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EVALUATION OF THE IMPACT OF PUMPED GROUNDWATER ON THE ENVIRONMENT AND THE SOCIO ECONOMIC BENEFITS THEREOF

Armand J. Beukes[1], Jeffrey Mahachi[2] and German K. Nkhonjera[3]
[1]*Student, University of Johannesburg, School of Civil Engineering and Built Environment, Department of Civil Engineering Technology*, 55 Beit Street, Doornfontein, Johannesburg 2028, *South Africa.*
Email: jmahachi@uj.ac.za
[2]*Senior Lecturer, University of Johannesburg, School of Civil Engineering and Built Environment, Department of Civil Engineering Technology*, 55 Beit Street, Doornfontein, Johannesburg 2028, *South Africa.*
Email: jmahachi@uj.ac.za
[3]*Lecturer, University of Johannesburg, School of Civil Engineering and Built Environment, Department of Civil Engineering Technology*, 55 Beit Street, Doornfontein, Johannesburg 2028, *South Africa.*
Email: germann@uj.ac.za

Abstract-With South Africa being one of the most water-scarce countries in the world, the limited water resources available must be well preserved and consciously utilized. Thepurpose of the research was to quantify the daily amount of groundwater pumpedout of the University's basement area, determining the impact that it has when discharged into the surrounding environment as well as the socio-economic benefits it holds for the community and theUniversity. By analyzing data recorded from installed meters, it was determined that there was an average of 192.89m^3 of groundwater extracted daily from March 2016 to February 2019. It was established that a total of 55.8% of this water was not utilised by the University and was discharged into the municipal stormwater system which was essentially wasted. Further investigations found that the installed meters did not account for all of the water flowing out of the basement area into the stormwater drain and that the amounts are greater than anticipated.The groundwater's point of discharge from the basement area was identified and it was discovered that due to the long term discharge of water at this point, a crack has formed in the pavement adjacent to the road surface. Remedial action is required in this area to prevent further deterioration of the road surface which may become a safety hazard for motorists. It was also determined that this groundwater possesses the potential to save the University expenditure on municipal water expenses and these savings can be utilised to improve the conditions on campus for the students. This groundwater also holds vast amounts of socio-economic potential to improve the lives of many poor individuals in the surrounding community.

***Keywords*:** Pumped groundwater, Socio-Economic benefits, Environmental impact, Stormwater system.

1. Introduction

Water that is found below the earth's surface is referred to as groundwater. Groundwater is contained within aquifers, a geological formation consisting of permeable material that is capable of storing water. Aquifers can be naturally recharged by rain, snowmelt or from water that leaks through the bottom of lakes and rivers [1].

Groundwater is becoming a more viable source of usable water throughout the country because there is little evaporation taking place that minimizes the quantity of available water, it is better protected from possible pollution [2] and dams do not need to be constructed to hold the water as it is already held naturally by aquifers.

An applicable example that can be used to illustrate the importance and the significance of groundwater in South Africa is that of the drought experienced in Cape Town in 2018. A strategy called “Day-Zero” was to be implemented on the 12 of April 2018 [3]. This endeavour consisted of shuttingthe main water supply to the entire city off, which involved residents collecting limited quantities of water at collection points [4] throughout the city. This meant that residents that had access to groundwater were self-sufficient and did not need to participate in the practice.

The water shortage epidemic experienced in Cape Town may not be unique for that city alone as it can happen anywhere in other geographic parts of South Africa including the province of Gauteng. Therefore, the need for an alternative water source such as groundwater becomes increasingly significant.

Groundwater in Gauteng is relatively abundant in certain areas and relatively shallow (between 5 & 15m from the surface) [5].This therefore implies that the groundwater is fairly easy to access and thus becomes a viable solution for water supply to the region.

At the University of Johannesburg's Doornfontein campus in the Qoboza Klaaste (Q/K) building's basement, there are notable amounts of reasonably shallow groundwater seeping out [6]. Some of this water is then accumulated into storage tanks and distributed as a source of water for fire hydrants and for the use of filling ablution facilities around the campus itself. However, there are still substantially large amounts of that water being discharged into the municipal stormwater systems which could be utilised more effectively elsewhere if not needed on the campus itself.

As mentioned earlier, due to the groundwater table being shallow and groundwater being reasonably abundant in the Johannesburg area [5], the concern is that the constant pumping of this groundwater from the University of Johannesburg's Doornfontein site, might negatively impact the stormwater system and the environment it is being discharged into. This water may also hold great socio-economic benefits for the surrounding community.

Problem Statement

With the growing demand for water and the impact that urbanisation and population growth has on water supply and demand, finding new and sustainable sources of water is imperative. Therefore, identifying groundwater as a sustainable source of water is of the utmost importance but, it will however come with its own set of challenges.

The concern of drawing shallow, abundant groundwater on a permanent basis from the sumps on campus and discharging it into the municipal stormwater system is that it might impact the surrounding stormwater systems and the environment in a negative way.

The challenge that faces the Q/K building is not unique as several surrounding buildings in the Doornfontein region that have deep basements, experience the same groundwater problems [7]. If one quantifies the water that the Q/K building is pumping out daily and take that as an average to create a baseline quantity for the surrounding buildings, a substantial amount of water being discharged into municipal stormwater systems will be reached.

This water might have a significant impact on the environment it is being discharged into which might even pose the potential of flooding or erosion.

Another aspect of the available groundwater that must be investigated is whether it is being properly and responsibly utilised or whether it is being misused. An example that can be used to demonstrate the significance of this statement is that the Vaal dam (which supplies water to the Gauteng province) experiences severe droughts from time to time, as it did in November of 2016 where the dam reached levels of 25% of its capacity [8]. This was before assistance was granted from Sterkfontein dam to relieve the drought stricken Vaal dam to adequate levels. The severe droughts coupled with changing weather patterns due to climate change, disintegrating infrastructure and lack of maintenance of the infrastructure in Johannesburg holds great reasons for concern regarding the surety that water demands in the future will be met.

The fact that the University is discharging reasonably large amounts of fair quality groundwater (tested groundwater samples suggested that the quality of the groundwater compared well with groundwater typically found in the West Rand group [7]) down the municipal stormwater system is therefore a reason for concern, as one of the means that this available groundwater can be better utilised, is for artificial recharge purposes. If this practice was to be correctly implemented and the groundwater discharged into the proper channels, this water can contribute to the Johannesburg water supply network to the Vaal Dam.

2. Study Area

The study area is in the University of Johannesburg Doornfontein Campus (DFC) (Figure 1). The campus is located in the Doornfontein area), within the Central Business District (CBD) of Johannesburg in South Africa. However, at DFC, the study area is the groundwater in the basement of the Qoboza and Klaaste (Q/K) Building (formerly known as the Perskor Building). This is at the corner of Beit and Height Street with the coordinates (26.1949° S, 28.0552° E).This building is situated about 1.3 km west of the Ellis Park rugby stadium. Hydrologically, the Doornfontein campus is situated in the Jukskei River Catchment of the upper Crocodile River sub-catchment. The Jukskei River drains towards the north and together with its tributaries forms part of the Crocodile (west) and Marico water management area. The Doornfontein campus is immediately north of the sub-continental surface water divide between the Vaal River basin to the south and the Limpopo River basin to the north [7].

Fig. 1:Image found on Google Earth (23/12/20), showing the Doornfontein Campus and the Q/K building

3. Methodology and Data

3.1. Data

The data that was required to determine the quantities of water that was being pumped as well as the quantities of water utilised by the University on a daily basis was determined from meter readings which were installed in the basement of the Q/K building. These readings were required for all the different phases of the groundwater present as well asfor the main municipal water inlet which supplies potable water to the University.These readings included groundwater extracted by the University for the use of filling the ablution facilities, water extracted for the use of fire hydrants around campus as well as groundwater that was discharged into the municipal stormwater system.

Water quantities that was utilised from municipal suppliers needed to be collected for this study to determine the amount of expenditure that the University would possibly be able to save if they were to utilise the available groundwater more effectively.

The location of the pumped groundwater discharge point needed to be located and identified in order to determine whether the constant flow of groundwater on that specific point had any negative effects on the environment. Furthermore, site visits, investigations and discussions with experts in the field had to be conducted in order to draw informed conclusions.

Required data also included statistics that were related to population growth. The data gave an indication of the increasing rate of water that would be needed to satisfy the amount of water consumed by the population. This also contributed to the economic part of this research as infrastructure will need to be upgraded in order to cope with the rise in water demand. An example that can be used to demonstrate the impact that population growth has on the infrastructure is anincident that occurred in the Johannesburg area in 2019. Water supply to some suburbs were shut off in the Ekurhuleni area for 54 hours from the 26/06/2019 to 28/06/2019 in order to install larger water supply conduits to the area. This caused major up rises by residents due to the fact that they didn’t have any water for more than two days.

Groundwater discharge and municipal water supply data was collected from the DFC maintenance department.

Previous situation assessments and impact studies done by external contractors also contributed to data used in this paper.

Discussions with staffmembers at Johannesburg Water brought about the alternative water source suggestion, which is a contributing factor to better utilisation of the groundwater at the University.

Several site inspections and meetings with the DFC maintenance department were conducted to collect data with regards to the location of the discharge point of the groundwater system. This data was then used to determine whether this point is positioned in an area where it can possibly cause erosion or flooding.

Further discussions with personnel at engineering firmsassisted in drawing conclusions with regards to the potential for flooding or erosion taking place at this point.

3.2. Data Processing

Meter Readings were taken andconverted to a quantity per unit timein (m^3/d) for each section. The readings measured the total amount of water that contributed to each section of the reclamation system. This included readings for water that flowed into the tank for fire hydrant supply, for the flushing of ablution facilities and discharge into the municipal stormwater system. The converted readings were used to create values for basic costing exercise as to how much revenue the University could save if they were to use the available groundwater to become self-sufficient. It was also used to determine the amount of water discharged into the surrounding environment.

With the data collected from the site inspections, discussions took place with engineers at consulting firms to discuss the impact that the constant flow of groundwater has on the point of discharge. Discussions also took place to find remedial actions to prevent further erosion from taking place on the road surface.

Contact was made with a senior economics lecturer at the University of Johannesburg who assisted by communicating information that would provide direction to address the objective with regards to the socio-economic aspect of the groundwater. Data obtained from literature and various other sources were studied and results drawn from this.

4. Results and Discussions

4.1. Quantities of Groundwater Extracted and Utilised by the University of Johannesburg

From visiting the site at the University of Johannesburg's Doornfontein Campus, the following information was gathered with regards to the quantities of groundwater extracted (Table 1) as well as the quantities from the municipal water supply (Table 2).

The first point that must be made is that there are indeed notable amounts of groundwater being extracted on a daily basis at the Doornfontein Campus with the following quantities recorded.

Table 1: Groundwater Readings

GROUNDWATER	
READINGS OBSERVED	
TOTAL AMOUNT OF GROUNDWATER USED FOR ABLUTION FACILITIES (m^3)	5 548
TOTAL AMOUNT OF GROUNDWATER USED FOR FIRE HYDRANTS (m^3)	87 416
TOTAL AMOUNT OF WATER DISCHARGED INTO MUNICIPAL STORMWATER SYSTEMS (m^3)	117 672
TOTAL AMOUNT OF GROUNDWATER EXTRACTED SINCE METERS WERE INSTALLED (m^3)	**210 636**
DAILY QUANTITIES CALCULATED	
DAILY AMOUNT OF WATER UTILISED FOR THE USE OF FILLING ABLUTION FACILITIES (m^3/d)	5,08
DAILY AMOUNT OF WATER UTILISED FOR THE USE OF FIRE HYDRANTS (m^3/d)	80,05
DAILY AMOUNT OF WATER DISCHARGED INTO MUNICIPAL STORM WATER SYSTEMS (m^3/d)	107,76
TOTAL AMOUNT OF GROUNDWATER EXTRACTED DAILY (m^3/d)	**192,89**

The meters in the basement area were installed on the 01-Mar-2016. The readings with regards to the groundwater quantities were recorded on the 26-Feb-2019 and the readings for the domestic water quantities on the 14-May-2019.

Table 2: Domestic Water Readings

DOMESTIC WATER	
READINGS OBSERVED	
TOTAL AMOUNT OF MUNICIPAL WATER UTILISED SINCE METERS WERE INSTALLED (m^3)	12339
DAILY QUANTITY CALCULATED	
TOTAL AMOUNT OF MUNICIPAL WATER USED DAILY (m^3/d)	10,6

4.2. Quantities of Groundwater Discharged Into the Stormwater System and Potential Uses Thereof

As can be determined from the recorded quantities, a total of 55.8% of the extracted groundwater was discharged into the municipal stormwater system daily. This water was essentially wasted, and can be better utilised in other aspects as mentioned below.

Through site investigations, it was found that the amount of stormwater reflected on the meter readings were not one hundred percent accurate. The meter reading only indicates the flow out of the two 45m³ tanks overflow and drain pipes but, does not take into account the overflow or the drain pipes coming out of the 90m³ and 150m³ tanks. Upon visiting the site on the 25th of May 2019, it was discovered that all the tanks were filled to capacity. The pump station on the right of the second 45m³ tank, pumps groundwater through a filter bank and into the 150m³ tank. On this particular day it was established that this station pumped water into the 150m³ tank every 90 seconds for periods of 45 seconds. As mentioned above, the tank was filled to capacity which means that the water pumped into this tank would have exited the tank through the overflow as the drain pipe's valve was closed. The amount of water that flowed through the overflow pipe and into the main drain pipe is unknown because the flow meter is on the left of where this pipe connects to the main drain pipe; hence this flow will not reflect on the flow meter. This implies that the meter reading taken on the discharge into the stormwater system is false and in reality the discharge might be far greater than initially anticipated.

4.3. Effects that the Water has at the Point of Discharge

Through numerous site visits, it was established that the groundwater discharge point is onto a kerb through a 2 inch pipe on the corner of Currey and Nindstreet. This means that the chance for erosion is minimal but not completely impossible. Through site investigations it was also established that due to the pavement being subjected to constant pressure of water being pumped onto it at a rate of 5.83 l/s (or 504 m^3/d) for a period of three years, a crack has formed in the lined pavement and with time it will develop further.

On further inspection, the actual driving surface is adjacent to the kerb and should no action be taken to limit the spreading of this crack, it is likely that it will spread to the driving surface and cause potholes to form. This may in turn cause a possible driving hazard for motorists and may lead to financial implications as the roadway would need to be repaired and damage claims may be made by motorists. Therefore, maintenance will play a vital role in preventing erosion from taking place on the kerb and the road itself to ensure that no further erosion takes place at this point.

There are also some negative impacts that the water flowing down the roadway have on the roadway itself that cannot be discarded. This includes the fact that not all the water flowing out of the discharge pipe down Nind Street always enters the stormwater system. There is regularly a steady stream of water flowing down Nindstreet(due to rubble preventing water from entering the stormwater drain) that ends up in Siemert road and occasionally causes pools of water to form in this road. These pools of water often affect the traffic by causing the roadway to become slick and causes the road surface to wear out more rapidly. This in turn, leads to potholes forming in some areas which increases driving difficulty and can affect motorists and their vehicles.

Further to the erosion taking place at the point of discharge, there is another point of concern in this system. This is at the point of entry where the groundwater enters the stormwater drain.On several site inspections, rubble was observed in the stormwater drain and will have to be regularly cleaned to ensure that the system functions at optimal efficiency otherwise blockages are more likely to occur.

4.4. Socio-Economic and Environmental Benefits of the DFC Groundwater

The groundwater present at the University is a valuable resource with some of the following benefits. It forms a reservoir of clean water which is typically recharged by rainfall. It can be used as a reliable source of water during dry periods when surface water might be unstable. It is a relatively safe means of water supply which provides large quantities of water which generally needs minimal treatment. The groundwater can generally be used at the point where it is extracted and therefore minimal infrastructure is required to convey it. The groundwater can also act as a valuable source of recharge for surface water bodies in form of artificial recharge, for example the Vaal Dam. This groundwater can also act as a resource for urban agriculture in the study area by acting as a source of irrigation for hydroponic farming.

The value of the groundwater at DFC was also very important. To determine the value of this groundwater in economic terms, the following factors need to be taken into account:

The economic value of groundwater is very dependent on its quality, quantity and its uses. There is no fixed rate of how the value of groundwater is determined, but there are many contributing factors such as the timing of when it is available and the duration over which it is available. This means that, the more permanent the water is and the more readily available it is, the higher its value will be. If the groundwater is instantly available, it will hold greater value than groundwater that will be available in the near future. From historical data, it is known that the water at the University of Johannesburg is permanently and immediately available as it has been a continuous occurrence since the building was acquired in 2011. Therefore its economic value has increased.

Another aspect that influences the economic value of a resource is the availability and cost of substitutes. This means that if there is another source of water in close proximity to the Doornfontein Campus groundwater, (say a borehole) and it is cheaper to extract water from that source, the value of the groundwater at Doornfontein Campus will decrease. The more unique the resource is, the more value it will hold. There is currently municipal water supply available to the study area but in times of drought, this will decrease. Hence, the groundwater at the Doornfontein Campus will still hold value in these periods.

The value of a resource is defined as the amount of money someone is willing to pay to acquire it [9].

Another dynamic that was also found was that the availability of the groundwater in the Q/K building, would contribute to the property value of the building itself if it were ever to be sold. This is due to the fact that the purchaser of the building will have access to this resource that can be utilised in and around the building without having to rely on municipal water supply.

With the aforementioned information taken into account, the following observations were made with regards to the socio-economic value of the groundwater in the Q/K building's basement area..

There are several poor communities in the Johannesburg area who do not have access to clean drinking water. If the University can collaborate with an institution (i.e. Johannesburg Water) to treat the available groundwater (whose quality is of relatively good stature, but not drinkable at this point in time [7]) to a drinkable state, they can distribute this water to these communities or perhaps sell off the water to other water users and in so doing, generate an income.

The socio-economic value of the groundwater at the University of Johannesburg holds a lot of potential to improve the daily lives of many underprivileged people in the community. It can help to generate income for these individuals as well as for the University itself. To look at this statement from an economic point of view, the following can be considered.

By making this water available to individuals in the community, it can potentially help with employment creation which will in turn help to improve the individual and his/her dependants standard of living because he/she will now generate an income which he/she can use to support their family.

An example that can be used to demonstrate this statement is that an individual can utilise the water he receives from the University to start a vehicle cleaning business and in so doing generate an income to support his dependants.

Ablution facilities can also be established with complimentary water which will improve the overall hygienic state of the city of Johannesburg especially for the many homeless people surrounding the campus area.

The available groundwater can be distributed among the agricultural community which will increase the employment rate and also provide food for an ever growing population in the surrounding area. The increase in employment canals usually decreases poverty.

4.5. Potential Uses of the Available Water

Due to the fact that there are still noticeable amounts of groundwater being discharged into the municipal stormwater system, one must recognize that this is a precious resource and that it must be preserved. Further to the groundwater's current uses of filling ablution facilities and the fire hydrant system, the following are also possible uses for the water.

After meetings conducted with personnel at Johannesburg Water, it was brought to light that this authority is looking for alternative water sources that can be accessed in times of severe drought and water shortages. It is their intention to collect the water from different sources and then discharge it at a strategic location where members of the community can go and collect the water for their daily use. It will be worthwhile for the University to participate in this endeavour so that they contribute to the lives of so many poor people living in the city.

Other means of utilising the groundwater being discharged into the municipal stormwater system is to distribute it into open fields and in this way artificially recharge the groundwater table. This action may hold a lot of potential because, if it is discharged into the correct channels, it may reach the Vaal dam or Vaal river aquifer. This water will then contribute to the capacity of the water that is needed every day for the livelihood of people within the city of Johannesburg. This is a long term solution but, it will be worth the effort at the end.

One of the most desirable potential uses for the available groundwater is for the use of irrigation on the campus itself. This will yet again contribute to expenditure savings for the University as municipal water would not be required in this regard. It is a very plausible solution because it will be inexpensive to implement and the license for this usage has already been approved.

4.6. Environmental Benefits

If the groundwater at the University is more widely utilised, it will ensure that the domestic water supply to the University will decrease. If the domestic water supply decreases as a result of the University being more self-sufficient, it will mean that there will be more water available for users in need of it elsewhere. This will ensure that there will be more water available for other users and also less strain on the source itself. If the University can become self-sufficient from utilising the groundwater supply it will mean that on average, a total of 10 600 litres of water will remain in the system per day.

This will also mean that the water currently flowing down Nind Street and not entering the stormwater system will in essence disappear or at least decrease because it is now being utilised in the University's system. This then means that it would no longer affect the road environment further down in a negative manner.

There is suggested that while the University is not utilising the groundwater and it is still discharged into the road environment, that an energy dissipater be installed to minimise the effects of the continuous flow of water has on the point of discharge.

5. Conclusions

The accuracy of the readings observed for the groundwater section of the system can be challenged. This is due to site investigations revealing that the flow meter measuring the quantities of groundwater flowing into the municipal storm water system, is not recording the quantities of water flowing from the overflow and drain pipes of two storage tanks. It was observed that the tanks were filled to capacity but the automated pumps still pumped groundwater into the tanks every 90 seconds for 45 second periods. This water then had to exit the tanks through the overflow pipes as the drain pipe's valves were closed. This therefore implies that the amount of water flowing into the municipal storm water system may be greater than initially anticipated.

An important aspect that must be taken into account is the current population growth rate. With the growth rate currently sitting at 1.43% p/a [10], it can be assumed that in five years’ time, South Africa will need to be able to supply a staggering amount more water than is being currently supplied. With the population currently at an estimated 58 775 022 (2019 est.) people. An estimated 23.7% of the population resides in Gauteng. This means that a total of 13 929 680 people live in Gauteng alone and this also means that in one year's time, water will need to be supplied to an additional 199 194 people in Gauteng alone. This will greatly impact the cost of upgrading infrastructure in order to supply sufficient quantities of water to the population residing in Gauteng. The infrastructure alone is not the greatest concern but, the origin of the water that has to meet the growing population's demand is.

6. Recommendations

There are numerous ways of better utilising the available groundwater than discharging it down the stormwater system as is currently being done. The following will be a better resolution in terms of both the economic and environmental aspects.

It is recommended that the Universityshould utilise the groundwater more judiciously and implement it into daily use. The institution will be able to save a great amount of revenue by not utilising and paying for water obtained from the municipality. The savings on expenditure from this endeavour can then be used to improve the conditions on campus for the students.

It is also recommended that the University investigate the potential of utilising this groundwater for urban farming purposes. There is a very effective method of growing vegetables or plants in the form of hydroponics. This method allows plants to grow in a soilless, nutrient rich water based environment. Hydroponics does not use soil; instead the root system is supported using an inert medium such as perlite, Rockwool, clay pellets, peat moss, or vermiculite.

Growing with hydroponics comes with many advantages, the biggest of which is a greatly increased rate of growth in plants. With the proper setup, plants will mature up to 25% faster and produce up to 30% more than the same plants grown in soil, according to [11]. The hydroponics system uses less water than soil based plants because it is grown in an enclosed environment which reduces evaporation.

The start-up cost of such a system is rather small and one can generate a reasonable income in a short period of time. The system also does not need a large amount of ground space to be installed because you can construct it in the air. The University has the capacity to assist some of the community members to start up a business which will aid the many poor individuals living within the city. This will also contribute to the socio-economic benefits that this groundwater holds.

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