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BUILDING INFORMATION MODELING APPLICATION FOR GROUNDWATER RECHARGE: DEVELOPMENT OF MULTIPLE STRUCTURES

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Abstract

Globally the researchers are identifying the new ways for better urban sustainability. One major issue in the current world is the lack of fresh water availability in cities due to rapid increase in the population. To meet water requirement, scientist are exploring different ways to enhance the groundwater recharge capacity. One such solution is the use of building information modelling (BIM) technology to identify multiple structures that can be constructed to provide the potential recharge. This research aims to develop multiple structures which can provide ground water recharge capability. For the development of the BIM design for the potential ground water recharge, multiple stages were implemented i.e., Collaborative Design, Virtual Design, Parametric Design, Pipeline Design, Simulated Installation and Material Table Statistics. Based on these stages, major structures of recharge from surface runoff water were identified. These structures included house rooftop rainwater harvesting, porous roads, small dams and gravel paths. This paper will provide the baseline methodology for the BIM development for water recharge construction projects.

Keywords: Building information modelling (BIM), ground water, porous road construction, rain water harvesting, urban sustainability

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1. Introduction

Currently, world is facing severe water shortage crisis which needs to be addressed. Increase in population leads to the escalated demand of water which reduces the water availability, thus disturbing the whole demand and supply chain (Custodio et al., 2016). Due to rapid urbanization and constantly increase in water demand, engineering configuration must be improved in order to satisfy the demand. Notable attention should be given to water supply and seepage structure designs in order to improve the general nature of water supply and waste works plans (Ghaffour et al., 2013; Teleman et al., 2005). To address these water problems it is crucial that modern approach like BIM is adopted and integrated with modern supporting software for water supply and waste structure programming under the collaboration of specialized engineers (Abanda and Byers, 2016; Kim et al., 2013; Volk et al., 2014).

Globally, in big cities where urban sprawl is happening at extremely rapid pace, the groundwater table is decreasing tremendously (Konikow and Leake, 2014). Urban sprawl is converting the barren or agricultural land into the concrete build up area (Rimal et al., 2018). This process decreases the

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permeability capacity of the soil and due to this, the potential of groundwater recharge decreases rapidly. Due to urban sprawl, recharge of groundwater will get further decreased and demand of water will get increased, thus leading to ground water deprivation (Wakode et al., 2018). Hence, it is imperative to devise a land use policy to mitigate such problems as well as to identify those areas, which increase the groundwater recharge potential. It is very difficult to preserve ground water resources as they are vulnerable to overexploitation or excessive use of ground water. This vulnerability is because of the lesser rainfall and increase in population in the urban areas (Strohschön et al., 2013). Most of the earth freshwater is found as stored underground (i.e. in aquifers) and not in the lakes and rivers. The aquifers are also the source of base flow water for the rivers in the absence of rainfall (Rumsey et al., 2015). Groundwater plays an important role in terms of the economic and social health of the urban population of the developing world. Cities need to supply water in various combinations as per demands of their private, public, industrial and commercial users. The urbanization process has always altered the quality and quantity of the local aquifer systems in various ways (Baier et al., 2014). Considering the changes in the hydrological cycle due to urbanization, it is important to study the effect of urbanization on local water resources and available groundwater source in the vicinity. As described in this study, latest technology like BIM can be very effective for studying the hydrological cycle and groundwater recharge (Ku and Taiebat, 2011).

Managed aquifer recharge (MAR), refers to increase the groundwater quality and quantity and is relatively a new concept for the subsurface water sustainability (IAH-MAR, 2018). It refers to set of solutions to maximize the groundwater efficiency under stress. Managed aquifer recharge is a term for a wide and growing range of measures to support active management of groundwater resources at the local and basin level, to make more efficient use of water resources, assist conjunctive management of surface and groundwater resources (Gale, 2005; Evans et al., 2012; Evans and Dillon, 2018), to buffer against increasing intensity of climate extremes, particularly drought, and to protect and improve water quality in aquifers. There are several new techniques established for groundwater preservation i.e., BIM is one of latest technology which helps for better MAR. To solve the problem of water scarcity, BIM (InfraWorks) has been used in the current study in order to develop different structures that will help in groundwater recharge from the runoff water. These structures are house rooftop water collection, porous roads, small dams and gravel footpaths. BIM as an advance tool is used to develop the 3D structures which involve the parametric design and virtual design representing all the major information with the building water supply and drainage design. Through such structures, the quantity of water being wasted can be estimated and also the amount of water being absorbed by the soil at given locations can be quantified. This can help in recharging the ground water table and figure out the water usage. Hence, this study primarily focuses on the development of recharge structures in the BIM environment for better visualization and computing the potential recharge of these structures.

Researchers identified the utilization of BIM not merely as an innovation but as a process (Azhar et al., 2012; Ahmad et al., 2018). Numerous researches concluded BIM application as a productive tool in minimizing errors and saving time during the design phase (Luthra, 2010). Moreover, BIM also empowers the designers in carrying out various plan alternatives in advance to check for sustainable interaction between natural system interactions with built facilities (Lee et al., 2012). To accomplish sustainable design along with Leadership in Energy and Efficient Design (LEED) certification, the role of BIM has been identified by various researchers (Langar and Pearce, 2016). Furthermore, BIM is also assistive in estimating water reserves (Azhar, 2011).

Siddiqui et al. (2009) pointed that an integrated approach can be utilized by combining various other technologies with BIM, but this could be more time taking and effort involving process. Despite the identification of numerous benefits of BIM, researchers have shown concerns regarding the operational ability of software with other disciplines (McGraw Hill Construction, 2009; Ku and Taiebat, 2011; Siddiqui et al., 2009). This short coming hinders the BIM application (Ku and Taiebat, 2011) and limits the range of benefits that were to be obtained by using BIM in research methods (Barlish and Sullivan, 2012). Along with aforementioned factors, unavailability of non-proficient personals and statistical consistency could also hinder the incorporation of BIM in large scale green designs and strategies.

Bonenberg and Wei (2015) used BIM tools to simulate rainwater harvesting and water circulation systems during the design phase, a case of tent-shaped roof was used to collect rainwater which was stored in a large water storage space under the ground and the collected rainwater was used for irrigation or other energy efficiency measures. Bernstein et al. (2015) argued that the Shanghai Tower in China applied BIM during the design stage to assist in the design of special curtain wall structure thereby reducing high-rise building wind loads and improving rainwater harvesting. Lu et al. (2017) pointed out that BIM mainly supported water consumption analysis during the design phase. As such, the BIM software assisted in optimizing the water distribution system of buildings.

Some studies concerning BIM execution utilized review strategies and dissected information from the point of view of general contractual workers (Ku and Taiebat, 2011). Langar and Pearce (2014) additionally recognized an exceptionally solid connection among BIM and green structures yet did not explore any connection among BIM and RwHTS. The relationship seen between green structures and BIM isn't really equivalent to that among RwHTS and BIM, on the grounds that RwHTS is a particular subcomponent of green structures. In this manner, this examination tries to decide if any relationship exists between the consideration of RwHTS in capital tasks and the utilization of BIM by the design firms required with them. For water supply and drainage designs, two-dimensional design is traditionally used, whose effectiveness was not remarkable with constrained imaging.

BIM technology, being advanced in visualization i.e. equipment measures the size of actual pipes, and the ability to develop three dimensional model, could efficiently cater for the problems in traditional designs. Better drainage designs can be obtained through collaboration and better decision making can be done through the use of BIM. BIM application being capable of developing 3D designs supports architects by providing an environment for effective development of water supply and drainage designs.

2. Methodology - the prototypical framework

For the methodological framework applied in this study (Fig. 1), initially the design of the recharge structures was identified, which included rooftop rainwater harvesting, porous roads, small dams and gravel paths. Then these shortlisted designs were virtually designed in AutoCAD and were later exported to InfraWorks (infrastructure design software for BIM) for further investigation. The specifications of all these designs were established in InfraWorks to simulate the structures. The detail of each step is presented below.

2.1. Preliminary/collaborative design

In the first step all the potential sources were identified that can contribute in groundwater recharge. The fundamental designs of these structures were studied from literature review and basic design of these structures were finalized. All the attributes of the design were identified and formulated as it is very important to understand the attributes of the data because only then further simulations and calculations can be possible. For example, to develop a design for the rooftop rain water storage, its key attributes are to identify the surface area of roof, roof slope, runoff coefficient and pipeline details (length, diameter, material, and components) (Fig. 2).

2.2. Virtual design

Once the preliminary designs of the recharge structures were identified; the layout of the 2D plans of the structures were generated on AutoCAD. Since the 3D (three-dimensional) structure data information in the BIM process is instinctive and accomplishes great information, these 2D raw designs were refined into 3D structures with all attributes included.

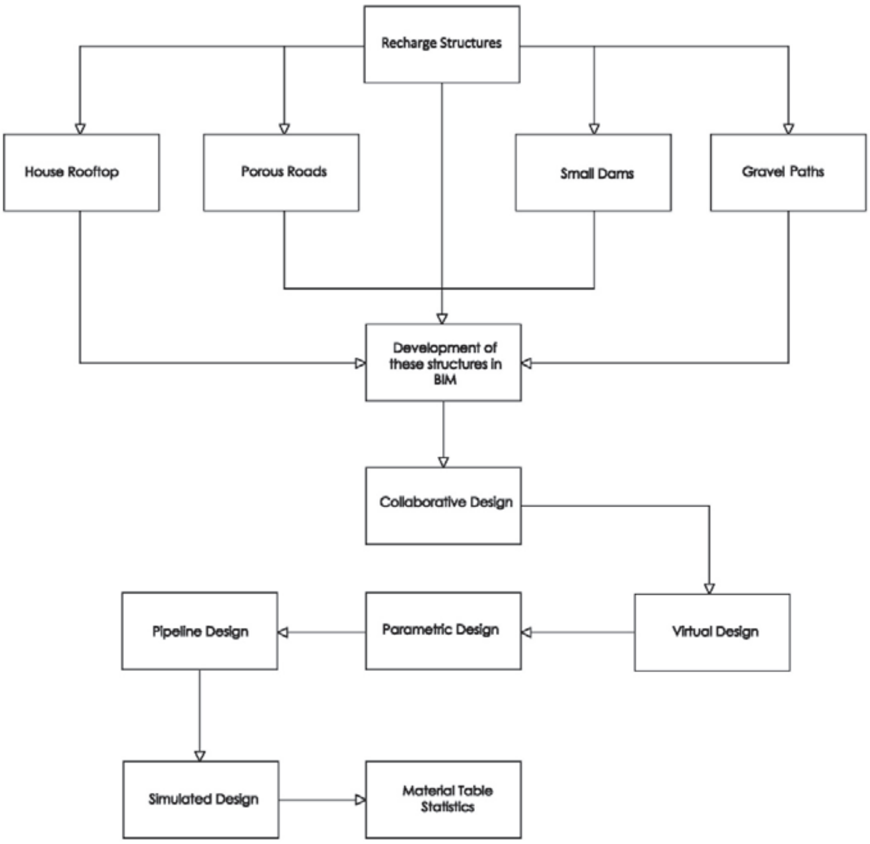
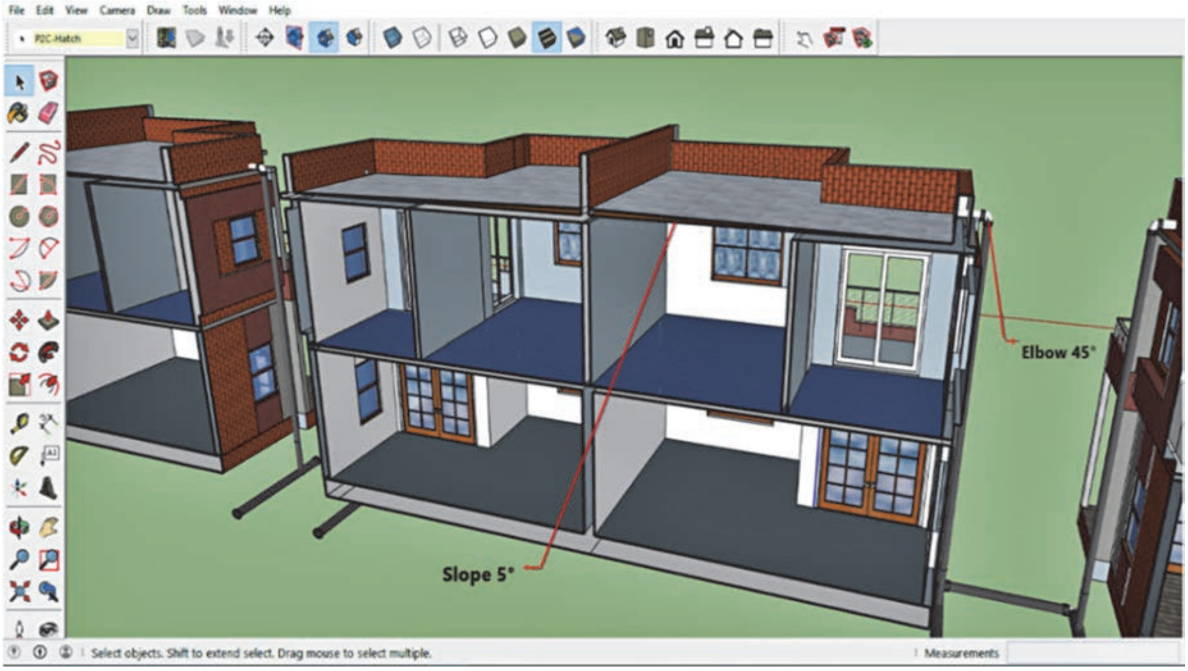


Fig. 1. Methodology of the study



Select objects. Shift to extend select. Drag mouse to select multiple.

Fig. 2. 3D building designed SketchUp

In this research all the structures designed in AutoCAD were imported in BIM InfraWork software and its different stages were identified, and multiple parts were added and modified. These parts are building roof top, pipelines, and storage tank. All these structures were further assigned with its attributes such as length, width, elevation and slope.

2.3. Parametric design

Once the virtual design of all the recharge structures have been developed in AutoCAD then its attributes were added from GIS database into another Autodesk developed software called BIM InfraWorks which helped in developing our required model in a more realistic and contextual environment. Advantage of InfraWorks is that if any parameters are changed, its wizards can control the plan of various areas and change the master plan. In short if the designer adjust and refine the parameters at any stage, the database in InfraWorks will be consequently refreshed. In this research multiple parameters were established for each structure which helped in further calculation.

2.4. Pipeline design

Since all the structures developed in this study have the basic purpose of groundwater recharge hence one common thing in each structure was the pipeline and joints in each structure which helped in water transfer. InfraWorks helps in pipeline identification and lets the user to easily estimate the discharge and other parameters very effectively. In case of any defect or error in structure planning or model, the issue can be resolved by utilizing BIM visual analysis, hence the structures can be modified with convenient improvements and modifications.

In this research all the piping structure intended to be used was first established and then verified in a 3D simulation to define its accuracy.

2.5. Simulated installation

BIM innovation can give established activity and structure direction for the water supply and seepage structures. The advantage for utilization of BIM display for virtual development is that the issue can be found ahead of time, and the establishment of the pipeline can be guided to control the development of the task and follow the structural planning easily. For instance, in a tall structure water supply and seepage configuration ventures, BIM innovation was utilized to modernize the pipeline establishment process. In this research, once all the structures were virtually designed and its parameters were established then all the parts of given structures were simulated together, and model testing was checked to verify that the structures are properly planned, developed and simulated together.

2.6. Material table statistics

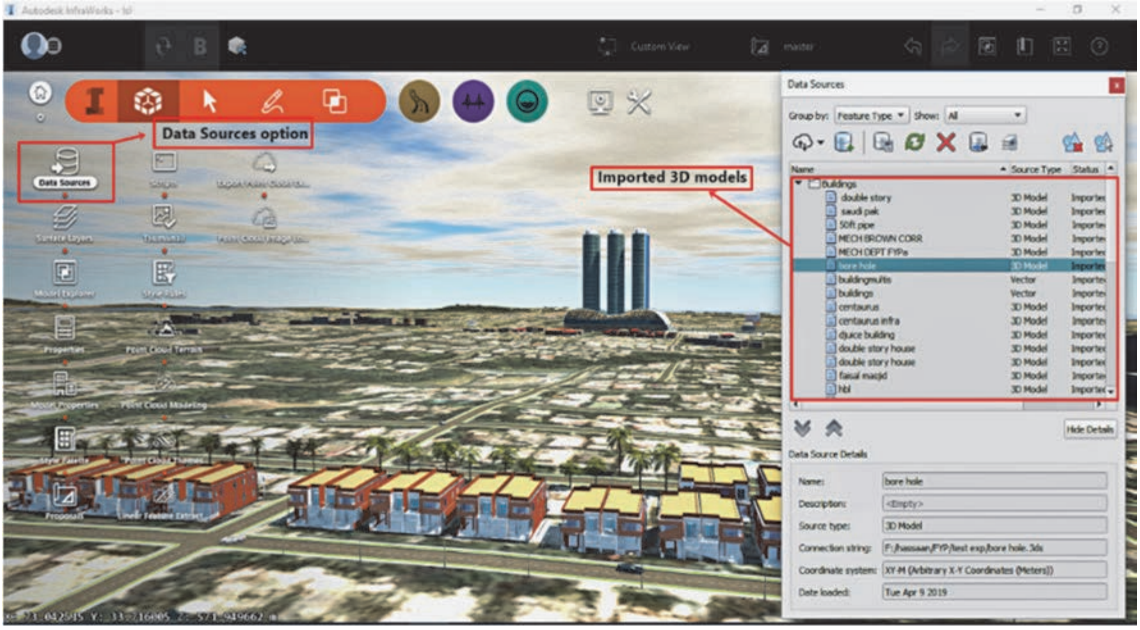
Earlier the statistical calculation i.e. costing, material and time for any given structures was done manually or in Excel sheets which was very time consuming. In BIM process all the statistical data must be completed first and database must be developed for each defined structure.

Once it is done, it becomes very easy to identify any dataset and one can correlate and compare the multiple datasets as well. In this research basic parameters were established which included the length and width of pipes, no. of pipes and surface area of the recharge structure.

3. BIM Infra works - procedure

Above mentioned methodology defined the working procedure of the BIM process. Now in InfraWorks software the above-mentioned structures were developed in a way that all the structures were designed using AutoCAD 2017 and then the finished model was the imported in SketchUp 2018 for additional modelling of the piping structure which was necessary to collect the rainwater that fall onto the roof surface of the building. The modeling was done in three steps i.e. the 2D plans of the required buildings were generated using basic AutoCAD commands. After this, the 2D models were converted into 3D models and a roof slope was defined for each building depending upon the area and nature of the building. The model was then imported into SketchUp for additional modeling of piping structure for the collection of rainwater (Fig. 2). Finally, all these models were imported in InfraWorks (Fig. 3).

InfraWorks is a platform which enables engineers to design and analyze models in a real-world environment. Autodesk team generates the specified area that would include the topography of the area, the road network, satellite imagery and a few models if available. InfraWorks has a wide range of options for data exchange and is compatible with the data sources as shown in the Fig. 4. After data has been imported, it needs to be configured. This means the data file needs to be assigned to a specified domain. To configure a data file it is required to enter its coordinates as per the chosen coordinate system. WGS 1984 coordinate system has been used for the current study. After the model has been placed on ground, its properties were modified such as roof slope, elevation, stylization and roof height (Fig. 5).

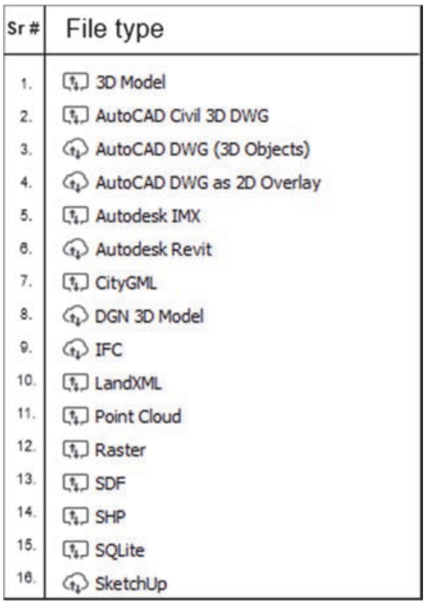


Name	Source Type	Status
Buildings		
double story	3D Model	Importe
saudi pak	3D Model	Importe
50ft pipe	3D Model	Importe
MECH BROWN CORR	3D Model	Importe
MECH DEPT FYPa	3D Model	Importe
bore hole	3D Model	Importe
buildingmults	Vector	Importe
buildings	Vector	Importe
centaurus	3D Model	Importe
centaurus infra	3D Model	Importe
djuice building	3D Model	Importe
double story house	3D Model	Importe
double story house	3D Model	Importe
faisal masjid	3D Model	Importe
hbl	3D Model	Importe

Data Source Details

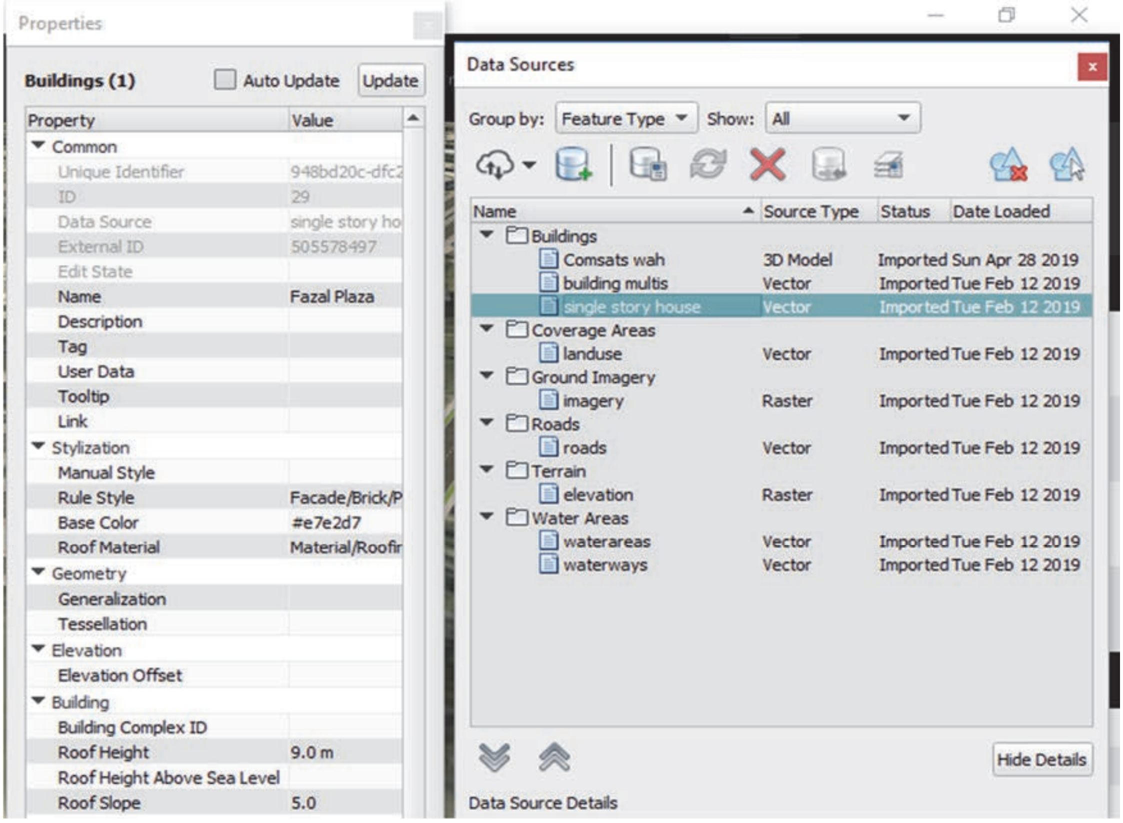
Name: bore hole
Description: <Empty>
Source type: 3D Model
Connection string: F:/hassaan/FYP/test exp/bore hole.3ds
Coordinate system: XY-M (Arbitrary X-Y Coordinates (Meters))
Date loaded: Tue Apr 9 2019

Fig. 3. Imported 3D structures



Sr #	File type
1.	3D Model
2.	AutoCAD Civil 3D DWG
3.	AutoCAD DWG (3D Objects)
4.	AutoCAD DWG as 2D Overlay
5.	Autodesk IMX
6.	Autodesk Revit
7.	CityGML
8.	DGN 3D Model
9.	IFC
10.	LandXML
11.	Point Cloud
12.	Raster
13.	SDF
14.	SHP
15.	SQLite
16.	SketchUp

Fig. 4. InfraWorks data compatibility options



Buildings (1)

Property	Value
Common	
Unique Identifier	948bd20c-dfc2
ID	29
Data Source	single story ho
External ID	505578497
Edit State	
Name	Fazal Plaza
Description	
Tag	
User Data	
Tooltip	
Link	
Stylization	
Manual Style	
Rule Style	Facade/Brick/P
Base Color	#e7e2d7
Roof Material	Material/Roofi
Geometry	
Generalization	
Tessellation	
Elevation	
Elevation Offset	
Building	
Building Complex ID	
Roof Height	9.0 m
Roof Height Above Sea Level	
Roof Slope	5.0

Name	Source Type	Status	Date Loaded
Buildings			
Comsats wah	3D Model	Imported	Sun Apr 28 2019
building multis	Vector	Imported	Tue Feb 12 2019
single story house	Vector	Imported	Tue Feb 12 2019
Coverage Areas			
landuse	Vector	Imported	Tue Feb 12 2019
Ground Imagery			
imagery	Raster	Imported	Tue Feb 12 2019
Roads			
roads	Vector	Imported	Tue Feb 12 2019
Terrain			
elevation	Raster	Imported	Tue Feb 12 2019
Water Areas			
waterareas	Vector	Imported	Tue Feb 12 2019
waterways	Vector	Imported	Tue Feb 12 2019

Fig. 5. Model properties in InfraWorks

Each model imported acts as an individual structure and changing the height would simply stretch the model in y-axis, so it's better to assign the desired slope to the structure during modelling stage. On the other hand changing the roof slope only modifies the top most structure of the model and modifies its slope as entered.

4. Results and discussion

The above section explains the concept of BIM that how it works in planning phase. InfraWorks in collaboration with AutoCAD gives the conceptual design of the structures which can be used for the ground water recharge. In the development of the BIM design for the potential recharge, multiple stages were implemented i.e., Preliminary Design, Virtual Design, Parametric Design, Pipeline Design, Simulated Installation and Material Table Statistics. For the development of groundwater recharge, multiple major structures were developed and studied. These structures included house rooftop rainwater harvesting (Fig. 6), small dams (Fig. 11), gravel paths (Fig. 12) and porous roads (Fig. 13). These structures are important because in any town they directly face the surface runoff water. As discussed in the methodology, collaborative designs of these structures were studied, and potential designs were identified based on literature review.

After identifying the collaborative designs of multiple recharge structures, all these structures were designed virtually in AutoCAD for the three-dimensional visualization (Fig. 7). This helps to visualize and understand the designs in a better way. All the proposed structures were virtually developed by taking simplest form of conceptual examples. Since the floor is a foundation in the customary water supply and seepage system, any minor change in the structure framework will influence various illustrations. One of the best utilizations of BIM innovation is that if any information changes, different information will be consequently refreshed, and the framework control is advantageous.

Once the virtual design has been established, next step was to investigate the feasibility of that design and give attributes to that design. All the information sheets, plans, illustrations, and other details were incorporated in the attributes of the structures in BIM. These attributes like surface area of the respective structures was used in the recharge volume estimation. Once all the structures were designed and virtually created and tested, pipelines were drawn. It is very important procedure for better planning of the recharge structure development because these pipes take rain or surface runoff water and transfer to the subsurface. For rooftop rain water harvesting, simplest pipe structure was tested (Fig. 7) as runoff rate does not make a huge difference in the groundwater recharge process, hence the structure which was most economical and simplest was chosen. Once the pipe structures were evaluated then these pipes and recharge structures were simulated together which means the entire system was now connected and can be tested. It helps to visualize that how the entire system would look like and how it will work. Now since the system was ready to be studied for the material table statistics, the building cost and material cost coold be estimated simultaneously by setting a unit cost for each building component. By setting the cost unit price, the cost of entire setup could be studied as well. Since above mentioned structures are virtual hence sample of these structures were considered for the statistical calculations of the potential recharge which will take place in these specific structures. For that matter below mentioned parameters were established for each potential recharge structure.

Fig. 6. Collaborated design of the rooftop structure

Fig. 7. Virtual design of the rooftop structure

4.1. House/building pipe

The vertical pipe which was simulated has length of 30ft (9.144m) and an outer diameter of 4 inches (101.6mm). The T-sections used for these pipes contain length of 1ft (0.305m) or 12 inches, with outer diameter of 4 inches (101.6mm) and inner diameter of 3.5 inches (88.9mm). Furthermore, the elbow used in the current study has outer diameter of 4.57 inches (116.08mm) and inner diameter of 3.5 inches (88.9mm) (Fig 8, Fig 9, Fig 10). These values have been taken for calculations because these are commonly used for external piping structures and are suitable and economical (Table 1).

4.2. Small dams

Artificial reservoirs can be used to store runoff water successfully. Small dams are constructed for intercepting and impounding the surface water runoff. Various types of dams exist for this purpose but in this study, the focus is on small earth dams for the collection of surface water runoff. The location of the dam should be such that the soil should be pervious, and a natural slope is available so that cost of labor can be reduced. The ground of the dam should be permeable so that the stored water can easily infiltrate to the subsurface and geologically the area should be stable because dams increases rate of seismicity due to overburden pressure of the water. In this study, a small dam was virtually designed having a length of 30m, width 20m and a depth of 3m. The side slopes were taken as 2:3. The area and storage capacity of the reservoir were calculated as 600 m^2 and 1800 m^3 (Fig 11).

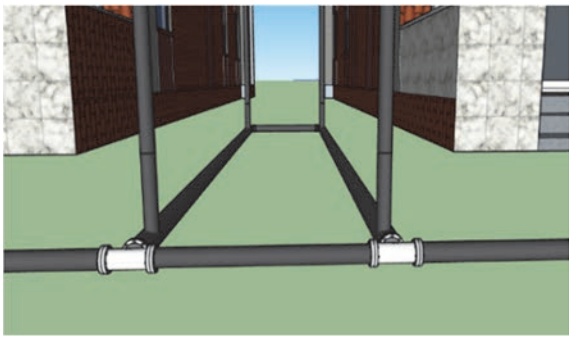


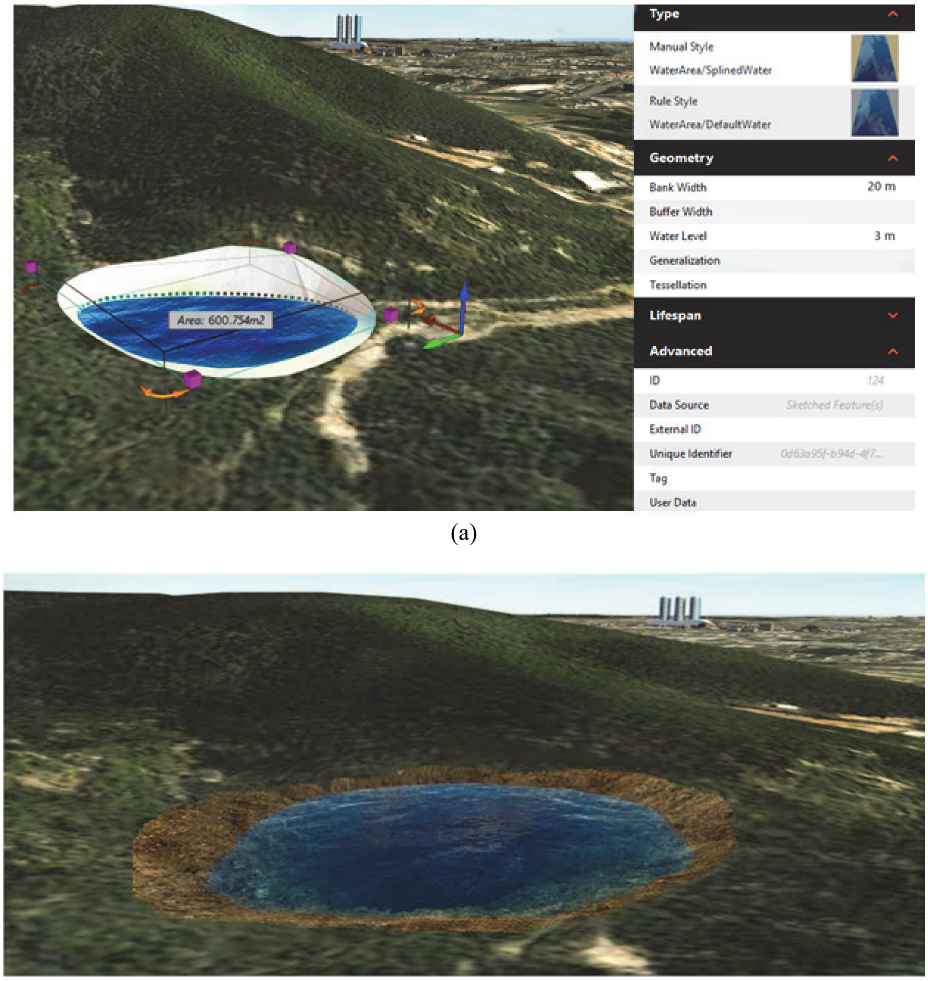
Fig. 8. Pipeline design for water flow

Fig. 9. Fully simulated rooftop model

Fig. 10. Virtual design of pipeline structure for groundwater recharge

Table 1. Rooftop pipe specification

Pipe Component	***Length***	***Material***	***Outer Diameter***	***Inner diameter***
Pipe	30ft/9.144m	PVC	4 inch/101.6mm	3.5 inch/88.9mm
T section	1ft/0.305m	PVC	4 inch/101.6mm	3.5 inch/88.9mm
Elbow	0.7ft/0.213m	PVC	4.57 inch/116.1mm	3.5 inch/88.9mm
Underground Pipe	50ft/15.24m	Galvanized iron	5.3 inch/134.6 mm	3.5 inch/88.9mm



Type
Manual Style WaterArea/SplinedWater
Rule Style WaterArea/DefaultWater
Geometry
Bank Width 20 m
Buffer Width
Water Level 3 m
Generalization
Tessellation
Lifespan
Advanced
ID 124
Data Source Sketched Feature(s)
External ID
Unique Identifier 0d63a95f-b94d-4f7...
Tag
User Data

Fig. 11. BIM based small dam: (a) represents the parametric design; b) represents the virtual design

4.3. Gravel footpaths

The gravel footpath simulated had 40% to 70% stone, well-graded 1/4 inch (6.35mm) to 2.5 inch (63.5mm) diameter; 30% sand and 10% +/- fines (Fig. 12). It resists abrasion, shed water and is capable of being compacted. Porous aggregate was poorly-graded from 3/8 inch (9.53mm) to 3/4 inch (19.05mm) diameter; with 25% to 40% porosity. It passes the heaviest rainfall without any difficulty. Such porous aggregate is often called open-graded base course (OBGC) when used under pavements (Fig. 12). The gravel footpath consists of the following components

Filter-pack

A filter pack containing coarse sand or fine gravel (2-6 mm diameter) was placed between the borehole wall and screen filter packs; it is used to settle-out fine-grained particles that may otherwise enter the pipe leading to the ground water table.

Lateral pipes

A series of pipes were laid along the length of the footpath for collecting the rainwater that passes through the gravels. These lateral pipes converge to a vertical pipe which then deposits all the rainwater into the ground.

Underground pipe

A vertical galvanized iron pipe was used to deposit the rain water into the ground. The length of this pipe was taken as the depth of the groundwater table which was 60ft (18.3m) for the area of its implementation.

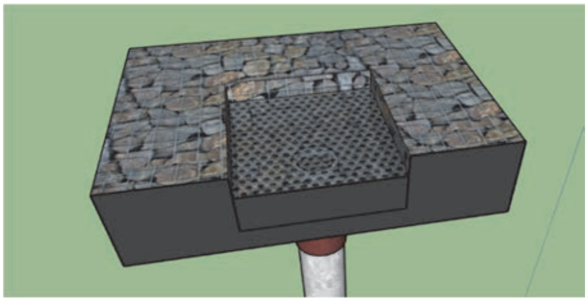


Fig. 12. BIM based gravel footpath and borehole

4.4. Porous road

In this study a 3km long road was selected with a ROW (right of way) of 60ft (18.3m) and a clearance width of 25ft (7.62m). The cross section of the road consisted of the following layers and components starting from top to bottom: 1) 3 inch (76.2mm) depth compacted porous asphalt cement, 2) 16 inch (406.4mm) depth compacted reservoir course, 3) 6 inch (152.4mm) depth porous cement concrete parking, 4) 12x12 inch (304.8x304.8 mm) Portland cement curb, 5) 16 inch (406.4mm) depth amended soil, 6) 4 inch (101.6mm) depth porous cement concrete, 7) 16 inch ((406.4mm) depth compacted reservoir course, 8) 2:1 side slopes with 1ft (304.8mm) height, and 9) a geotextile was laid at the end for separation from the soil bed (Fig. 13, Fig. 14).

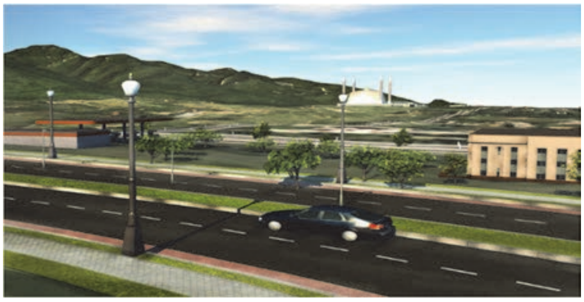


Fig. 13. BIM based porous road

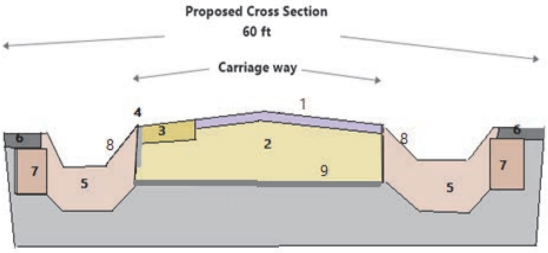


Fig. 14. Cross section of proposed porous road

Once the parameters were defined, all structures were given same amount of rainfall water availability which is 100mm while recharge factor was different for each case depending on the capability of that structure to absorb the water and seep it down to groundwater for recharge (Table 2). Patra and Gautam (2011) derived the coefficient of runoff as given in Table 3. For example, since gravel footpaths have lower surface area and water movement is normally very fast on it hence almost 80% of the water is lost and only 20% of water can be filtrated. On the other hand, house roof tops, porous roads or small dams have potential to filtrate more than 50% of the runoff water and can contribute to groundwater recharge massively.

Gould and Nissen-Petersen (1999) gave the following formula for potential rainwater storage (Eq. 1):

$$S = R * A * C_r \qquad (1)$$

Here in this equation (Eq. 1), S is potential rainwater storage, R is the amount of rainfall, A is the surface area of specific type and C_r is the coefficient of runoff. So, to calculate the potential recharge in liters, surface area of the structures was multiplied with the recharge factor and water availability in mm (Table 2). All the values were taken as hypothetical and were used for model building. For house rooftop if surface area is of 100m^2, water availability is 100mm and recharge factor is 0.8, then potential recharge would be 8000 liters.

For porous roads if surface area is of 5000m^2, water availability is 100mm and recharge factor is 0.6, then potential recharge would be 300000 liters. Similarly, for small dams if surface area is of 5000m^2, water availability is 100mm and recharge factor is 0.8, then potential recharge would be 40000 liters. While for gravel footpaths, if surface area is of 100m^2, water availability is 100mm and recharge factor is 0.2, then potential recharge would be 2000 liters. This basic calculation clears the idea that enough amount of water can be stored, and groundwater can be recharged.

Hence, it can be declared that BIM is a useful technique to design and develop three-dimensional model which contributes in the recharge of groundwater (Azhar, 2011; Ding et al., 2014). Also, BIM can estimate the cost to build those structures and can verify the structural implications as well which is not included in current study. Further, generic calculations confirm that these structures can be useful in groundwater recharging.

Table 2. Statistical calculation of potential recharge

Sr. No.	***Recharge Structure***	***Surface Area (m^2)***	***Water Availability (mm)***	***Recharge Factor***	***Potential Recharge (liters)***
1	House Rooftop	100	100	0.8	8000
2	Porous Roads	5000	100	0.6	300000
3	Smalls Dams	5000	100	0.8	400000
4	Gravel footpaths	100	100	0.2	2000

Table 3. Runoff coefficient of different catchment

Sr. No.	*Types of Catchment Runoff Coefficient*	*Types of Catchment Runoff Coefficient*
1	House Rooftop	0.75 – 0.95
2	Paved area/Porous Roads	0.50 – 0.85
3	Bare ground/Gravel footpath	0.10 – 0.20
4	Small Dams	0.8 - 1

It is important to know that all these calculations were done on generic hypothetical values and basic purpose of this research was to build a model in BIM and identify the potential of different structures for groundwater recharge. Local parameters i.e., geological setting, rainfall or any other real data can be incorporated in this model to identify the on ground recharge potential as per local setting.

5. Conclusions

This study gives an inside detailed overview of the utility of the BIM technology which can contribute in the groundwater recharge studies. Since fresh water availability is a major problem in current world hence it is very important that serious actions must be taken to prevent this natural resource. Therefore, all the latest technologies must be considered to maximize the efficiency of these efforts. BIM is one of such examples which can be helpful in this regard.

This research mainly focuses on explaining the BIM application for identifying the potential groundwater recharge structures. Multiple structures were developed and investigated which may contribute to groundwater recharge. These structures are important because in any town of the world these basic core structures are developed and these structures directly face the surface runoff water. In the end, a statistical relationship was used to identify each structure potential to contribute in the recharging of groundwater.

The study confirms that all the proposed structures contribute to recharge and can be very cost-effective development at a local stage. All these structures which are developed and proposed are highly recommended. Although the results of the current study provide great platform for the artificially groundwater recharge structures, on ground datasets and experiments are highly recommended for the future work for the better results. Further, the current study will be helpful in understanding the utilization of BIM technology for the groundwater recharge studies.

References

Abanda F., Byers L., (2016), An investigation of the impact of building orientation on energy consumption in a domestic building using emerging BIM (Building Information Modelling), *Energy*, **97**, 517-527.

Ahmad Z., Thaheem M.J., Maqsoom A., (2018), Building information modeling as a risk transformer: An evolutionary insight into the project uncertainty, *Automation in Construction*, **92**, 103-119.

Azhar S., (2011), Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry, *Leadership and Management in Engineering*, **11**, 241-252.

Azhar S., Khalfan M., Maqsood T., (2012), Building information modelling (BIM): now and beyond, *Construction Economics and Building*, **12**, 15-28.

Baier K., Schmitz K., Azzam R., Strohschön R., (2014), Management tools for sustainable ground water protection in mega urban areas–small scale land use and ground water vulnerability analyses in Guangzhou, China, *International Journal of Environmental Research*, **8**, 249-262.

Barlish K., Sullivan K., (2012), How to measure the benefits of BIM-A case study approach, *Automation in Construction*, **24**, 149-159.

Bernstein H.M., Jones S.A., Gudgel J.E., (2015), The business value of BIM in China, Dodge Data and Analytics Report, Bedford, MA, On line at: https://damassets.autodesk.net/content/dam/autodesk/www/solutions/building-information-modeling/bim-value/EN_Business_Value_of_BIM_In_China_SMR_(2015)FINALf.pdf.

Bonenberg W., Wei X., (2015), Green BIM in sustainable infrastructure, *Procedia Manufacturing*, **3**, 1654-1659.

McGraw Hill Construction, (2009), The business value of BIM: Getting building information modeling to the bottom line, *Smart Market Report*, 1-35, On line at: https://bimforum.org/wp-content/uploads/presentations/philly-october-2009/Smartmarket.pdf.

Custodio E., del Carmen Cabrera M., Poncela R., Puga L.O., Skupien E., del Villar A., (2016), Groundwater intensive exploitation and mining in Gran Canaria and Tenerife, Canary Islands, Spain: Hydrogeological, environmental, economic and social aspects, *Science of the Total Environment*, **557**, 425-437.

Ding L., Zhou Y., Akinci B., (2014), Building Information Modeling (BIM) application framework: The process of expanding from 3D to computable nD, *Automation in Construction*, **46**, 82-93.

Evans R.S., Dillon P., (2018), *Linking Groundwater and Surface Water: Conjunctive Water Management*, In: *Advances in Groundwater Governance*, Villholth K.G., Lopez-Gunn E., Van Der Gun J., Conti K., Garrido A., (Eds.), CRC Press/Balkema, Lisse, The Netherlands, .

Evans W.R., Evans R.S., Holland G.F., (2012), Thematic paper 2: conjunctive use and management of groundwater and surface water within existing irrigation commands-the need for a new focus on an old paradigm. IAH contribution to GEF-FAO Groundwater Governance Thematic Paper 2, 50, On line at: www.groundwatergovernance.org/ resources/thematic-papers/en/.

Gale I.N., (2005), Strategies for managed aquifer recharge in semi-arid areas. UNESCO-IHP Publ, On line at: https://recharge.iah.org/files/2017/01/Gale-Strategies-for-MAR-in-semiarid-areas.pdf.

Ghaffour N., Missimer T.M., Amy G.L., (2013), Combined desalination, water reuse, and aquifer storage and recovery to meet water supply demands in the GCC/MENA region, *Desalination and Water Treatment*, **51**, 38-43.

Gould J., Nissen-Petersen E., (1999), *Rainwater Catchment Systems for Domestic Supply: Intermediate Technology*, Intermediate Technology Publications, London.

IAH-MAR, (2018), International Association of Hydrogeologists - Commission on Managing Aquifer Recharge, On line at: https://recharge.iah.org/.

Kim H., Anderson K., Lee S., Hildreth J., (2013), Generating construction schedules through automatic data extraction using open BIM (building information modeling) technology, *Automation in Construction*, **35**, 285-295.

Konikow L.F., Leake S.A., (2014), Depletion and capture: revisiting "the source of water derived from wells", *Groundwater*, **52**, 100-111.

Ku K., Taiebat M., (2011), BIM experiences and expectations: the constructors perspective, *International Journal of Construction Education and Research*, **7**, 175-197.

Langar S., Pearce A., (2014), *State of Adoption for Building Information Modeling (BIM) in the Southeastern United States*, 50th ASC Annual Int. Conf. Proc., 1-7.

Langar S., Pearce A.R., (2016), Implementation trends for rainwater-harvesting technologies and strategies and their relationship with building information modeling, *Journal of Architectural Engineering*, **23**, https://doi.org/10.1061/(ASCE)AE.1943-5568.0000228

Lee S.I., Bae J. S., Cho Y.S., (2012), Efficiency analysis of Set-based Design with structural building information modeling (S-BIM) on high-rise building structures, *Automation in Construction*, **23**, 20-32.

Lu Y., Wu Z., Chang R., Li Y., (2017), Building Information Modeling (BIM) for green buildings: A critical review and future directions, *Automation in Construction*, **83**, 134-148.

Luthra A., (2010), Implementation of building information modeling in architectural firms in India, Purdue University, West Lafayette, On line at: https://pdfs.semanticscholar.org/39aa/0f5424b2c7e7fbac8196da22f012f5bd9153.pdf.

Patra A.K., Gautam S., (2011), A pilot scheme for rooftop rainwater harvesting at Centre of Mining Environment, Dhanbad, *International Journal of Environmental Sciences*, **1**, 1542-1548.

Rimal B., Zhang L., Stork N., Sloan S., Rijal S., (2018), Urban expansion occurred at the expense of agricultural lands in the Tarai Region of Nepal from 1989 to 2016, *Sustainability*, **10**, 1341-1360.

Rumsey C.A., Miller M.P., Susong D.D., Tillman F.D., Anning D.W., (2015), Regional scale estimates of baseflow and factors influencing baseflow in the Upper Colorado River Basin, *Journal of Hydrology: Regional Studies*, **4**, 91-107.

Siddiqui M.Z., Pearce A.R., Ku K., Langar S., Ahn Y.H., Jacocks K., (2009), *Green BIM Approaches to Architectural Design for Increased Sustainability*, Proc. of the Int. Conf. on Construction Engineering and Project Management, ICCEM-ICCPM, 73-75.

Strohschön R., Wiethoff K., Baier K., Lu L., Bercht A., Wehrhahn R., Azzam R., (2013), Land use and water quality in Guangzhou, China: A survey of ecological and social vulnerability in four urban units of the rapidly developing megacity, *International Journal of Environmental Research*, **7**, 343-358.

Teleman D., Wilderer P.A., Teodosiu C., Kötzle T., (2005), Enhanced primary treatment of municipal wastewater by ion exchange and membrane process, *Environmental Engineering and Management Journal*, **4**, 67-75.

Volk R., Stengel J., Schultmann F., (2014), Building Information Modeling (BIM) for existing buildings-Literature review and future needs, *Automation in Construction*, **38**, 109-127.

Wakode H.B., Baier K., Jha R., Azzam R., (2018), Impact of urbanization on groundwater recharge and urban water balance for the city of Hyderabad, India, *International Soil and Water Conservation Research*, **6**, 51-62.