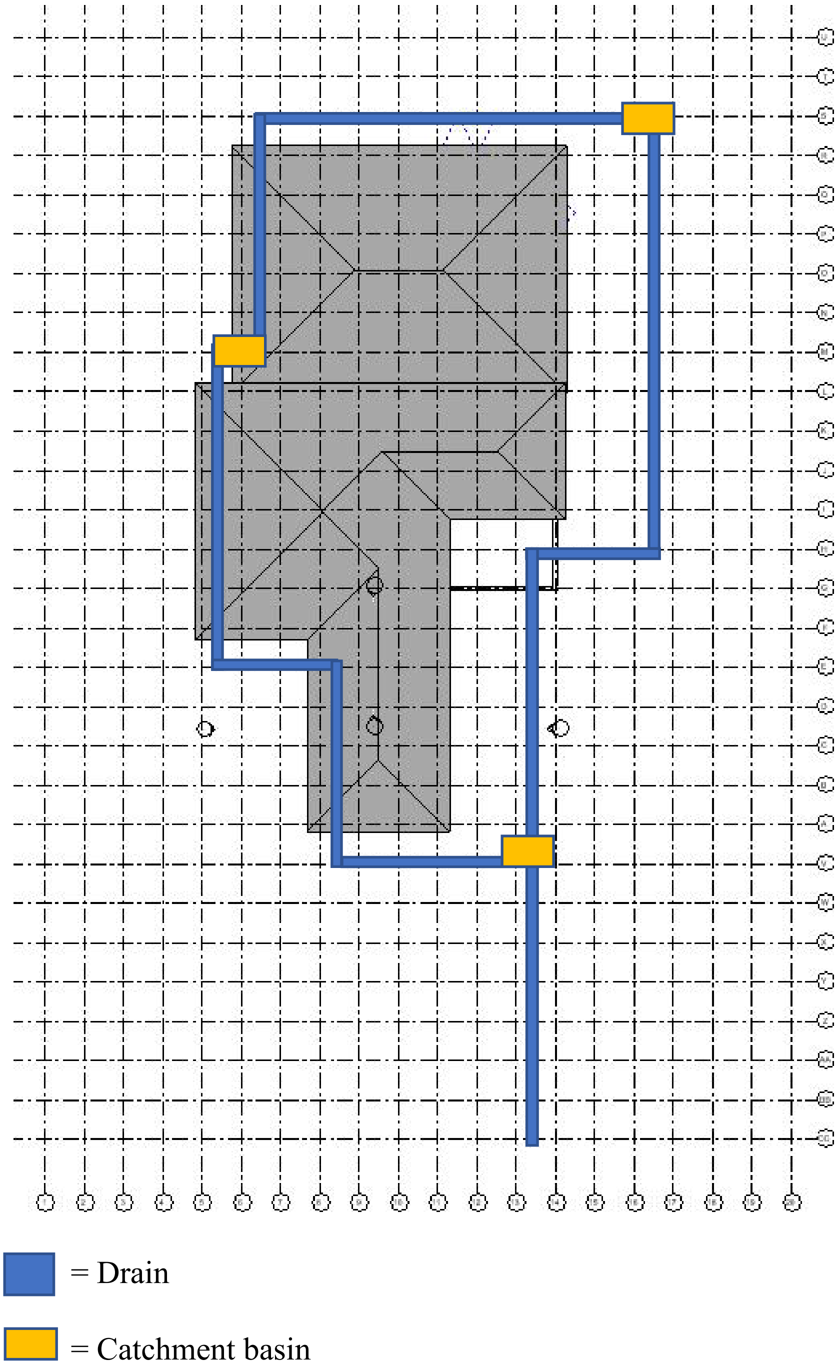

Figure 4.8: Drawing of the drainage system

6	1829002	Setor JPS Batu Pahat	64.099	0.174	0.201	0.826

Batu Pahat Region 5

Area = 0.4 ha

Assume the design for minor = 10 year

No.	Area No.	Sump to sump label	Drain type	Catch.area	Catch.area	Length of Drain		Landuse				Runoff Coefficient	L	slope	Overland time	Area	Wetted Perimeter	Hydraulic Radius	slope	Manning's Equation	travel time in channel	time concentration		ARI	Constants				Empirical IDF Curve	Rational Method	Q	remarks
								Impervious		Pervious										smooth finish												
				(sqm)	(ha)	(mm)	(m)	%	C	%	C	C	m	%		sqm	m	m	(1:450)		minutes	minutes	hours	years	λ	K	θ	η				
1	HOUSE	J1 -J3	RCP	3446.85	0.344685	21000	21	0.5	0.7	0.5	0.4	0.55	1723.425	1.5	70.976444	3	6.325	0.4743083	0.002222	0.015	0.183115487	71.15955984	1.185992664	10	64.099	0.0174	0.201	0.826	50.92112556	5.266021	4.778405	OK!
2	HOUSE	J3- J2	RCP	143	0.0143	16000	16	0.1	0.7	0.9	0.4	0.43	71.5	1.5	24.570771	3	6.325	0.4743083	0.002222	0.015	0.139516562	24.71028789	0.411838132	10	64.099	0.0174	0.201	0.826	99.97781477	0.170806	4.778405	OK!
3	HOUSE	J2 - J1	RCP	152	0.0152	21000	21	0.1	0.7	0.9	0.4	0.43	76	1.5	25.075791	3	6.325	0.4743083	0.002222	0.015	0.183115487	25.25890642	0.420981774	10	64.099	0.0174	0.201	0.826	98.76223472	0.181556	4.778405	OK!
4	HOUSE	J1 - OUT	RCP	210	0.021	7000	7	0.3	0.7	0.9	0.4	0.57	105	1.5	27.928431	3	6.325	0.4743083	0.002222	0.015	0.061038496	27.98946979	0.466491163	10	64.099	0.0174	0.201	0.826	93.16638709	0.3325	4.778405	OK!
					0.395185			0.3																							19.11362	

Table 4.1: Empirical IDF curves using Rational Method

Calculation	Output
Batu Pahat – Region 5 -Southern Project Area = 0.4 ha Terrain Slope Mild % Of Impervious Area = 30 %	
PSD 40% = 75.7 25% = 74.8 30% = $\left(\frac{75.7-74.8}{40-25} \times (30-25)\right) + 74.8 = 75.1$ l/s/ha For area of 0.4ha, PSD = 0.4 x 30.04	=30.04 l/s =0.03004 m^3/s
SSR	=125.0532 m^3

40% = 340.9 25% = 298.5 30% = $\left(\frac{340.9-298.5}{40-25} \times (30-25)\right) + 298.5 = 312.633$ l/s/ha For area of 0.4 ha, SSR = 0.4 x 312.633	
PSD 40% = 56.2 25% = 55.6 30% = $\left(\frac{56.2-55.6}{40-25} \times (30-25)\right) + 55.6 = 55.8$ l/s/ha For area of 0.4ha, PSD = 0.4 x 55.8	=22.32l/s =0.02232 m^3/s
SSR 40% = 273.8 25% = 234.7 30% = $\left(\frac{273.8-234.7}{40-25} \times (30-25)\right) + 234.7 = 247.733$ l/s/ha For area of 0.4ha = 0.4 x 247.733	= 99.0932 m^3
Inlet Flow 40% = 146.0 25% = 127.0 30% = $\left(\frac{146.0-127.0}{40-25} \times (30-25)\right) + 127.0 = 133.333$ l/s/ha For area of 0.4ha = 0.4 x 133.333	= 53.333 l/s = 0.05333 m^3/s

Volume 40% = 138 25% = 120 30% = $\left(\frac{138-120}{40-25} \times (30-25)\right) + 120 = 126$ m^3/ha For area of 0.4ha = 0.4 x 126	= 50.4 m^3
Inlet Pipe 40% = 306 25% = 288 30% = $\left(\frac{306-288}{40-25} \times (30-25)\right) + 288 = 294\ mm$ For area of 0.4ha = 0.4 x 294	= 117.6 mm
Outlet Pipe 40% = 135 25% = 135 30% = 135 mm For area of 0.4ha = 0.4 x 135	= 54 mm
Inlet Pipe (Use inlet flow = 0.05333 m^3/s)	= 303 mm
Outlet Pipe (Use PSD =0.02232 m^3/s)	= 261 mm
PSD = 22.32 l/s	Storage Tank = 200 m^3 > 125.0532 m^3

SSR =125.0532 m^3 Q = 19.11362 m^3 (from Rational Method) Sizing of tank Required = 125.0532 m^3 L = 10m ; W = 10m ; H = 2m	(Ok!) Adapted size Inlet = 117.6 mm Outlet = 54 mm

Table 4.2: OSD Tank Calculation

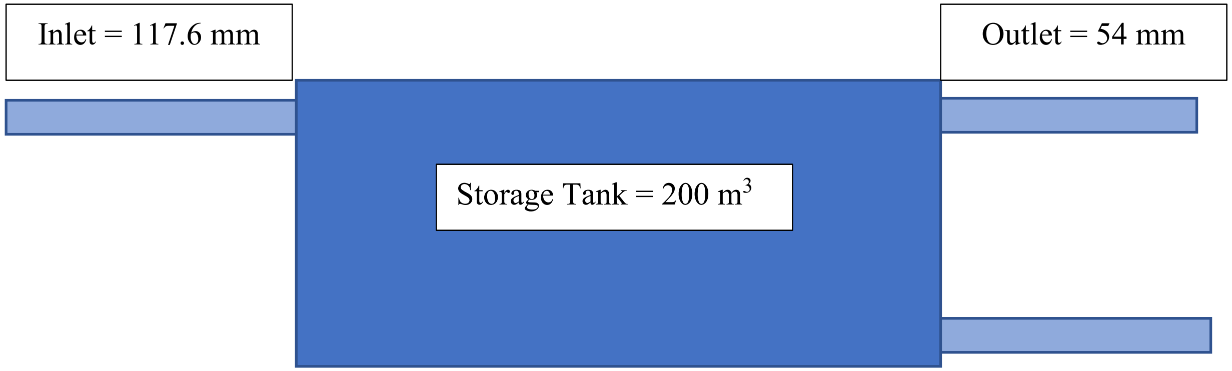

Figure 4.9: Drawing of OSD tank

As shown from figure above, the OSD tank can be placed in the underground level 2 of the house as the height is 2m. The OSD is that used for normal water storage needed for a typical detached housing. In the event of flooding that additional water can stored here.

(Source from MSMA 2nd Edition)

4.3 Results and Discussion for Rainwater Harvesting

Below shows the calculation for the rainwater harvesting tank.

<table>
<tr><td>Calculation</td><td></td></tr>
<tr><td>Compute Annual rainwater demand(m3)
<table>
<tr><th>Use (Appliance)</th><th>Unit</th><th>Average Water Use</th><th>Total Water use (l/day)</th></tr>
<tr><td>Dual Flush Toilet</td><td>5 nos</td><td>40 l/day</td><td>200</td></tr>
<tr><td>Washing Machine</td><td>1 was</td><td>80 l/day</td><td>80</td></tr>
<tr><td rowspan="2">Dishwasher/General cleaning</td><td rowspan="2">3 loads</td><td rowspan="2">50 l/load</td><td>150</td></tr>
<tr><td>150</td></tr>
<tr><td>Gardening</td><td>20 minutes</td><td>20 l/minute</td><td>400</td></tr>
<tr><td>Washing once a week for 20 minutes</td><td>20 minutes/ car</td><td>20 l/minute</td><td>57.143 (20 x 20/7)</td></tr>
<tr><td colspan="3">total</td><td>957.143</td></tr>
</table>
Annual rainwater demand = 365 days x 957.143l/day</td><td>= 349.4 m2</td></tr>
<tr><td>Tank size estimation
Roof top catchment, Ar =340.8m^2 ,
Tank Size , St = 0.01 x 340.8m^2</td><td>= 3.408m^3
= 3.5 m^3</td></tr>
<tr><td>Average Annual Rainwater Yield (m^3)
For Batu Pahat, the AARY for 3.5 m^3 tank size = 3.5 x 128</td><td>= 448 m^3</td></tr>
<tr><td>Percentage of water yield over rainwater demand (%)
= 448/349.4 x 100</td><td>= 128.22%</td></tr>
<tr><td>Annual domestic water demand (m3)
= 365 days x 10 capita x 250 litres/capita/day</td><td>= 912 m^3</td></tr>
<tr><td>Percentage of water yield over domestic water demand (%)
= 448/912 x 100</td><td>= 49.12%</td></tr>
</table>

Table 4.3: Rainwater Harvesting Tank Calculation

From this calculation, it is shown that the rainwater harvesting tank is 3.5 m^3. The dimension will be 2m of height,0.7m of width and 2.5m length. The remaining area can be used for storage.

The area for storage is being calculated by using the OSD tank specifications

L = 10m ; W = 10m ; H = 2m

(Source from MSMA 2nd Edition)

4.4 Results and Discussion For Pipe Sizing

Below shows the calculation for the pipe sizing of the underground tank

<table>
<tr><td>Calculation</td><td></td></tr>
<tr><td>The loading rating per unit appliance
<table>
<tr><th>Piping Component</th><th>Loading Rating per Unit Appliance (unit)</th><th>Number of Appliance (nos)</th><th>Total Loading (unit)</th></tr>
<tr><td>W.C. flushing system (WC)</td><td>2</td><td>2</td><td>4</td></tr>
<tr><td>Wash basin (WB)</td><td>3</td><td>2</td><td>6</td></tr>
<tr><td>Shower (SR)</td><td>3</td><td>2</td><td>6</td></tr>
<tr><td>Total Loading</td><td colspan="2"></td><td>16</td></tr>
</table>
</td><td></td></tr>
<tr><td>The flow rate for 16 units loading</td><td>= 0.4 l/s</td></tr>
<tr><td>Flow rate with 25 mm of OD copper pipe
<table>
<tr><th>Piping Component</th><th>Equivalent Length (m)</th><th>Number of Component (Nos.)</th><th>Total Headloss (m)</th></tr>
<tr><td>Elbow</td><td>0.7</td><td>3</td><td>2.1</td></tr>
<tr><td>Tee</td><td>1.8</td><td>1</td><td>1.8</td></tr>
<tr><td>Total Headloss due to friction resistance in fittings</td><td colspan="2"></td><td>3.9</td></tr>
</table>
</td><td></td></tr>
<tr><td>Effective length =20 + 3.9</td><td>= 23.9m</td></tr>
<tr><td>The head loss in 25mm copper pipe due to frictional resistance</td><td>= 0.045m</td></tr>
<tr><td>The head loss due to fitting of stop valve</td><td>=0.3m</td></tr>
<tr><td>The total headloss due to pipe and fittings
= (23.9× 0.045) + 0.3</td><td>=1.4m</td></tr>
<tr><td>Residual head = available head – total headloss= 4 – 1.4 (>0)</td><td>= 2.6 > 0 Ok!</td></tr>
</table>

Required pipe size using Thomas-Box equation $$d = \sqrt[5]{\frac{0.4^2 \times 25 \times 23.9 \times 10^5}{2.6}}$$	= 20.6 mm = 25mm is OK

Table 4.3: Pipe Sizing of The Underground Tank Calculation

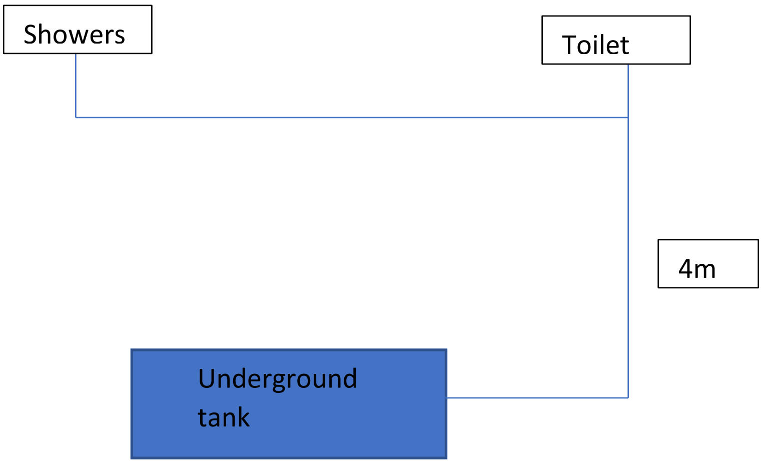

Figure 4.10: Drawing of the piping system underground

From these results, it is shown that the house is using 25mm copper pipe to connect the pipelines from the underground tank to the water system in the house.

(Source from MSMA 2nd Edition)

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This study was carried out to resolve the flooding water in the housing area in Malaysia, which is a frequent event. On the other end, as the potable water demand is increasing enough supply of water is challenging. Therefore, the concept of SMART tunnel was referred to mitigate the flooding water for detached housing states. Two storage systems were proposed: rainwater harvesting tanks and onsite stormwater detention (OSD) tanks. The tank's planning was done using BIM REVIT.

In conclusion, flooding and rainwater are consider annual disaster to happen every year. By using BIM to replicate the traditional house and use it as a reference for this study are proven the efficient. By having extra precaution is never foolish. The means provided by study is to have a private OSD tank that can store and reduced the amount of water from causing flooding in areas that traditionally does not have united OSD tank or small. The underground feature for both OSD and rainwater harvesting tanks are added for a bonus as it can save more spaces and tidiness.

Traditional housing area tends to have the whole other area except the house to be filled with plants and farm as it is used as their side income. In this study for 0.24 hectare, the home only occupies 1/10 of the whole area. The other area is either harvest or farm animals. The idea of having underground area is better for spacing without disturbing any of the harvest. The OSD tank dimension are being used as the underground wall reference so that the rainwater harvesting tank while being on the underground level 1 have extra space that can be used as storage. The rainwater that flows from the roof will enter from a different line to separate the sourcing of water than OSD line.

As for recommendation, this study could become a reference as to how to do private rainwater harvesting but it does not include the technicality of building it. Since this is an underground tank, many may think that it is a bit far fetch as it requires more work done. A filter system can be added as feature to filter out the impurities from the system.

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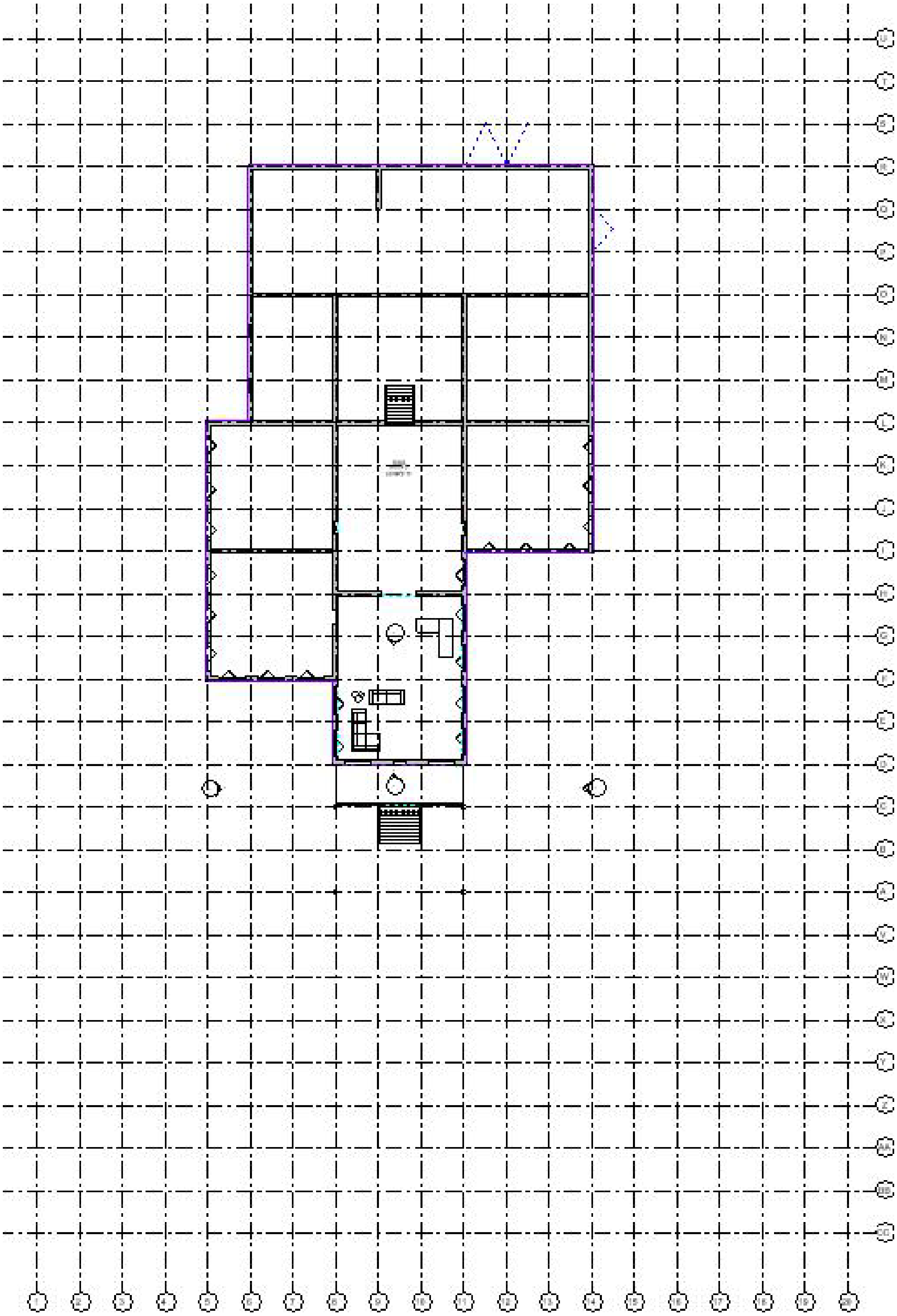
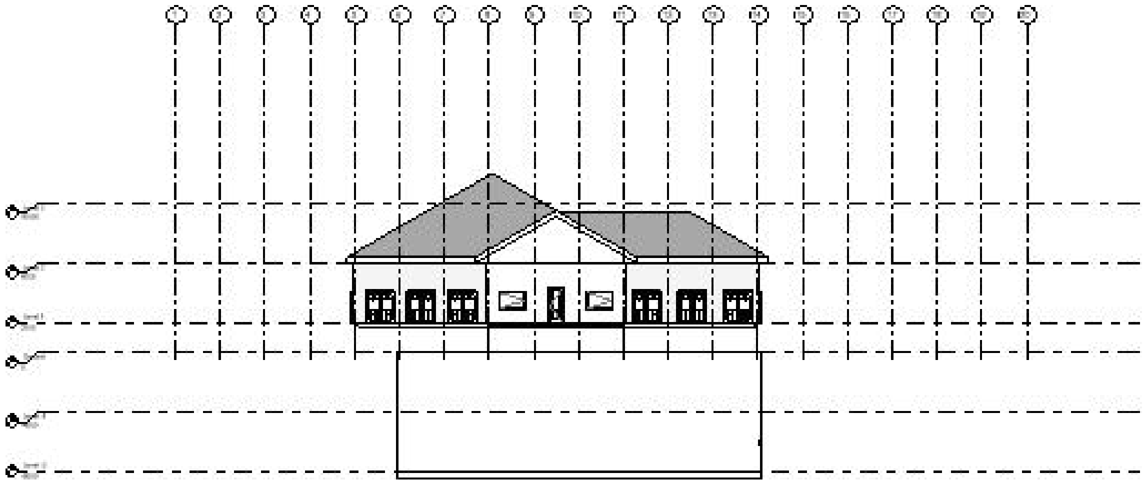
APPENDICES

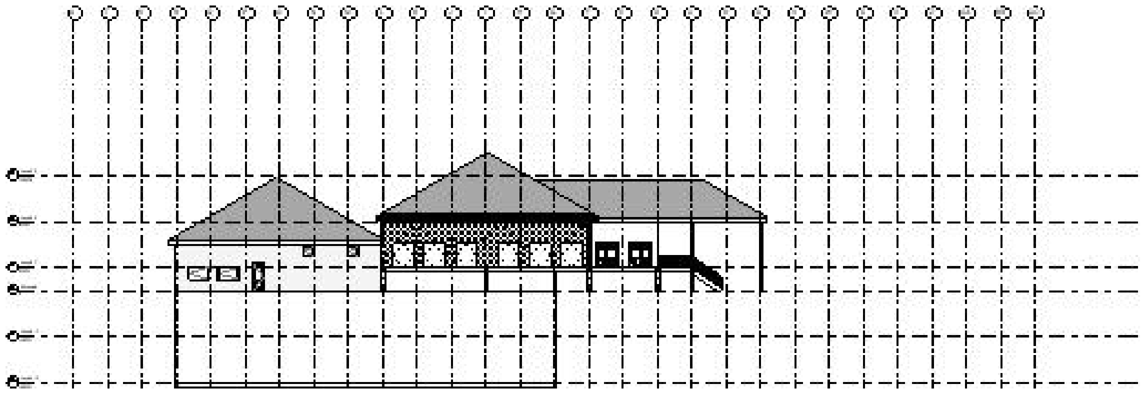
APPENDIX 1: Other Results from ReVit for BIM Modelling



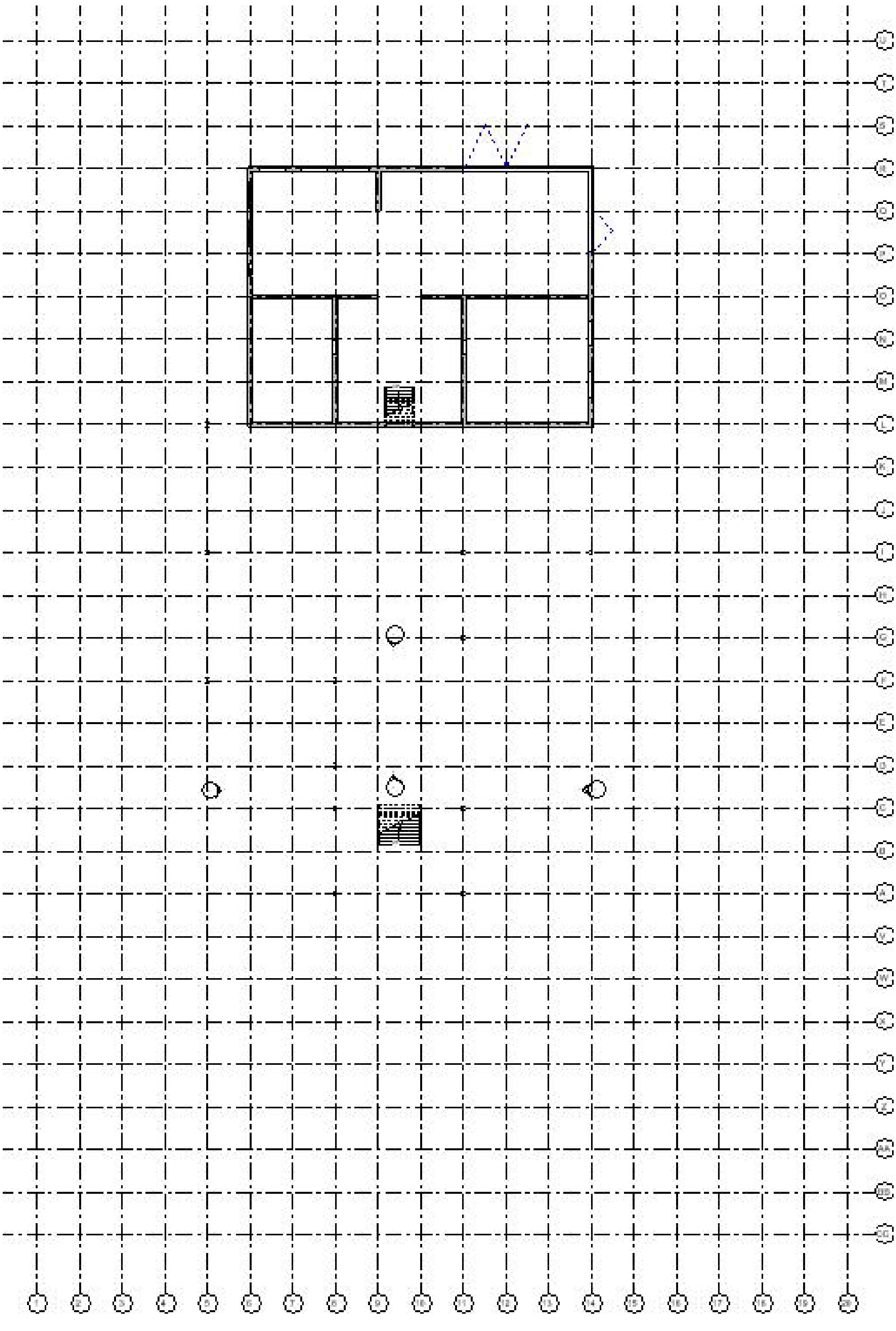
Area Plan (Gross Building) - Level 1



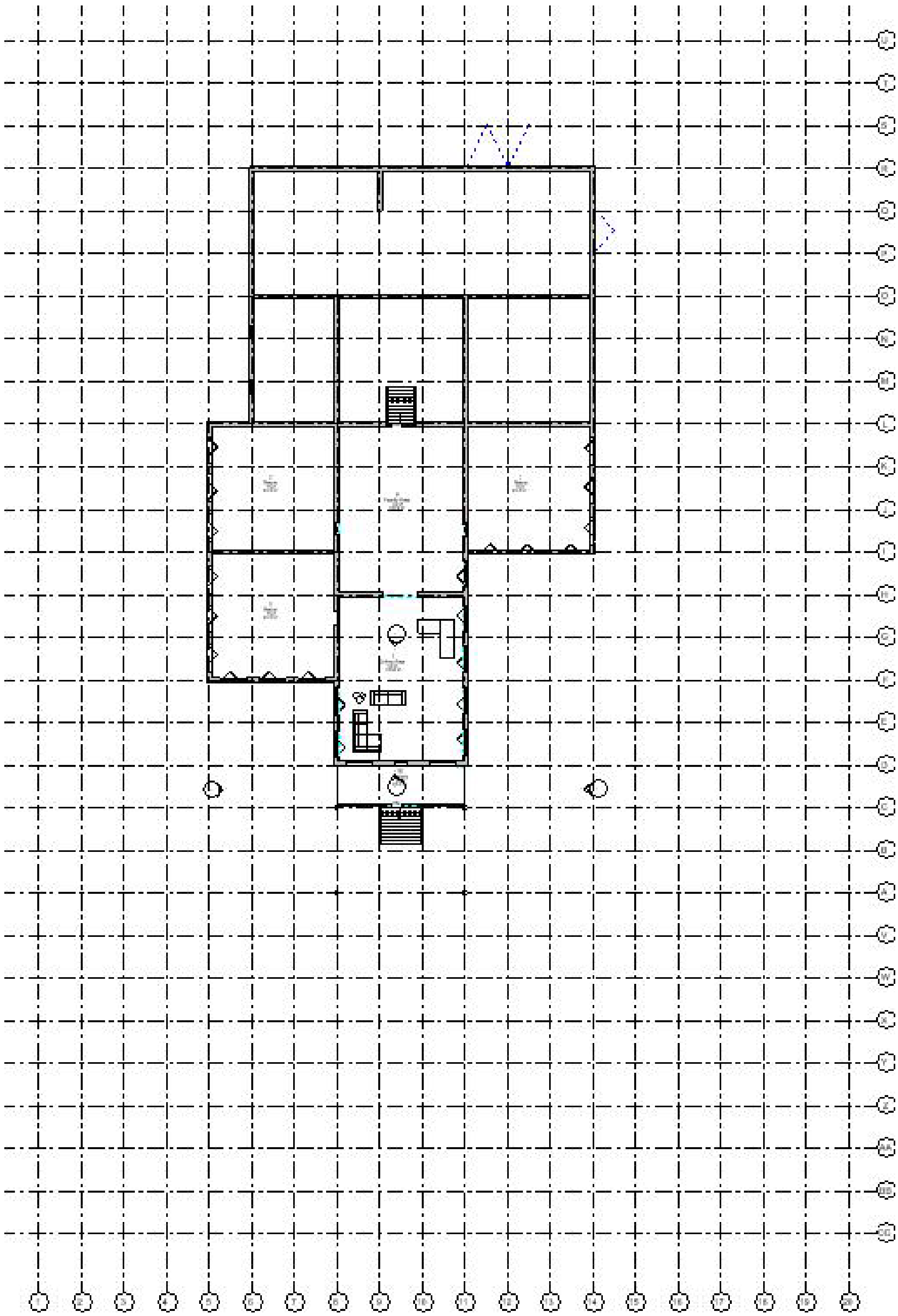
Elevation - South



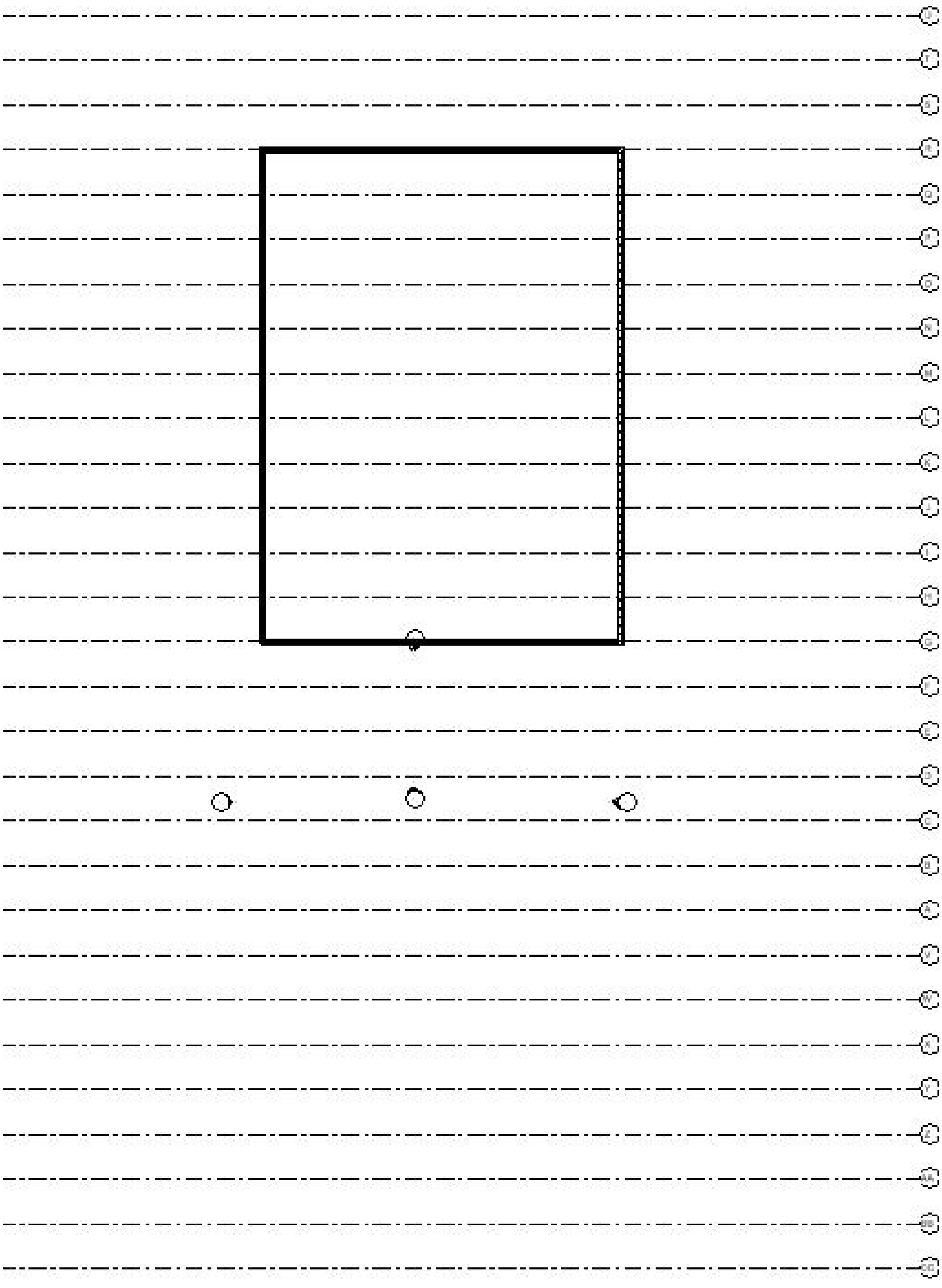
Elevation - West



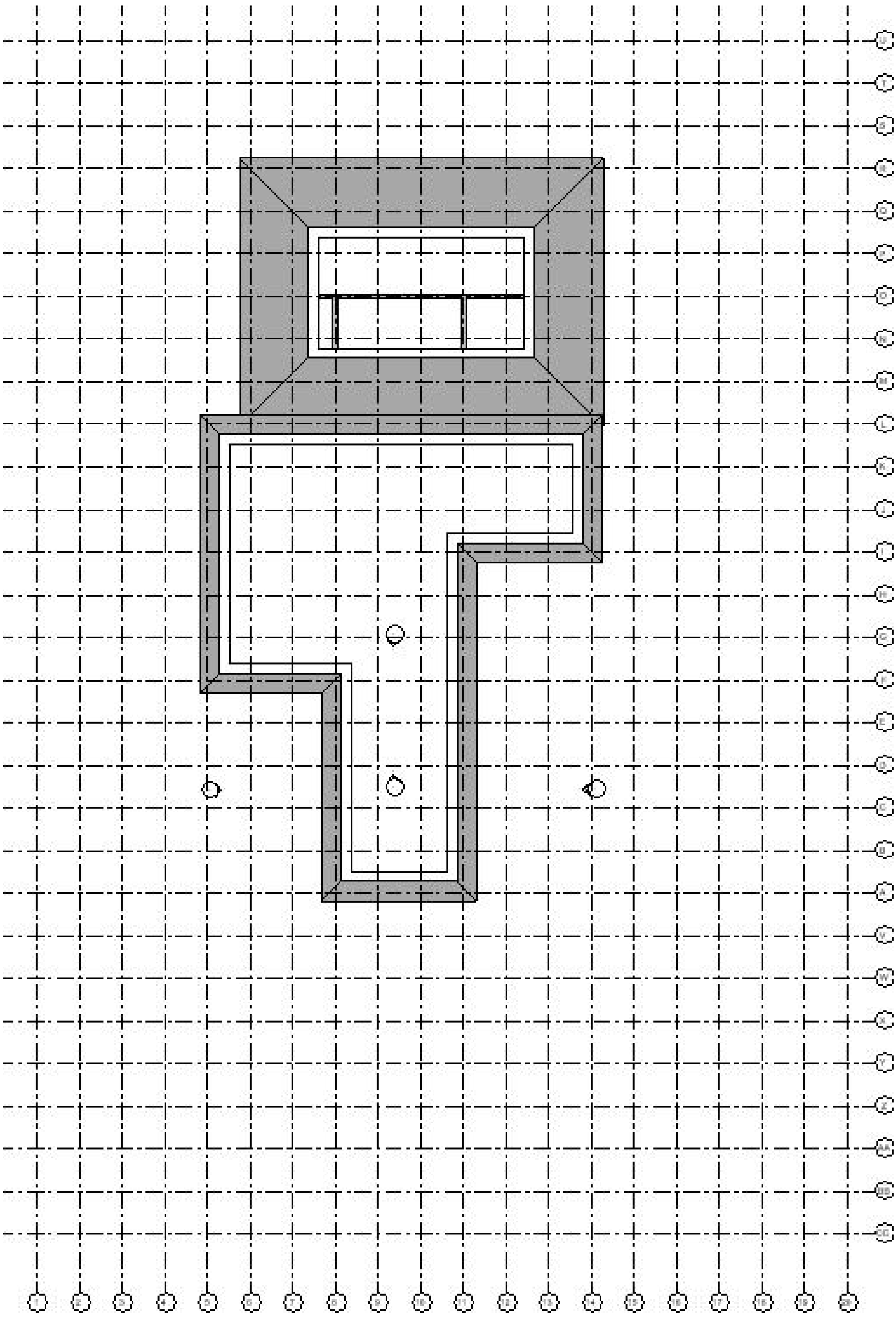
Floor Plan - Ground



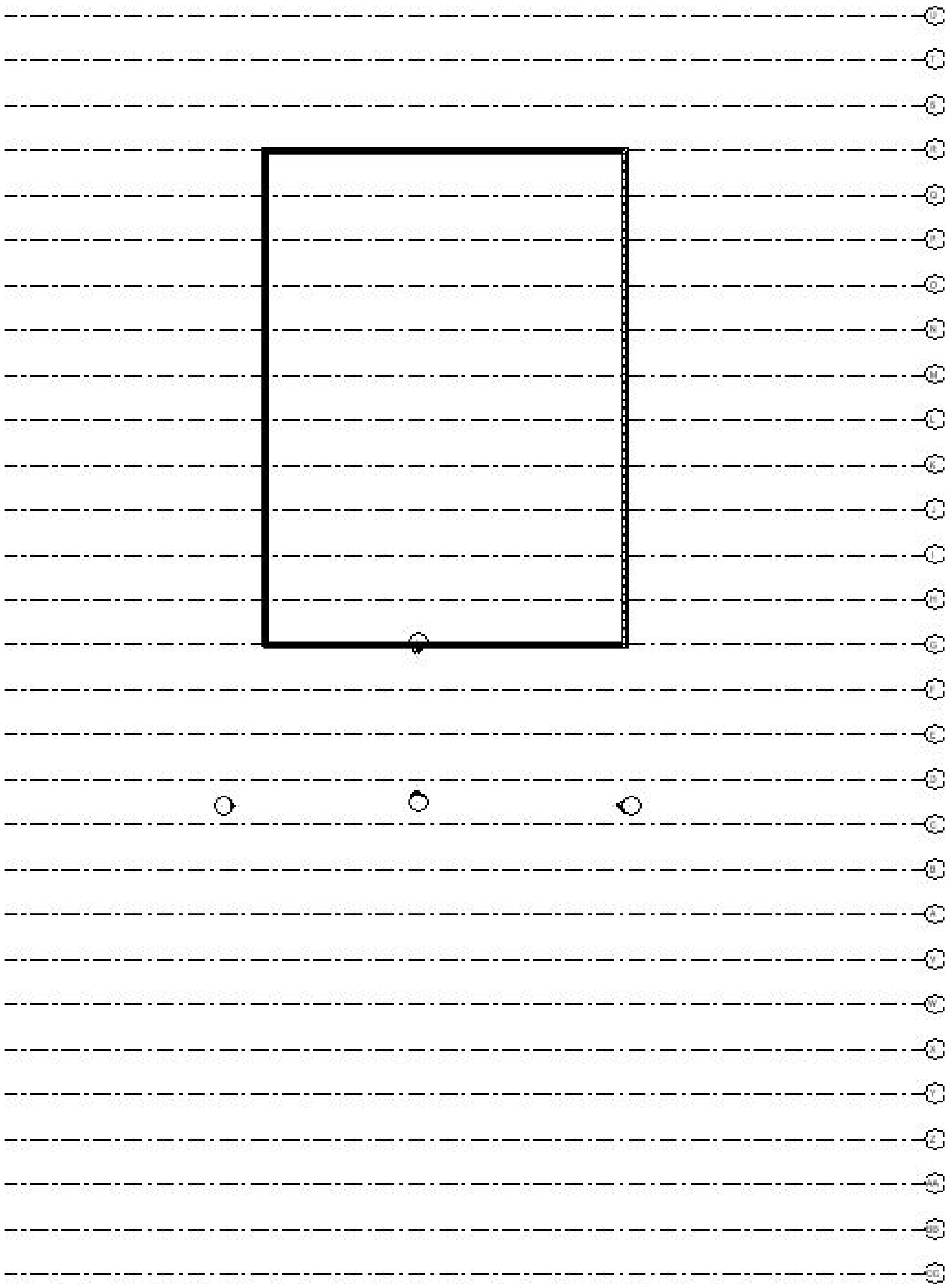
Floor Plan - Level 1



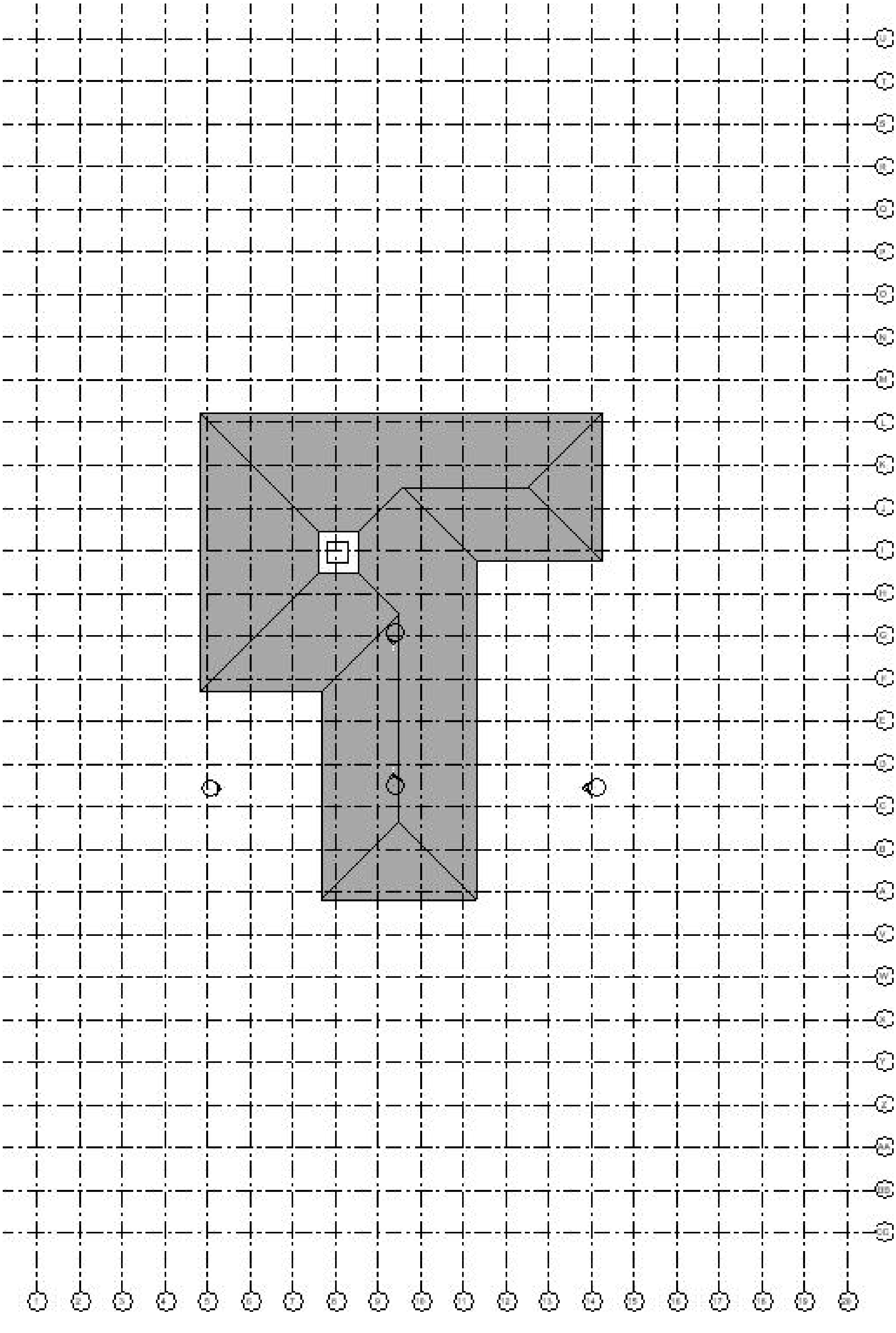
Floor Plan - Level -1



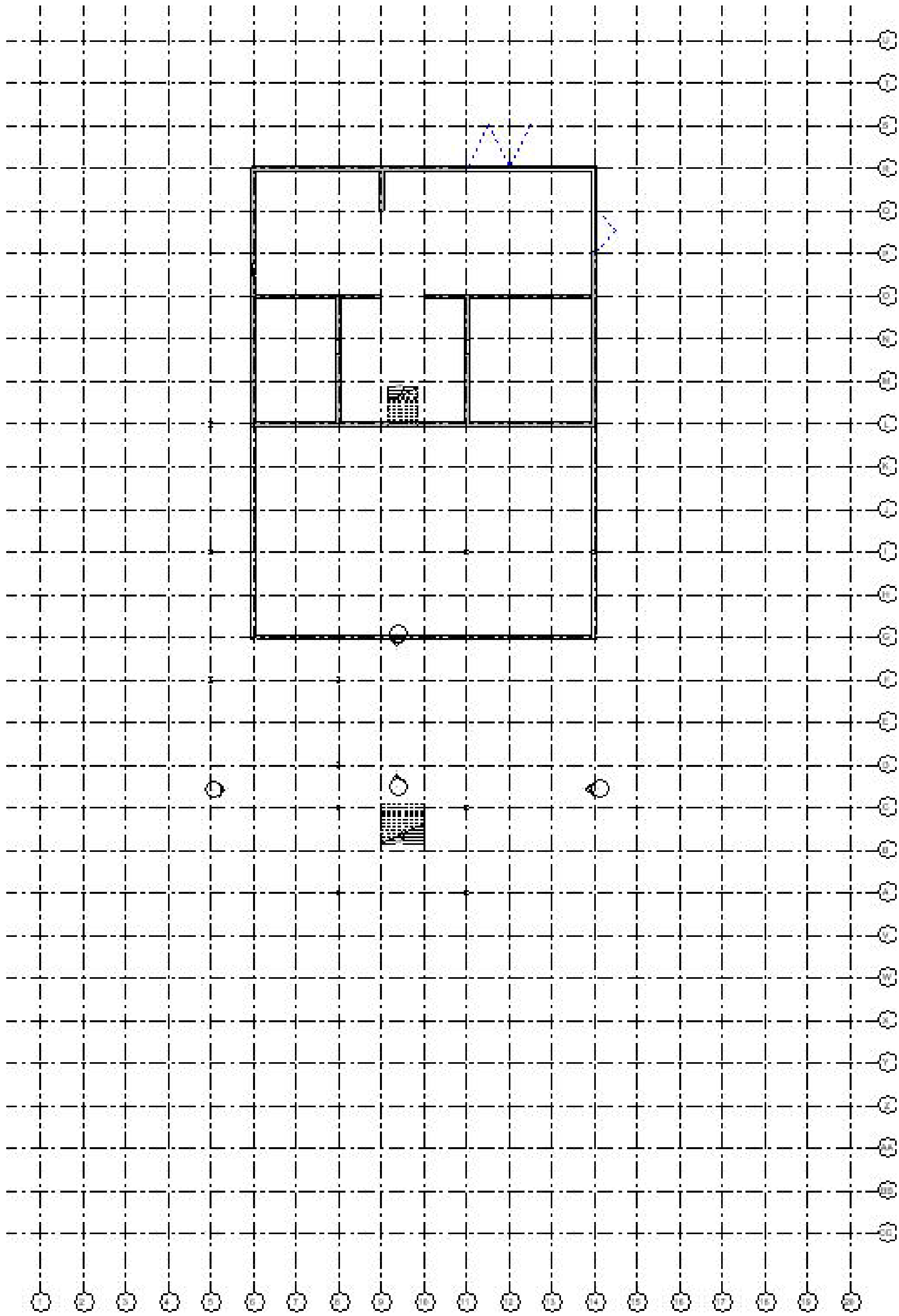
Floor Plan - Level 2



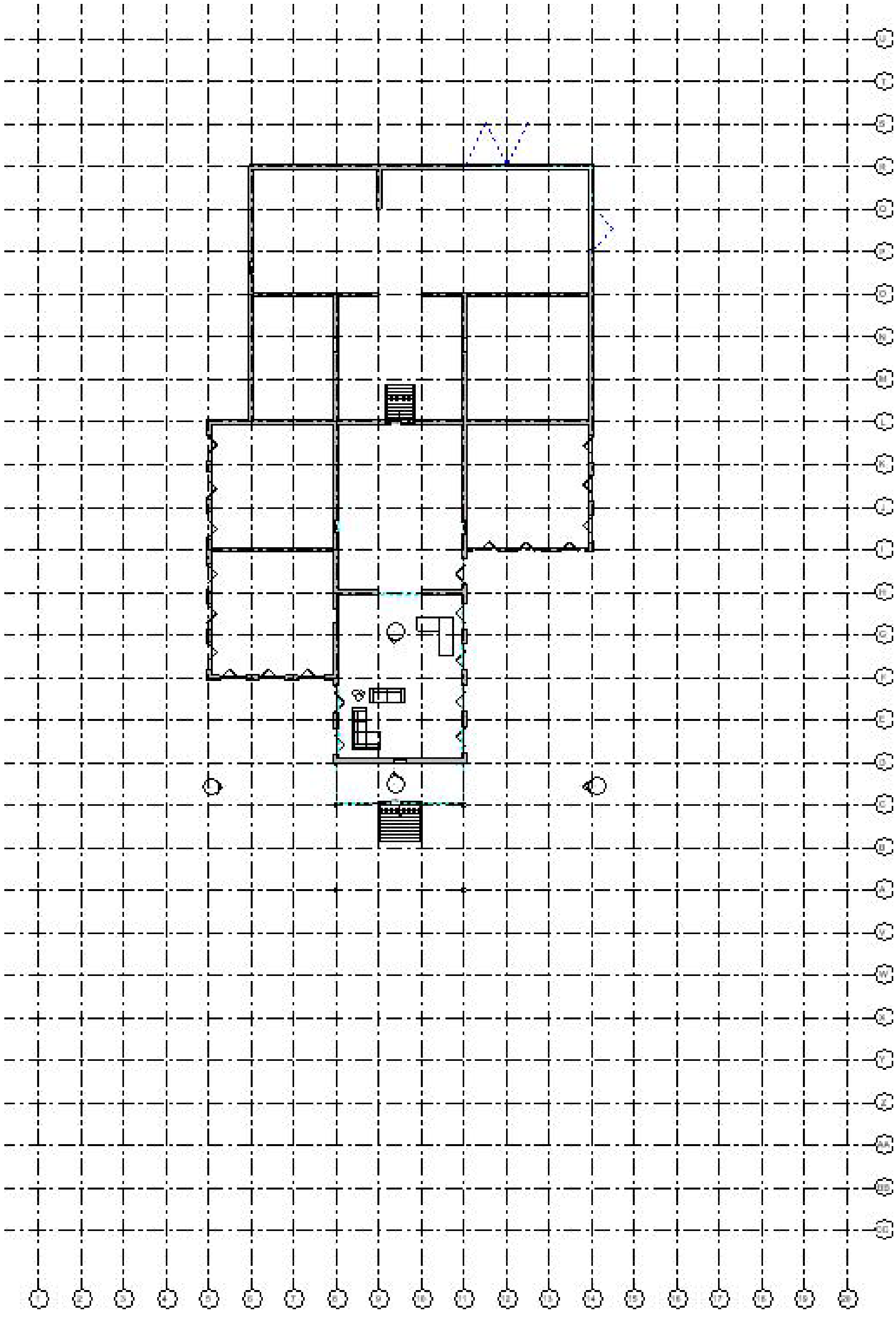
Floor Plan - Level -2



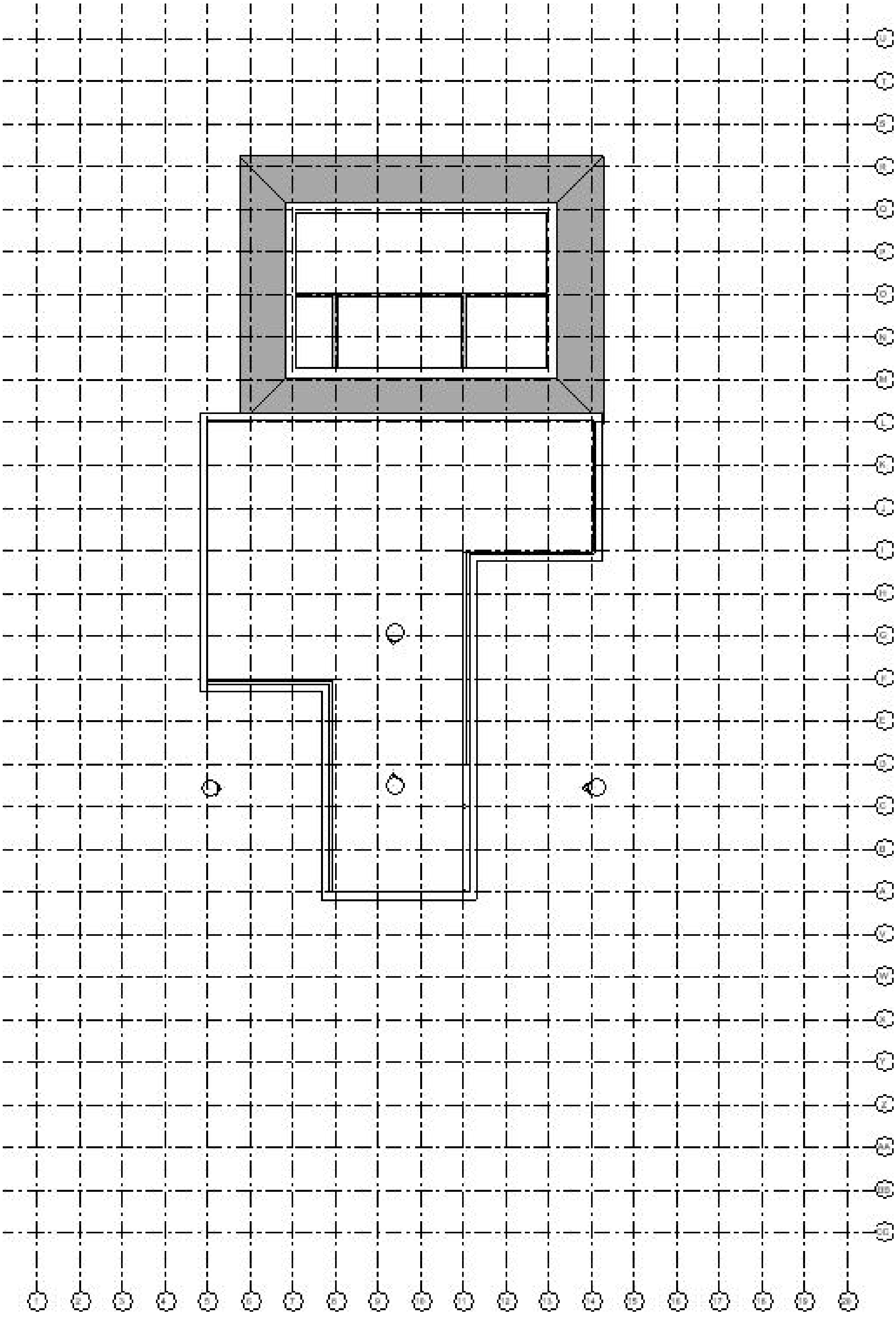
Floor Plan - Level 3



Structural Plan - Ground

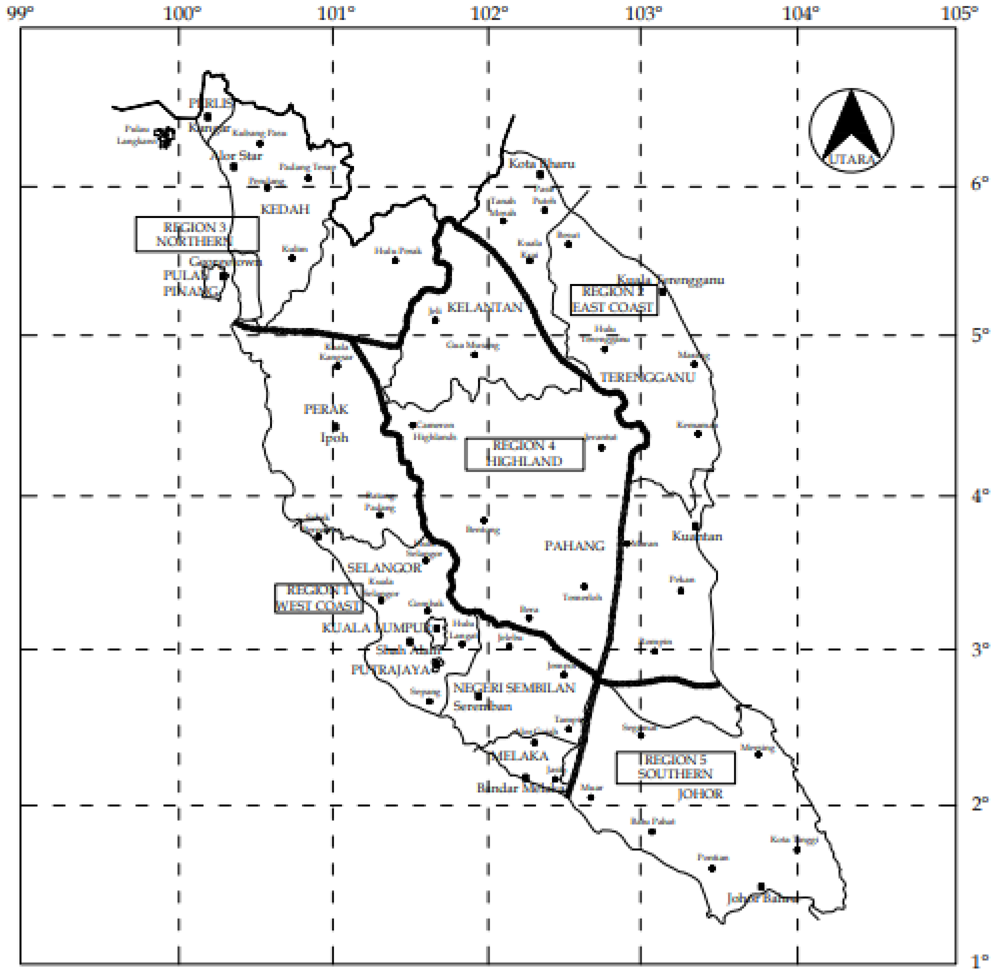


Structural Plan - Level 1



Structural Plan - Level 2

Appendix 2 : Five (5) Design Regions in Malaysia



Appendix 3 : Maximum Permissible Site Discharge (PSD) and Minimum Site Storage Requirement (SSR) Values in Accordance with The Five Regions in Peninsular Malaysia

REGION 5 - SOUTHERN

Lowlying	61.1	61.9	62.2	62.8	63.1	315.0	362.0	398.4	501.0	572.7
Mild	74.8	75.7	76.1	76.9	77.2	298.5	340.9	372.6	465.9	532.3
Steep	83.4	84.3	84.8	85.7	86.1	288.5	323.3	352.5	442.8	505.0

Appendix 3 : Maximum Permissible Site Discharge (PSD), Minimum Site Storage Requirement (SSR) and Inlet Values in Accordance with The Major Towns in Peninsular Malaysia

Terrain / Slope Condition	PSD (l/s/ha)					SSR (m^3/ha)					Inlet (l/s/ha)				
	Impervious Area (as a Percentage of Project Area)														
	25%	40%	50%	75%	90%	25%	40%	50%	75%	90%	25%	40%	50%	75%	90%
BATU PAHAT															
Low-lying	45.1	45.6	45.9	46.3	46.6	249.2	293.7	331.1	437.3	502.6	107.0	125.0	137.0	166.0	184.0
Mild	55.6	56.2	56.6	57.1	57.4	234.7	273.8	304.7	403.7	468.4	127.0	146.0	158.0	189.0	208.0
Steep	62.3	63.0	63.4	64.0	64.3	225.6	261.8	291.3	383.5	447.1	140.0	159.0	172.0	204.0	224.0

Appendix 5: OSD Volume, Inlet Size and Outlet Size for Region 5 in Peninsular Malaysia

Project Area (ha)	Impervious Area (as Percentage of Project Area)														
	25%			40%			50%			75%			90%		
	Volume (m³)	Inlet & Overflow Dia. (mm)	Outlet Dia. (mm)	Volume (m³)	Inlet & Overflow Dia. (mm)	Outlet Dia. (mm)	Volume (m³)	Inlet & Overflow Dia. (mm)	Outlet Dia. (mm)	Volume (m³)	Inlet & Overflow Dia. (mm)	Outlet Dia. (mm)	Volume (m³)	Inlet & Overflow Dia. (mm)	Outlet Dia. (mm)
TERRAIN : LOWLYING, SLOPE 1 : 2000 TO 1 : 5000															
0.1	32	133	61	37	141	62	40	147	62	50	160	62	58	168	62
0.2	63	188	86	73	200	87	80	208	87	96	226	87	115	237	87
0.4	126	265	122	146	283	124	160	294	124	192	319	124	230	336	124
0.6	189	325	149	219	346	151	240	355	151	288	391	151	345	411	151
0.8	252	375	172	292	400	175	320	416	175	384	451	175	460	475	175
1	315	419	192	365	447	195	400	465	195	500	507	195	575	531	195
2	750	443	272	880	484	276	970	510	276	1260	569	276	1460	604	276
3	1125	542	333	1320	593	339	1455	624	339	1890	697	339	2190	739	339
4	1500	626	384	1760	685	391	1940	721	391	2520	804	391	2920	854	391
5	1875	700	430	2200	765	437	2425	806	437	3150	899	437	3650	954	437
TERRAIN : MILD, SLOPE 1 : 875 TO 1 : 1999															
0.1	30	144	68	35	153	68	38	158	68	47	172	69	54	179	69
0.2	60	204	96	69	217	96	75	224	96	93	243	97	107	253	97
0.4	120	288	135	138	306	135	150	317	135	186	343	137	214	358	137
0.6	180	353	166	207	375	166	225	388	166	279	420	168	321	439	168
0.8	240	408	192	276	433	192	300	448	192	372	485	194	428	507	194
1	300	456	214	345	484	214	375	501	214	465	542	217	535	567	217
2	740	482	303	850	522	303	940	546	303	1220	606	307	1420	638	307
3	1110	590	371	1275	639	371	1410	669	371	1830	742	376	2130	782	376
4	1480	681	428	1700	738	428	1880	772	428	2440	857	434	2840	903	434
5	1850	761	479	2125	826	479	2350	863	479	3050	958	485	3550	1010	485
TERRAIN : STEEP, SLOPE 1 : 100 TO 1 : 874															
0.1	30	152	71	32.5	160	71	35	165	72	44.5	178	72	50.5	186	72
0.2	59	215	101	65	227	101	70	234	102	89	252	102	101	263	102
0.4	118	304	143	130	321	143	140	331	145	178	357	145	202	372	145
0.6	177	372	175	195	393	175	210	405	177	267	437	177	303	455	177
0.8	236	429	202	260	454	202	280	468	204	356	505	204	404	526	204
1	300	480	226	320	507	226	290	523	229	405	564	229	485	588	229
2	700	512	319	800	555	319	880	580	323	1130	640	323	1300	673	323
3	1050	627	391	1200	680	391	1320	710	396	1695	784	396	1950	825	396
4	1400	724	451	1600	785	451	1760	820	457	2260	906	457	2600	952	457
5	1750	810	505	2000	878	505	2200	917	511	2825	1013	511	3250	1065	511

Appendix 6 : Discharge and Pipe Diameter Relationship

Terrain: Lowlying

Discharge (m^3/s)	Pipe Diameter (mm)
0.01	236
0.02	247
0.04	270
0.06	292
0.08	315
0.1	338
0.12	361
0.16	406
0.22	474
0.24	497
0.28	542
0.32	587
0.36	633
0.42	701
0.48	769
0.52	814
0.56	860
0.62	928
0.66	973
0.72	1041
0.78	1109
0.82	1154

Terrain: Steep

Discharge (m^3/s)	Pipe Diameter (mm)
0.01	259
0.02	269
0.04	288
0.06	307
0.08	326
0.1	345
0.12	364
0.16	402
0.22	459
0.24	478
0.28	516
0.32	554
0.36	592
0.42	649
0.48	707
0.52	745
0.56	783
0.62	840
0.66	878
0.72	935
0.78	992
0.82	1030

Terrain: Mild

Discharge (m^3/s)	Pipe Diameter (mm)
0.01	250
0.02	261
0.04	282
0.06	303
0.08	325
0.1	346
0.12	367
0.16	410
0.22	474
0.24	495
0.28	538
0.32	581
0.36	623
0.42	687
0.48	751
0.52	794
0.56	836
0.62	900
0.66	943
0.72	1007
0.78	1071
0.82	1114

Appendix 7: Rainwater Demand for Domestic Application

Use (Appliance)	Type	Average Consumption	Average Total Rainwater Demand
A. Indoor			
Toilet	Single Flush	9 litres per flush	120 litres per day
	Dual Flush	6 or 3 litres per flush	40 litres per day
Washing Machine	Twin Tub (Semi- auto)		40 litres per wash
	Front Loading		80 litres per wash
	Top Loading		170 litres per wash
Dishwasher	-		20-50 litres per load
General Cleaning	-	10-20 litres per minute	150 litres per day
B. Outdoor			
Sprinkler or Handheld Hose		10-20 litres per minute	1000 litres per hour
Drip System			4 litres per hour
Hosing Paths/Driveways		20 litres per minute	200 litres per wash
Washing Car with a Running Hose		10-20 litres per minute	100-300 litres per wash

Appendix 8: Average Annual Rainwater Yield for Selected Towns

No.	Name of Town	Average Annual Rainwater Yield (m^3)
1	Alor Star	103
2	Ipoh	99
3	Klang	107
4	Kuala Lumpur	116
5	Seremban	98
6	Melaka	100
7	Kluang	115
8	Johor Bahru	128
9	Kota Bharu	95
10	Kuala Terengganu	94
11	Kuantan	111
12	Kuching	156
13	Sibu	144
14	Bintulu	148
15	Kota Kinabalu	109
16	Sandakan	120
17	Tawau	89

Note: AARY was computed from tank size of $1m^3$ and roof area of $100m^2$.

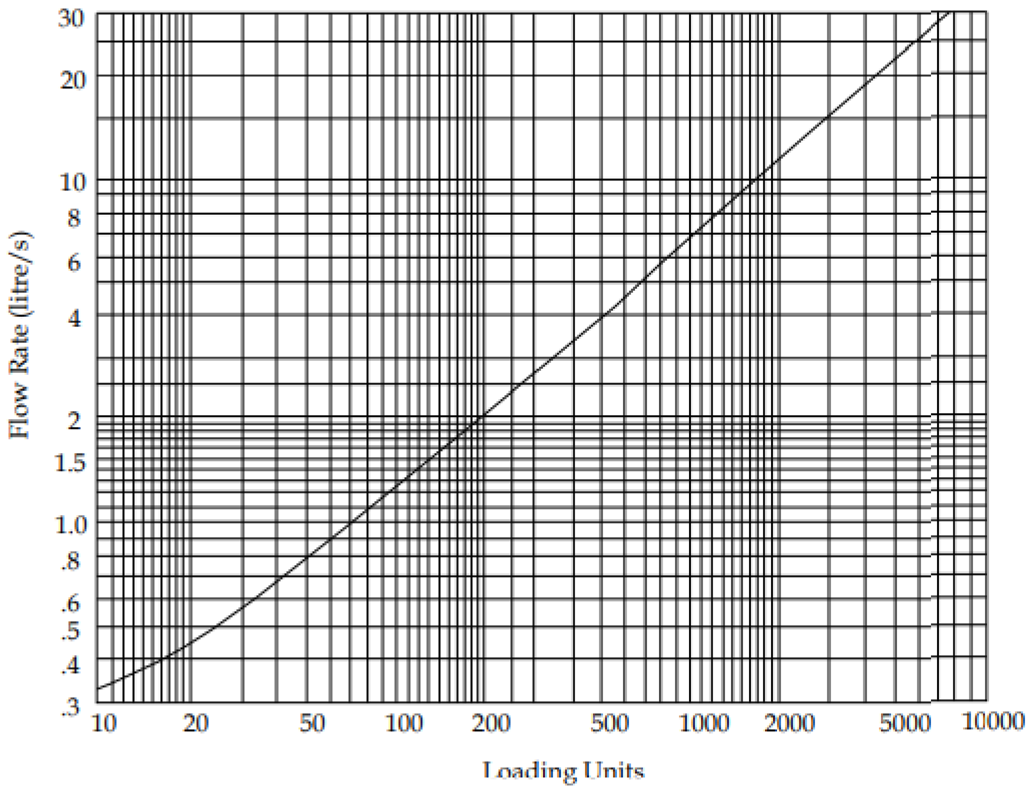
Appendix 9: loading unit Rating for various Applications

Type of Appliance	Loading Unit Rating
Dwelling and Flats	
W.C. Flushing Cistern	2
Wash Basin	1.5
Bath	10
Sink	3 - 5
Offices	
W.C. Flushing Cistern	2
Wash Basin (Distributed Use)	1.5
Wash Basin (Concentrated Use)	3
School and Industrial Buildings	
W.C. Flushing Cistern	2
Wash Basin	3
Shower (with Nozzle)	3
Public Bath	22

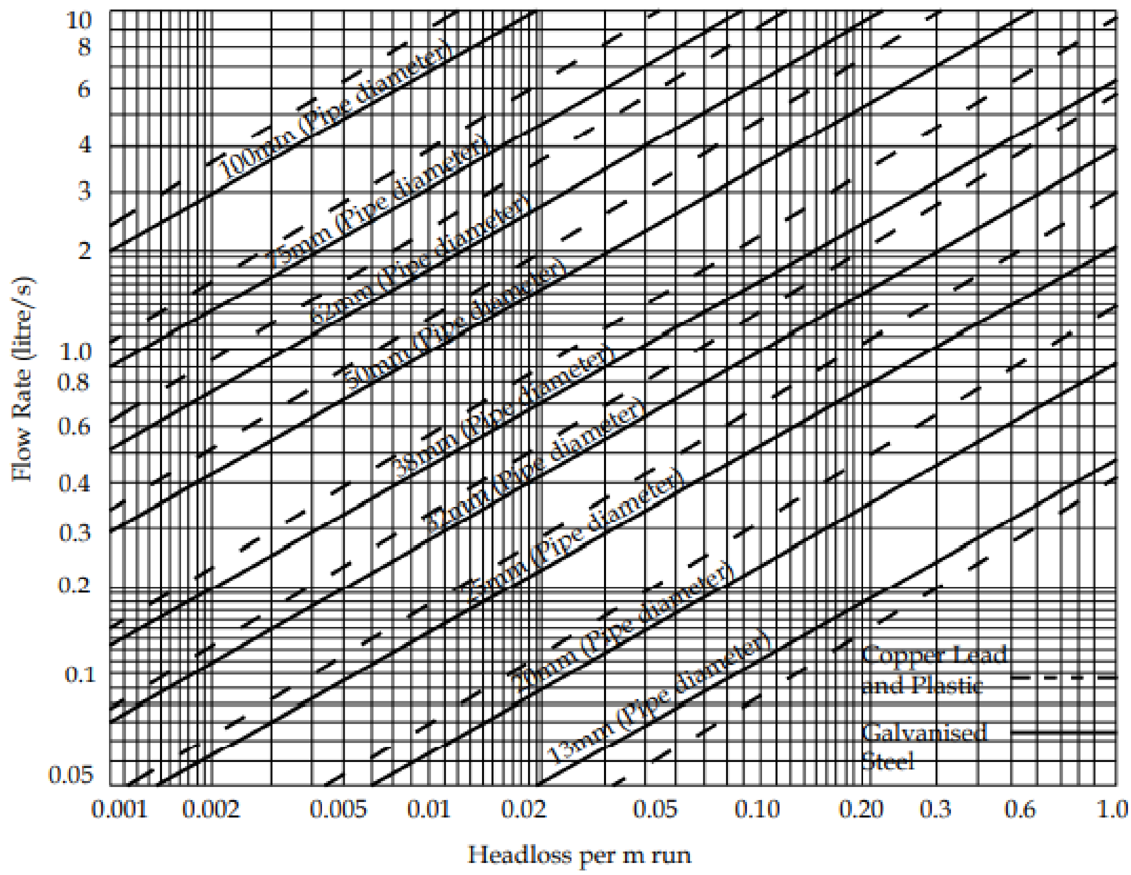
Appendix 10 : Frictional Resistance of Fittings expressed in Equivalent Pipe Length

Nominal Outside Diameter (mm)	Equivalent Pipe Length (m)		
	Elbow	Bend	Tee
15	0.5	0.4	1.2
20	0.6	0.5	1.4
25	0.7	0.6	1.8
32	1.0	0.7	2.3
40	1.2	1.0	2.7
50	1.4	1.2	3.4
65	1.7	1.3	4.2
80	2.0	1.6	5.3
100	2.7	2.0	6.8

Appendix 11: Sizing chart for design flow rate for various loading units



Appendix 12: Sizing chart for headloss for Various Pipe Size and Flow Rate



Appendix 13: Sizing chart for headloss through Stop Valve