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Determination of Rainwater Harvesting System in Mindat District

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Abstract: This study is described about the determination of rainwater harvesting system in Mindat district, Chin State of Myanmar. Firstly, rainfall volume collected from the rooftop catchment is calculated using rational method and the existing roof catchment areas; 400 sq ft, 840 sq ft and 1200 sq ft are used to collect rain. Two types of roofing materials such as GI sheet and thatch are considered. The data length is ten years period from 2003 to 2012 and these data are recorded from department of Metrology and Hydrology. To calculate monthly water use (demand), daily water consumption for one person is taken as 15 gallons and six household members are considered in a family. 30 days in a month and 30 gallons of wastage as example for roof washing or for flushing out are considered. Comparing the demand and rainfall collected, 1200 sq ft roof catchment area with GI sheet roof in Mindat can give reliable rainwater storage. In Matupi, Kanpetlet and Paletwa, surplus rainwater is collected from GI sheet roofs of 840 sq ft and 1200 sq ft roof catchment areas. Rainfall runoff collected from the roof catchment of 400 sq ft does not meet to satisfy the demand. Secondly, surface runoff harvesting is considered to collect the rains on every catchment area where the rain falls. It is calculated by applying the rational method also. The catchment area is determined by using GIS-ArcMap 9.3. Collecting the rain that falls on the surface, required demand for the study area is satisfied.

Keywords: Rooftop Catchment, Rational Method, Surface Runoff Harvesting, GIS-Arcmap 9.3.

I. INTRODUCTION

In the world today, many communities are approaching the limits of their traditional water resources due to the overall increased demand for the use of water. Therefore rainwater harvesting has now been introduced as part of an integrated water supply. Because of one of the purest sources of water available, rainwater can be used to supply potable water and non-potable water [5]. It can be used for multiple purposes ranging from irrigating crops to washing, cooking and drinking. So rainwater harvesting is an ancient technique enjoying a revival in popularity due to the inherent quality of rainwater [4]. In areas which have regular rainfall, the most appropriate alternative way to solve the problem of water shortage is the collection of rainwater called rainwater harvesting. Rainwater harvesting means collection, preservation and obtaining maximum use of rain.

According to the catchment method used, rainwater harvesting can be categorized as; in-field RWH (IRWH), ex-field RWH (XRWH) and domestic RWH (DRWH). In IRWH, part or all of the target area is used as catchment area. In XRWH, the catchment area is separate from the target area and harvested water is transported through channels to the target area. In DRWH, rainwater is collected from rooftops or other compact surfaces and stored in underground tanks or above ground tanks for domestic uses and other small scale activities [11]. Collection and storage systems for rainwater can be as simple as the collection of rainwater running off a roof and conveyed to a storage tank or as complex as bigger scale systems involving land surface and urbanized catchments. [6]There are two main ways to harvest rainwater; collecting rain from roof and collecting surface runoff-the water that flow runoff land when it rains.[10] In this study, rainwater collection with both rooftop and surface runoff catchment are considered.

II. STUDY AREA PROFILE

Myanmar possesses tropical and sub-tropical climates with three general seasons. The raining season starts during the South West monsoons from mid-May to mid-October, the dry cool season from mid-October to mid-February and the hot season from mid-February to mid-May. The various ranges of rainfall over the country are described in Figure 1. Chin state is located in the north- west of Myanmar and having common borders with India and Bangladesh. As the state is a mountainous region with almost no plains, high mountain makes temperature drop. The average annual rainfall ranges 80- 100 inches in Chin state. It is a region with good rainfall and has abundant natural forests. Chin state is divided into North and South portion. The southern parts of Chin get much rain due to the storms that come from Bay of Bengal. Each township in the southern part of Chin is a rural society and most of its population are in the villages. The collection and storage of rain from the rooftop area for domestic use has been practiced in the study area and every part of Myanmar since ancient times. Rainwater is the only source which can provide considerable water resource in humid and semiarid and arid regions.

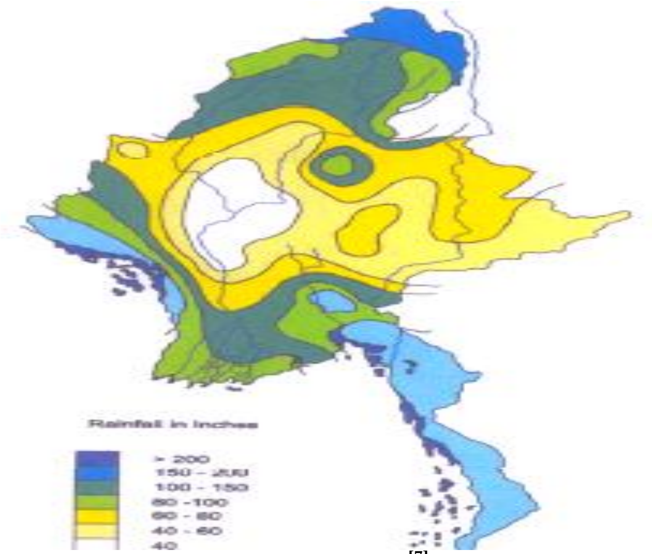

Figure1. Rainfall Map of Myanmar [7]

III. COMPONENTS OF ROOFTOP RAINWATER CATCHMENT SYSTEM

The components of rooftop rainwater harvesting system are (a) roof catchment (b) collection and conveyance system (c) pre-treatment system (d)storage tanks/cisterns (e) distribution system [2]. The typical component of rooftop rainwater harvesting system is described in Figure 2.

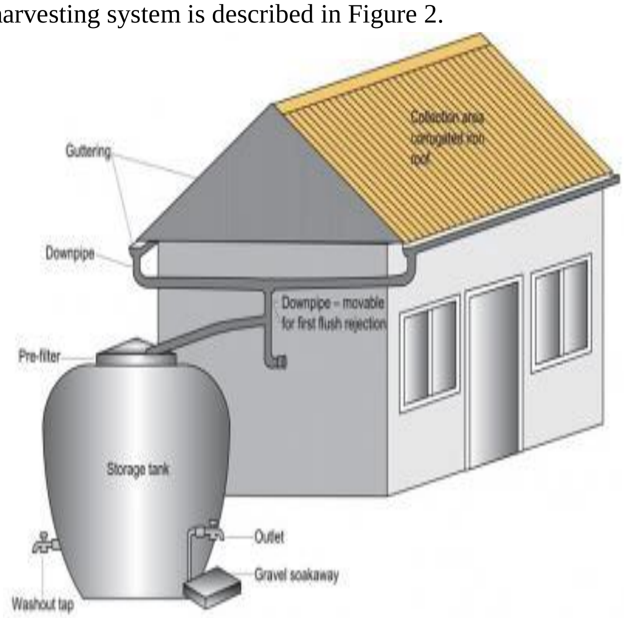

Figure2. Rainwater Harvesting System with Roof Catchment Connecting Pipes and Storage Tank[8].

A. Roof Catchment

Rainwater can be collected from most form of roofs. Roof is a catchment that can provide good quality water, clean enough for drinking if the rooftop is clean, impervious and made from non-toxic materials and located away from overhanging trees. Water quality is affected according to the type of roof material. Runoff coefficient varies with the type of roofing material. According to the type of material used for roof, volume of rainfall collected can vary. Effect on the water quality with the type of materials used for roof and values of runoff coefficient with the type of roofs are described in Table 1 and Table 2[2].

TABLE I: TYPE OF ROOF CATCHMENT AND EFFECT ON THE WATER QUALITY

Type	Effect on water quality
GI sheets and AI sheets	Excellent water quality Surface is smooth and High temperature Help to sterilize the water(kill bacteria)
Tiles	Good quality water Unglazed tiles harbor mould Contamination can exist in tile joints
Asbestos-cement sheets	New sheets give good quality water No evidence of carcinogenic effect from ingestion of fibers Slightly porous so reduce runoff coefficient Older roofs harbor moulds and even moss
Organic material (Thatch)	Poor water quality Little first flush effect High turbidity due to dissolved organic material which does not settle

TABLE II: RUNOFF COEFFICIENT VALUES WITH VARIOUS TYPES OF ROOF MATERIALS

Type	Runoff Coefficient
Galvanized iron sheets	>0.9
Tiles(glazed)	0.6-0.9
Aluminum sheets	0.8-0.9
Flat cement roof	0.6-0.7
Organic(e.g. Thatched)	0.2

B. Collection and Conveyance System

The collection and conveyance system consists of gutters, downspouts and pipes that channel rain into the storage tank. Various types of gutters are described in Figure 3. Gutters can be made from plain galvanized iron sheet, aluminium sheet, and semi-circular pipe material and even from bamboo poles. [3] Even plastic sheet gutter can be used to collect rain for temporary.

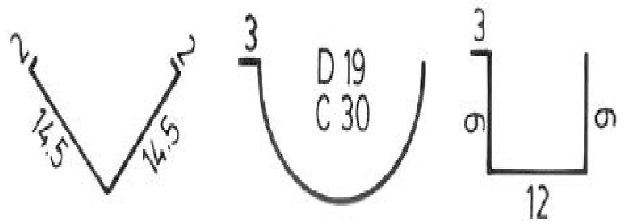

Figure3. Dimensions of V Shape, Semi-circular and Square Gutters [3].

C. Pre-treatment System

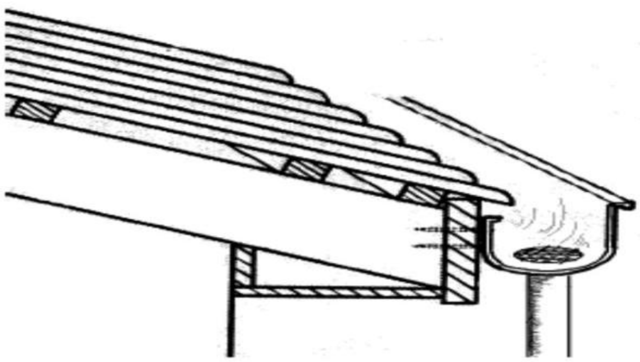

Figure4. In Pipe Coarse Filter [2]

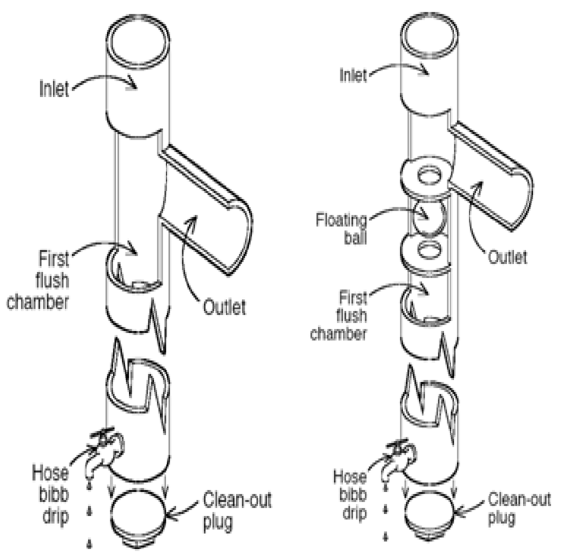

Figure 5. Stand Pipe First Flush Diverter[4]

Pre-treatment is needed to remove debris, dust and leaves that accumulate on roofs and prevent clogging within the rainwater harvesting system. Common pre-treatment devices are filters and first flush diverters. Some types of filters and first flush diverters are described in Figure 4 and Figure 5.

D. Storage Tanks/Cisterns

The storage tank is the most important and typically the most expensive component of a rainwater harvesting system. Tanks may be located above ground or underground or partially underground depending upon the availability of space. Schematic for aboveground and underground tank are described in Figure 6.

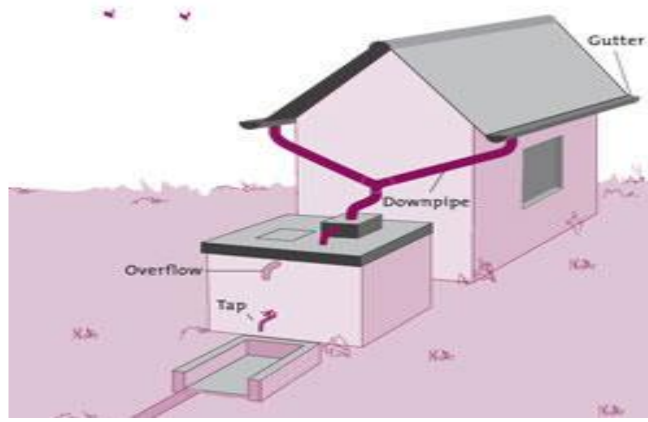

Figure 6. Aboveground Tank [7]

E. Distribution System

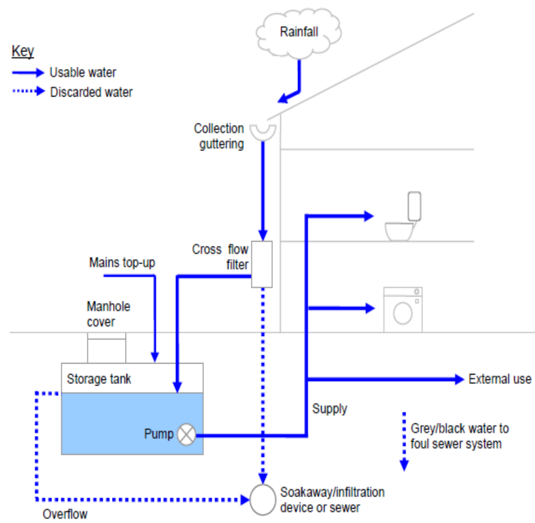

Figure7. Indirectly Pumped System [1]

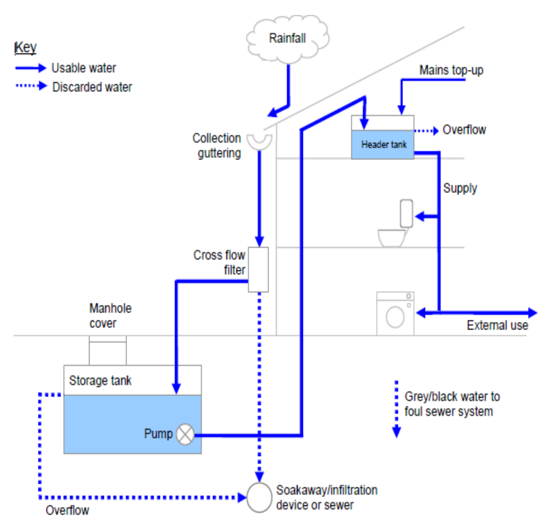

Figure 8. Directly Pumped System[1]

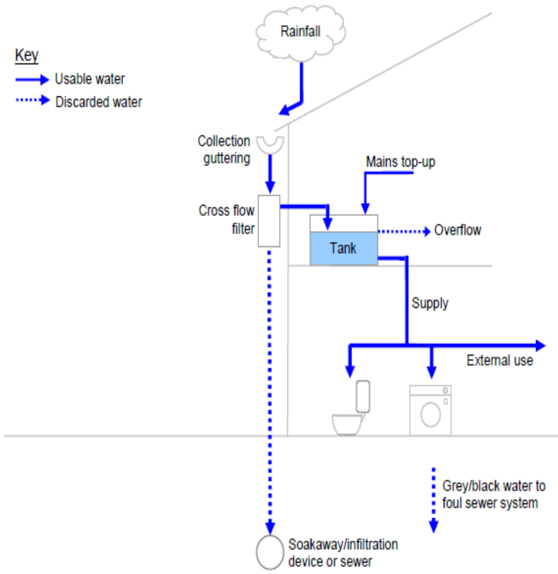

Figure 9. Gravity Fed System [1]

There are three basic types of distribution system for supplying water to buildings for internal and external uses; directly pumped, indirectly pumped and gravity fed systems. These types of distribution systems are described in Figure 7, 8 and 9.

IV. SURFACE RUNOFF HARVESTING

In areas such as road, footpaths or cattle tracks, cultivated lands grasslands and bare soil surface, a lot of rainwater is lost as it falls and flows away from these surface. If this rainfall falling on like these surfaces is collected in a pond, or in a water pan or in a reservoir, it is useful for many purposes. There are many ways to harvest rainwater on the land surface. One of the ways to harvest surface water is to build an open pan or a pond. The water pan can be build in a natural dent or depression or in a small valley where there is heavy soil like clay. But the stored water may be lost due to seepage and evaporation. Loss of water due to evaporation and seepage is not considered in this study. The main features of a water pan are described in Figure 10.

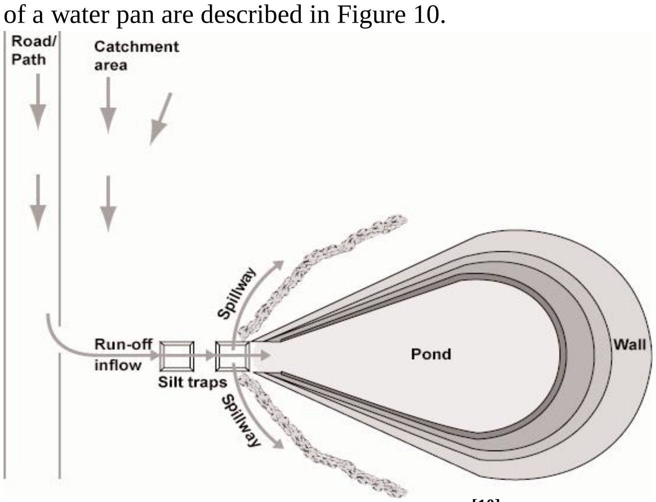

Figure10. Main Features of a Water Pan [10]

The excavated ponds can be used for livestock consumption. But in rural community, they can also be used for domestic supply. To reduce the seepage, the pond bottom can be compacted or lined with masonry, concrete or durable plastic sheets. The photo of excavated pond in Mindat is shown in Figure 11.

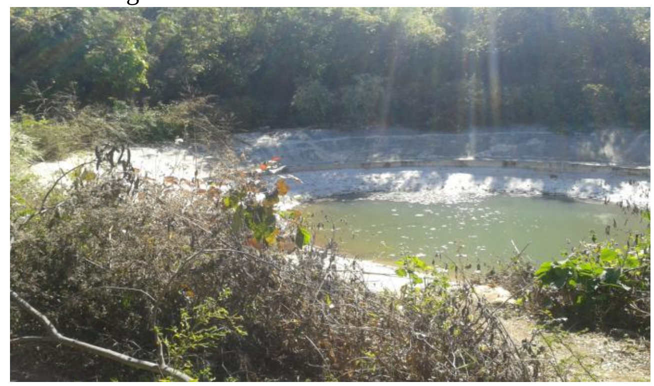

Figure11. Photo of an Excavated Tank in Mindat.

Runoff coefficient varies according to the type of surface. Typical values of runoff coefficient are shown in Table 3.

TABLE IIII: RUNOFF COEFFICIENT VALUES WITH VARIOUS TYPES OF SURFACES

Type of Surface		High	Low
Paving; Concrete, asphalt		1.00	0.90
Gravel;		0.70	0.25
Soil;	Flat, bare	0.75	0.20
	Flat, with vegetation	0.60	0.10
Lawns;	Flat, sandy soil	0.10	0.05
	Flat, heavy soil	0.17	0.13

V. DETERMINATION OF ROOFTOP RAINWATER HARVESTING VOLUME

In this study, design consideration of rooftop rainwater harvesting system is determined based on the existing conditions. Rainfall runoff values according to existing various roof sizes are calculated. There are three groups of roof sizes in the study area, such as 400 square feet, 840 square feet and 1200 square feet. Galvanized iron sheet and thatch are used as roofing materials. Estimation of monthly runoff volume is determined by the rational method as the following equation [5];

$$S = R \times A \times Cr \quad (1)$$

Where, S= Water storage (gallon)
R= Monthly rainfall (in)
A=Catchment area of roof (sq-ft)
Cr=Runoff coefficient

A. Calculation of Monthly Water Storage

30-days are taken as an average in a month and six household members are considered in a family. Daily consumption for water use per capita is taken as 15 gallons and 30 gallons of wastage for example roof washing or flushing out is considered as wastage. The typical calculation for Mindat is as follow and as shown in Tables 4 to 9.

B. Calculation of Monthly Water Storage for Mindat

Monthly water demand

per family = 30 days × 15 gal × 6members/household = 2700 gal/household

Rainfall volume

Collected in January = 0.193×1200×0.9×0.52 = 108.39 gallon

TABLE IV: MONTHLY WATER BALANCE FROM 1200 SQ FT GI SHEET ROOF CATCHMENT IN MINDAT

Month	Monthly Use (gal)	Monthly Rainfall (in)	Rainfall Collect (gal)	Wast -age (gal)	After Deducted (gal)	End of Month Storage (gal)
Jan	2700	0.193	108.39	30	78.39	-2621.61
Feb	2700	0.075	42.12	30	12.12	-5309.49
March	2700	0.387	217.34	30	187.34	-7822.15
April	2700	1.36	763.78	30	733.78	-9788.38
May	2700	7.35	4127.76	30	4097.76	-8390.62
June	2700	8.036	4513.02	30	4483.02	-6607.60
July	2700	6.061	3403.86	30	3373.86	-5933.74
Aug	2700	11.381	6391.57	30	6361.57	-2272.17
Sep	2700	14.981	8413.33	30	8383.33	3411.16
Oct	2700	10.04	5638.46	30	5608.46	6319.62
Nov	2700	0.784	440.29	30	410.29	4029.92
Dec	2700	0.632	354.93	30	324.93	1654.85

Average annual rainfall; 61.28 inches

TABLEV: MONTHLY WATER BALANCE FROM 1200 SQ FT THATCHES ROOF CATCHMENT IN MINDAT

Month	Monthly Use (gal)	Monthly Rainfa-ll (in)	Rainfall Collect (gal)	Wast age (gal)	After Deduct ed(gal)	End of Month Storage (gal)
Jan	2700	0.193	24.09	30	0	-2700
Feb	2700	0.075	9.36	30	0	-5400
March	2700	0.387	48.30	30	18.30	-8081.70
April	2700	1.36	169.73	30	139.73	-10641.97
May	2700	7.35	917.28	30	887.28	-12454.69
June	2700	8.036	1002.89	30	972.89	-14181.80
July	2700	6.061	756.41	30	726.41	-16155.39
Aug	2700	11.381	1420.35	30	1390.35	-17465.04
Sep	2700	14.981	1869.63	30	1839.63	-18325.41
Oct	2700	10.04	1252.99	30	1222.99	-19802.42
Nov	2700	0.784	97.84	30	63.84	-22438.57
Dec	2700	0.632	78.87	30	48.87	-25089.70

Average annual rainfall; 61.28 inches

TABLE VI: MONTHLY WATER BALANCE FROM 840 SQ FT GI SHEET ROOF CATCHMENT IN MINDAT

Month	Monthly use	Monthly rainfall	Rainfall Collect	Wast -age	After deducte d	End of Month Storage
Jan	2700	0.193	75.87	30	45.87	-2654.13
Feb	2700	0.075	29.48	30	0	-5354.13
March	2700	0.387	152.14	30	122	-7932.13
April	2700	1.36	534.64	30	504.64	-10127.49
May	2700	7.35	2889.43	30	2859.43	-9968.05
June	2700	8.036	3159.11	30	3129.11	-9538.94
July	2700	6.061	2382.70	30	2352.70	-9886.24
Aug	2700	11.381	4474.10	30	4444.10	-8142.14
Sep	2700	14.981	5889.33	30	5859.33	-4982.81
Oct	2700	10.04	3946.93	30	3916.93	-3765.89
Nov	2700	0.784	308.21	30	278.21	-6187.68
Dec	2700	0.632	248.45	30	218.45	-8669.23

Average annual rainfall; 61.28 inches.

TABLE IVII: MONTHLY WATER BALANCE FROM 840 SQ FT THATCH ROOF CATCHMENT IN MINDAT

Month	Monthly Use (gal)	Monthly Rainfa-ll (in)	Rainfall Collect (gal)	Wast-age (gal)	After Deduct -ed (gal)	End of Month Storage (gal)
Jan	2700	0.193	16.86	30	0	-2700
Feb	2700	0.075	6.55	30	0	-5400
March	2700	0.387	33.81	30	3.81	-8096.19
April	2700	1.36	118.81	30	88.81	-10707.38
May	2700	7.35	642.10	30	612.10	-12795.29
June	2700	8.036	702.03	30	672.03	-14823.26
July	2700	6.061	529.49	30	499.49	-17023.77
Aug	2700	11.381	994.24	30	964.24	-18759.53
Sep	2700	14.981	1308.74	30	1278.74	-201808.79
Oct	2700	10.04	877.09	30	847.09	-22033.70
Nov	2700	0.784	68.49	30	38.30	-24695.40
Dec	2700	0.632	55.21	30	25.21	-27370.18

Average annual rainfall; 61.28 inches

TABLE VII: MONTHLY WATER BALANCES FROM 400 SQ FT GI SHEET ROOF CATCHMENT IN MINDAT

Month	Monthly Use (gal)	Monthly Rainfa-ll (in)	Rainfall Collect (gal)	Wast -age (gal)	After Deducted (gal)	End of Month Storage (gal)
Jan	2700	0.193	36.13	30	6.13	-2693.87
Feb	2700	0.075	14.04	30	0	-5393.87
March	2700	0.387	72.45	30	42.45	-8051.42
April	2700	1.36	254.59	30	224.59	-10562.83
May	2700	7.35	1375.92	30	1345.92	-11881.83
June	2700	8.036	1504.34	30	1474.34	-13107.49
July	2700	6.061	1134.62	30	1104.62	-14702.87
Aug	2700	11.381	2130.52	30	2100.52	-15302.35
Sep	2700	14.981	2804.44	30	2774.44	-15227.91
Oct	2700	10.04	1879.49	30	1849.49	-16078.42
Nov	2700	0.784	146.76	30	116.76	-18661.66
Dec	2700	0.632	118.31	30	88.31	-21273.35

Average annual rainfall; 61.28 inches

TABLE IX: MONTHLY WATER BALANCE FROM 400 SQ FT THATCH ROOF CATCHMENT IN MINDAT

Month	Monthly Use (gal)	Monthly Rainfall (in)	Rainfall Collect (gal)	Wast-age (gal)	After Deducted (gal)	End of Month Storage (gal)
Jan	2700	0.193	8.03	30	0	-2700
Feb	2700	0.075	3.12	30	0	-5400
March	2700	0.387	16.10	30	0	-8100
April	2700	1.36	56.58	30	26.58	-10773.42
May	2700	7.35	305.76	30	275.76	-13197.66
June	2700	8.036	334.30	30	304.30	-15593.36
July	2700	6.061	252.14	30	222.14	-18071.22
Aug	2700	11.381	473.45	30	443.45	-20327.77
Sep	2700	14.981	623.21	30	593.21	-22434.56
Oct	2700	10.04	417.66	30	387.66	-24746.90
Nov	2700	0.784	32.61	30	2.61	-27444.29
Dec	2700	0.632	26.29	30	0	-30144.29

Average annual rainfall; 61.28 inches

VI. CALCULATION OF WATER STORAGE AND DEMAND AT THE END OF YEAR IN THE STUDY AREA

The volume of rainfall collected per one household for Mindat, Kanpetlet, Matupi and Paletwa is described in the following Table 9.The average annual rainfall of Mindat, Kanpetlet, Matupi and Paletwa are 61.28 inches, 80.109 inches, 112.35 inches and 117.79 inches respectively.

TABLE X: VOLUME OF WATER STORAGE AND DEMAND AT THE END OF YEAR IN THE STUDY AREA

Location	Size of Roof Area	Type of roof material	Surplus water at end of year; (gal)	Deficit water at end of year; (gal)
Mindat	1200 sq ft	GI sheet	1654.85	
		Thatch		25089.70
	840 sq ft	GI sheet		8669.23
		Thatch		27370.18
	400 sq ft	GI sheet		21273.35
		Thatch		30144.29
Kanpetlet	1200 sq ft	GI sheet	12260.39	
		Thatch		22710.08
	840 sq ft	GI sheet		1226.81
		Thatch		25698.06
	400 sq ft	GI sheet		17712.78
		Thatch		29344.66
Matupi	1200 sq ft	GI sheet	30336.31	
		Thatch		18738.59
	840 sq ft	GI sheet	11407.43	
		Thatch		33904.86
	400 sq ft	GI sheet		11727.89
		Thatch		28073.46
Paletwa	1200 sq ft	GI sheet	33391.44	
		Thatch		18032.01
	840 sq ft	GI sheet	13546	
		Thatch		22432.14
	400 sq ft	GI sheet		10695.05
		Thatch		27859.43

VII. DETERMINATION OF SURFACE RUNOFF RAINWATER HARVESTING VOLUME

In this study, volume of surface runoff is estimated by applying the rational method also. The data length is 10 years period from 2003 to 2012 and the average annual rainfall for each town is used to calculate the average annual rainfall volume. The surface catchment area of each town is determined by using the GIS-ArcMap 9.3. These areas are shown in Table XI. To get the accurate volume of the storage, it should be multiplied by actual runoff coefficient.

TABLE XI: CATCHMENT AREA OF THE TOWNS

Town	Area (sq ft)
Mindat	22502044.493
Kanpetlet	18708885.782
Matupi	1764322. 556
Paletwa	7848379.229

Average annual runoff volumes of the four towns are shown in the following Table XII.

TABLE XII: AVERAGE ANNUAL RUNOFF VOLUME OF THE TOWNS

Town	Runoff Volume (mil gal)
Mindat	717.041
Kanpetlet	779.350
Matupi	103.08
Paletwa	480.72

There are 7176 numbers of houses in Mindat, 3254 numbers of houses in Kanpetlet, 6541 houses in Matupi and 15918 houses in Paletwa. 75 percent of the houses use GI sheet roof and the left have thatch roofing. In Mindat, there are 20% of the houses that have 1200 sq ft, 35% of 840 sq ft and 45% of 400 sq ft. In Kanpetlet and Matupi, about 20% of the houses have 1200 sq ft, 30% of 840 sq ft and 50% of houses occupy 400 sq ft. In Paletwa, about 25% are 1200 sq ft roofing area, 30% are 840 sq ft and 45% of house roofs are 400 sq ft. The required demand for the whole town is shown in Table XIII.

TABLE XIII: REQUIRED VOLUME OF THE TOWNS AT THE END OF YEAR

Town	Runoff Volume (mil gal)
Mindat	118.38
Kanpetlet	11.94
Matupi	74.48
Paletwa	152.06

VIII. DISCUSSION AND CONCLUSION

In this study, quantity of rainwater volume collected from the existing roof catchments are calculated using rational method at first. The data are taken from the department of Metrology and Hydrology in Mindat and the data length is 10 years period from 2003 to 2012. . There are three groups of roof sizes in the study area, such as 400 square feet, 840 square feet and 1200 square feet. Galvanized iron sheet and thatch are used as roofing materials. For a family with six household members, the required demand per month is 2700 gallons. Based on the rainfall data, area of roof catchment and type of roof material, how much rain is captured can be determined. From the comparison of the demand and collected rainwater volume, 1200 sq ft GI sheet roof can meet the demand at the end of year in the study area. In the case of Matupi and Paletwa, rainfall collected from the GI sheet roof of 840 sq ft can also provide surplus water storage. For the catchment area of 400 sq ft, another source of water should be used to satisfy the demand. Secondly, surface runoff harvesting is considered for all the four towns. The surface catchment area of each town is determined by using GIS. In this study, runoff coefficient for various surface types is not considered. Only a rough estimate of the surface runoff volume is calculated and compared with the deficit from the rooftop catchments. To get the actual surface runoff volume, it should be multiplied by runoff coefficient. It is found that surface runoff harvesting satisfy the demand and can give a reliable water storage for the study area. But maintenance and pre treatment of water is needed for potable use of water. It can be said that rainfall can provide considerable resource in the study area.

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