REPORT ON THE ESTIMATION OF RUNOFF FROM ROADS AND GROUND WATER RECHARGE THROUGH EARTH DAM CASE STUDY: KATANGI LOCATION, MACHAKOS COUNTY

SUBMITTED BY

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Declaration

This project report is my own original work and has not being submitted to any organization

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This project report has been submitted to Metameta Organization “Roads for Water”

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ABSTACT

Water is short in many places but roads are everywhere. When it rains it is often along the roads that most water runs as roads unknowingly either serves as a dike or a drain. By harvesting the water with these roads, water shortage can be overcomed and climate change addressed.

The development of roads nowadays often has negative impacts. Roads can cause floods and water logging along the way. Whereas the more concentrated runoff from drains and culverts can cause erosion and sedimentation. These negative impacts are often related with the practice in road engineering to evacuate water away from the roads as soon as possible rather than making use of water for beneficial purposes.

There is a high potential for the application of road water harvesting practices while taking the often limited available infrastructural budget, data availability and data quality into account. Road alignment, culvert locations and culvert discharge capacity are the most important parameters in the improvement of road design. Road construction in conjunction with drainage structures (culverts) when combined with water harvesting can benefit groundwater resources for poor rural communities namely for small scale irrigation animal watering and household activities. Such as nursery garden.

Earth dam are reservoirs for surface waters. When water collected from roads accumulate in the dam, over several years, losses are due to evaporation and infiltration. Over a long period of time, the infiltrated water may have micro impacts on the groundwater system. Therefore, earth dam being one of the technic used to harvest runoff from roads in urban areas, this research project will fill this gap by analyzing the impact of rainwater harvesting from roads to groundwater recharge through earth dam.

Data used in the analysis was both primary data and secondary data. Primary data was collected directly from the test well which included water level. Water level data was collected using a diver which was installed in the shallow well. Secondary data included water level from the borehole which was recorded and stored by water resources management in kitui sub-region. The data was coded, processed and analyzed by use of Microsoft Excel in accordance to the various objectives of the study.

The results shows that there is a positive impact of road runoff to groundwater recharge. This conclusion was based on the behavior of water level in the shallow test well that was dug. The water level fluctuations was very small despite the fact that data was taken during the dry season. From the desk stop study that was conducted during the study period, it was found out that two shallow wells which were dug in the same location that is katangi,had dried up during the dry period. The entire katangi generally had poor record of groundwater.

For comparison purposes, a borehole which is located fifteen kilometers away from the earth dam was monitored. The groundwater level fluctuation was compared with that of the shallow well.it was found out that during the dry season, the water level in the borehole was so low.

The research was unable to quantify the percentage of the road runoff contribution to ground water recharge thus it remains a research gap which should be addressed.

Contents

CHAPTER ONE

INTRODUCTION TO THE STUDY

1.1 introduction

Water is short in many places but roads are everywhere. When it rains it is often along the roads that most water runs as roads unknowingly either serves as a dike or a drain. By harvesting the water with these roads, water shortage can be overcome and climate change addressed.

The development of roads nowadays often has negative impacts. Roads can cause floods and water logging along the way. Whereas the more concentrated runoff from drains and culverts can cause erosion and sedimentation. These negative impacts are often related with the practice in road engineering to evacuate water away from the roads as soon as possible rather than making use of water for beneficial purposes.

This negative character however can be turned around and roads can be used as the instrument for water harvesting. This can generate substantial positive impact especially as water is becoming scarcer. With the investment in roads in many countries exceeding that of any other programme, there is large opportunity to improve the productive environment and increase the climate resilience of the population in the vicinity of the road

The potential to scale up the use of water with roadside is enormous, especially with ongoing investment on road building globally with every area having its own specific best solution.

At present, unfortunately, the construction of roads often leads to local flooding, gulley erosion, water logging dust and sedimentation. Yet this can be turned around and roads and water rather than being enemies, can be friends.

Beyond the scope of harvesting water on roads, there is also another competing argument, if done well, harvesting water with roads will reduce water damage and simply maintence.

Integrating roads and water development can contribute to floods protection, sand harvesting, nature protection and sand dune control and groundwater recharge.

1.2 problem statement

Improved rural road planning and design for dry lands should integrate the risk of road flooding and erosion and avoid or minimize road related problems for surrounding farming communities by optimizing the interception, concentration and deviation of runoff. Techniques must be applied to spread concentrated runoff in space and time and focus on infiltration measures (Nyssen et al, 2002; Steenbergen and Tuinhof, 2010).

There is a high potential for the application of road water harvesting practices while taking the often limited available infrastructural budget, data availability and data quality into account. Road alignment, culvert locations and culvert discharge capacity are the most important parameters in the improvement of road design. Road construction in conjunction with drainage structures (culverts) when combined with water harvesting can benefit groundwater resources for poor rural communities namely for small scale irrigation animal watering and household activities. Such as nursery garden.

Ground water development has played a key role in boosting agricultural production and thus reducing poverty in Asia (sha, 2010)

Several studies have been done on rainwater harvesting both in Kenya and outside kenya.in Kenya, a lot of studies are based in ukambani region where rain fed agriculture is not reliable. Of the studies done in Kenya, none has focused on earth dam as a reservoir for rainwater harvesting on roads for groundwater recharge.Earthdam are reservoirs for surface waters.whenwater collected from roads accumulate in the dam, over several years, losses are due to evaporation and filtration. Over a long period of time, the infiltrated water may have micro impacts on the groundwater system. Therefore, earth dam being one of the technic used to harvest runoff from roads in urban areas, this research project will fill this gap by analyzing the impact of rainwater harvesting from roads to groundwater recharge.

1.3: main objective

I. To estimate the amount of runoff to be generated from road catchment in Katangi area.

1.4 specific objectives

II. To compare the recharge under influence of road runoff versus without road runoff.
III. To assess the impact of rainwater harvesting to the ground water recharge

1.5: research question

I. How much runoff will be generated from roads and road catchments?
II. How is the ground water recharge under the influence of road harvesting different from recharge without road runoff harvesting?
III. How does water from roads contribute to the ground water recharge?

1.6: research justification

Road system currently causes alteration in local hydrology which results in erosion related problems. Farmer communities living along the road are affected and the road authority invests a substantial amount of their budget in road maintenance. There is high potential for improved rural road design including a further integration of the concept of road water harvesting into road system design.

Improved rural road design would reduce the current observed problems and enable an extra water source for agricultural purposes to promote local food security .Increased economic resilience and food security of these communities will be of high priority in national policy .These positive relation between infrastructure and development is best clarified by the fact that an improved rural road network enables an increased market integration of the previously isolated communities. Also it provides access to health center, education and contributes to welfare development and improve quality of livelihood. Roads being a good catchment for surface runoff, integration of road infrastructure and water system can be of economic use.

The findings of this study will contribute positively to groundwater systems. This is because the study aims to coordinate different sectors in natural resources management and road infrastructure development. If the different sectors in agriculture, forestry, water and roads sector can embrace the road-water relationship focusing on ground water replenishment, at a larger scale, water stress in the lower eastern part of Kenya will be reduced. Therefore, the findings of this research will enable more efforts to be directed to road water harvesting for ground water recharge. Since Machakos is a water scarce county this practice after a long period of time will lead to long term sustainability of ground water system thus increasing the water supply of the katangi area

CHAPTER TWO: LITERATURE REVIEW

In rural development, roads are built to improve people's mobility and enhance access to markets and schools and are credited with important social-economic changes.as a result; roads are important component of storm water runoff quality and quantity.

Majority of studies on roads for water have concentrated on effects of heavy metals such as lead, copper zinc and iron on surface runoff on roads.

Other studies shows that direct effect of road pollution are spatially limited to soil adjacent to roads in the areas of car splash usually influencing a strip narrower than 25m(Garcia millan,1994,Reinirken 1996).

However, other authors (ward e savage, 1994) confirm a significant increase of soil metal content up to 100m from the road (London m25)

Some studies show that detention extended and wet ponds can be used to treat highway runoff. Dry detention ponds store peak runoff for one to two hours and then are dry between storm events.

Some authors focus on a sand filter facility in treating runoff .in this technology, runoff is detained and then filtered through a layer of sand. Treated runoff is then collected by drainage pipes beneath the sand filter and discharged downstream.

With 7-10billion USD investment annually in roads in sub Saharan Africa alone and 70,000 kilometer of new road constructed a year, roads have major impact on water management and on the environment immediately surrounding them(kubbinga 2010)

Road development changes the surface and sub-surface hydrology, roads massively change runoff patterns and can collect water from their own surface and this is a phenomena that should be put into beneficial use (Garcia-Landarte et al.2014)

The support of NOW (Netherlands scientific council) under the program 'feeder road development for inclusive productive employment 'and the UPGRO (NERC) programe"optimizing Road Development for Groundwater Recharge and Retention.

other studies in Ethiopia recommends that when planning road development in a certain catchment it is important to look at options on how water from a road(drains,culverts,bridges,fords, road surface) could be harvested for economic benefit of the local communities, this concerns both paved and unpaved roads.

The impermeable structure and road foundation on tarmac roads can block subsurface flows altering the availability of shallow groundwater and drying up shallow wells on the lower end of the road and increasing water tables on the upper end of the road .groundwater drainage system and placement of cross-drains can help modify this phenomena (santinho Faisca et.al 2008).

Groundwater is the main source of water for domestic use in the area. Moreover, shallow groundwater is increasingly used for small scale irrigation in Ethiopia (woldearegay and van steenbergen, 2014)

The links between roads and development are multi-dimensionless. Mobility and access are obviously the prime functions of road infrastructure and it is normally assumed that roads reduce poverty associated with spatial isolation and promote economic productivity but also access to health and educational services(world bank, 1994; venables and limao 1999;Crawford et.al 2003;pomfret,2006; Bryce son et.al 2008; Ericson,2008)

Roads affect the hydrology, can cause erosion, and they change the immediate environment.in terms of where people benefit or suffer, the effects of roads are evenly distributed (Wilson 2004; demenge 2011) the impacts are particularly mixed at local level, those living along the roads do not necessarily benefit from the road(riverson et.al 1991;fishbein ,2001;mahapa and mashiri,2001).environment may suffer from the opening of new and unprotected area. Also local hydrology may be affected, an example is the severe gullying from road runoff (jungerius et.al, 2002)

According to study done by kubbinga(2012),road runoff harvesting can have several positive environmental impacts such as increased plant growth and diversity, increased soil biodiversity, increased soil moisture and stream flows and increased amount of soil nutrients and reduced soil erosion.

A study done by ICRAF Malesu(2006) indicates that gender issues needs special attention with respect to rain water harvesting system due to their direct impact on the lives of rural women. The systems release women from the burden of collecting water over long distances. Examples described by Ngigi(2003) shows his appreciation to rainwater harvesting system since women have become economically empowered since the time saved from fetching water was allocated to other activities such as acquiring skills in home economics and management, microfinance and leadership.

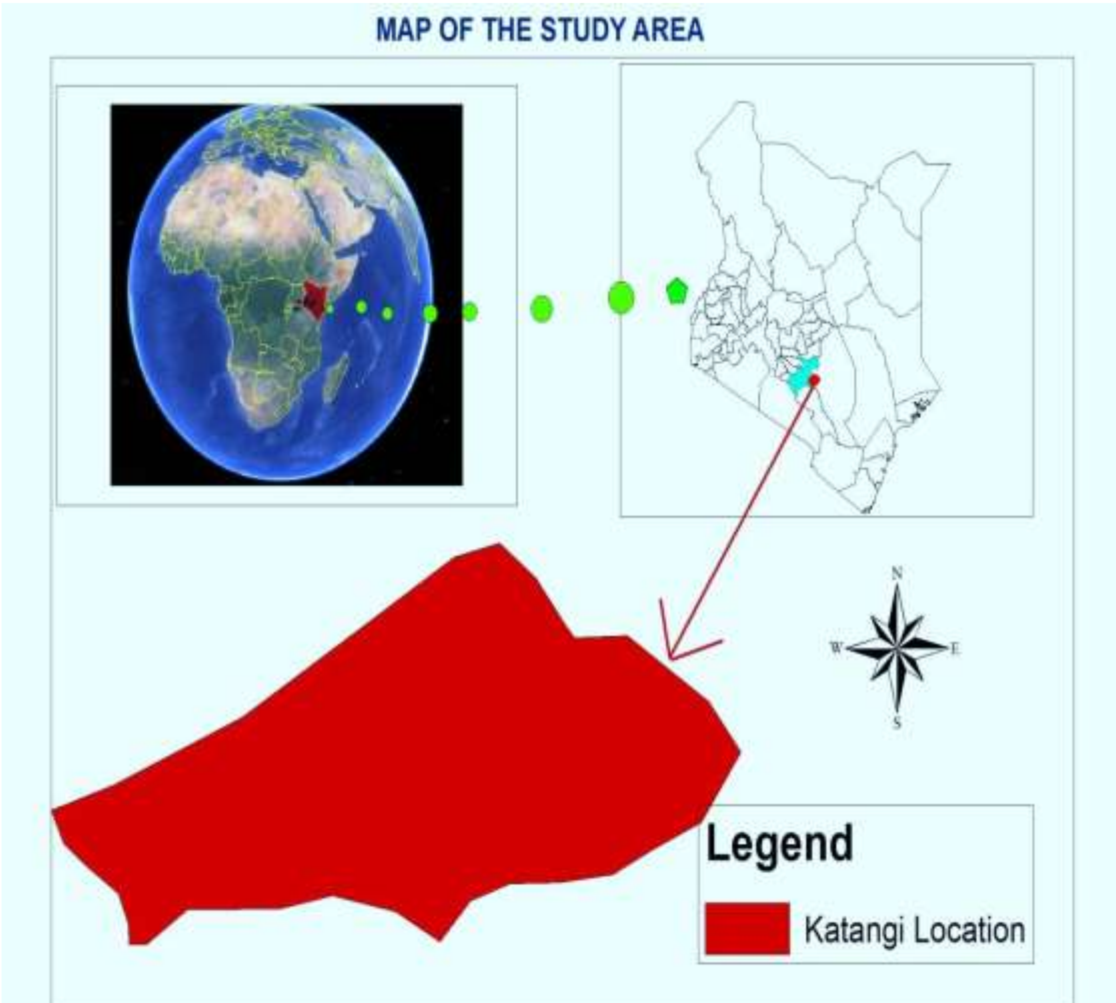
Impacts of road water harvesting technic on rural livelihood concerns: increase in agricultural productivity, and water availability, larger diversity of production-in terms of crop choices,agroforestry,improved environmental protection and conservation, new sources of income ,for instance, from sand harvesting(ngigi,2003;nissen-pertesen,2006;kubbinga,2012)

Nissen Petersen(2006) find out that most road construction works have no provision for the storage of runoff water generated from road drainage.moreover,most roads are built with little consideration for hydrology .many rural roads project do not require a formal E.I.A and consequently, little importance is given to environmental issues during planning, design or construction(Griffiths et.al..,2000)

According to the study done by Malesu(2006,),found out that it is important to be sensitive to the distributional differences of water harvesting between communities located in the vicinity of the road and communities further away. These inequalities can be the source of conflict and need to be addressed properly. New water harvesting system may intercept runoff at the upstream part of the catchment thus depriving downstream users of the water resource.

CHAPTER THREE

3.0 DESCRIPTION OF THE STUDY AREA



The study area proposed is the Katangi location in Machakos County.

Katangi is situated between longitude 36˚45̍E and 37˚45̍E and latitude 1˚31̍S and 0˚45̍S.

3.1 physiography and climate

Machakos county consists of hills and small plateaus, ranging between 700m and 2100m asl surrounded by a high plateau about 1700m asl in the west and 700m in the southeast.

The location is generally hot and dry with a bimodal rainfall distribution. The long rains are expected between March and May and the short rains between October and December.

The annual average rainfall ranges between 500m and 1300mm.there are significant spatial and temporal variations within the district and rainfall reliability is quite low.

The mean monthly temperature varies between 18˚c and 25˚c.july is the coldest month while October and March are the hottest.

The highland areas which receive higher rainfall are more suitable for Rain fed agriculture than lowland areas.

The majorities of people in the district are rural and derive their income from agriculture and livestock production activities.

According to the 1997-2001 district development plans, subsistence agriculture is the main source of income accounting for 29.5%of labor force.

3.2 The soils

The soils of Katangi area reflect the largely metamorphic parent material and the rainfall regimes that contribute to their formation.

In katangi the dominant soils are ultisols and ox sols which are highly erodible. The ultisols are susceptible to sealing which increase runoff and makes the clay soils hard to plough by the end of the dry seasons. A rough estimate of the agricultural quality of the regions soils indicate that less than 20% has well drained, deep red and brown clays of good fertility. More than 60% of the region has very erodible, shallow and sticky soils.

3.3 Vegetation

The dominant vegetation in this part of Kenya is dry bush with trees and in the higher areas, savanna with scattered trees. The hills were once forested but by the beginning of the colonial period most of the desirable agricultural land had been cleared leaving patches and corridors of forest along ranges, rivers, ravines and hilltops as well as

dry forest in large expanse of grazing land.

Characteristic vegetation at the higher altitude (above 1700m) includes remnant ever green forest and ever green thicket clumps in grassland.

The most widespread vegetation is the semi-arid deciduous thicket and bush land, particularly acacia.

3.4 The socio-economic activities

Subsistence agriculture is mostly practiced with maize and drought-resistant crops such as sorghum and millet being grown due to semi-arid state. Open air market concept with major market days where large amount of produce are traded. Fruits, vegetables and other food stuffs like maize and beans are sold in the market.

CHAPTER FOUR

4.0 METHODOLOGY

4.1: Research design

The study involved assessing and mapping of the existing culverts and earth dam holding runoff from roads. The main box culvert diverting runoff from the road catchment lies within latitude 1°24.553’S and longitude E 37°41.357’. The estimation of runoff to be generated from roads was executed by use of hydrological modeling formulas. However, for ground water monitoring entailed digging of test wells in an area with an earth dam and comparing with borehole data which is far away from the earth dam basing on the assumption that the water level in the borehole is not influenced by road runoff from the katangi road catchment. The test well was monitored for a period of two months. A diver was installed in the test well to enable ground water level monitoring.

4.2: Data collection and analysis

For the estimation of runoff generated from the road catchment, rainfall depth is required thus, the rainfall data for the area was obtained from the World Meteorological Database.

Furthermore, estimation of runoff from the stretch of the road was obtained by multiplying the length of the road by its width, by runoff coefficient of the tarmac road by the rainfall depth. This will give us the total runoff produced by that day. Total annual runoff volume generated has been obtained by multiplying the length by width by runoff coefficient by the annual estimated rainfall figure.

Field survey was done in order to familiarize with the study and local community. Field survey was aimed at understanding the problem under investigation.

A shallow well was dug in the vicinity of the earth dam. The depth was 13meters.The shallow well was dug to indicate whether runoff collected in the earth dam has any impact to the groundwater system. This was important for comparison analysis for groundwater recharge in areas with road water harvesting technics and without road water harvesting practices.

A diver was installed in the shallow well to record the water levels. The water level fluctuation was monitored for a period of three months. The data collected was used to plot the ground water hydrograph. For the comparison analysis, data from Nyumbani children borehole was collected from Water resources management. The borehole is approximately 15km away from the earth dam. It is located in an area where surface runoff from roads is not practiced.

For comparison analysis, this borehole was chosen because it is the only borehole which is monitored in the nearby area. Although the water discharged from the borehole is from the storage water reservoirs, running a correlation analysis will be somehow difficult since the water discharged in the shallow well is from the surface water. But then, since the water contained in aquifers is from the surface waters, the surface runoff collected from roads replenishes the ground water aquifers even though it in small percentage.

2.2.2: Equipment and Tools for Data Collection

- ✓ **Piezometers:** this are for measuring the ground water level of the drilled test wells
- ✓ **GPS Gadget:** for recording the Coordinates which will be used in the mapping using the GIS
- ✓ **Tape Measure:** for measuring the dimensions of the earth dams and the length and width of the roads (catchment area).
- ✓ **Probing Rod:** for determining the depth of the earth dam in order to calculate the volume (holding capacity).

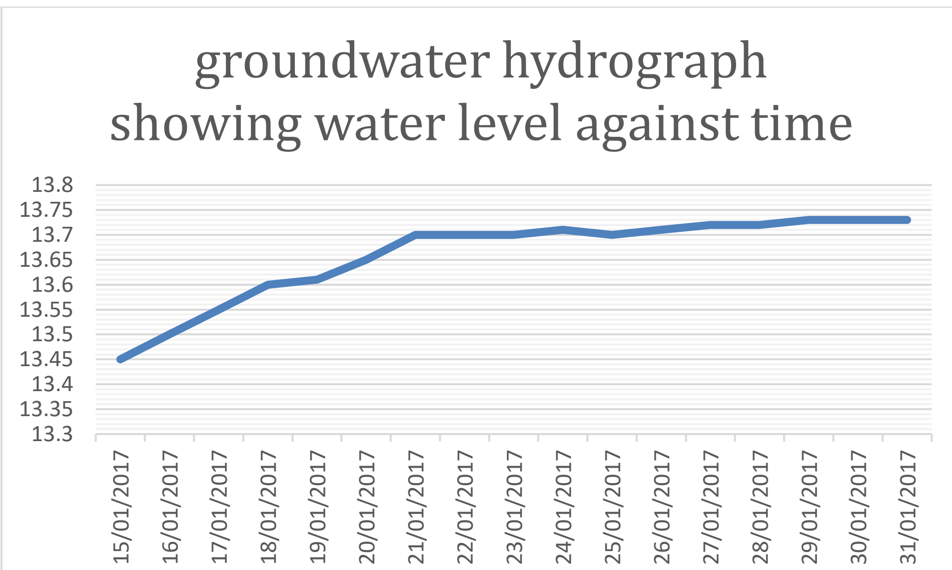
CHAPTER FIVE

5.0 RESULTS AND DISCUSSIONS

5.1 Introduction

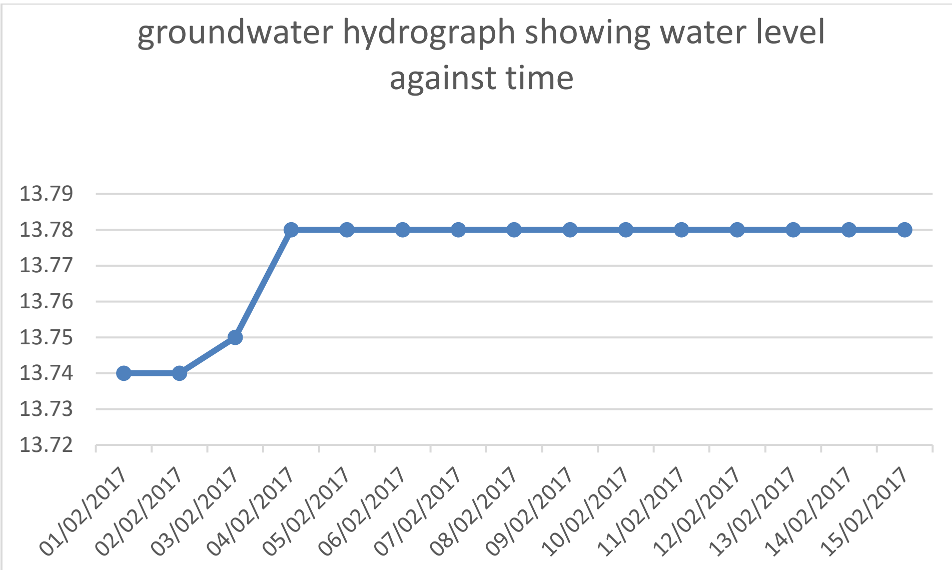
This chapter provides the results on the analyzed data from the excel spreadsheet and the analyzed scenarios from the frequency distribution models. Further a discussion that explains the results/findings of this study is provided enable in putting the study objectives into more understanding. This chapter represents the results obtained in charts, tables and graphs that represent the parameters and variables showing the respective correlation coefficients

5.2: The results of groundwater fluctuation in the well.

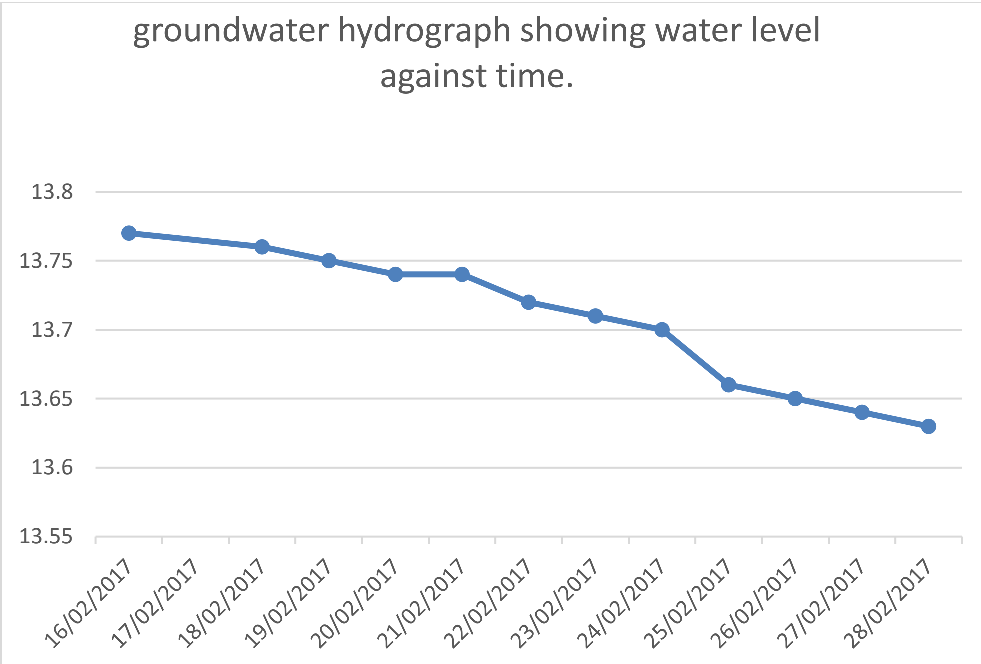


The trend line above indicates that groundwater fluctuation was very small. The first level was recorded to be 13,45m.after installation of the diver, six thousands liters of water was withdrawn from the shallow well by the community during morning hours. Thereafter, the shallow well was allowed to recharge again. Water level recorded the following morning was 13.5m. This shows an increase of 0.5m.on daily basis, water was withdrawn from the shallow well and from the trend line, the water level was increasing steadily.

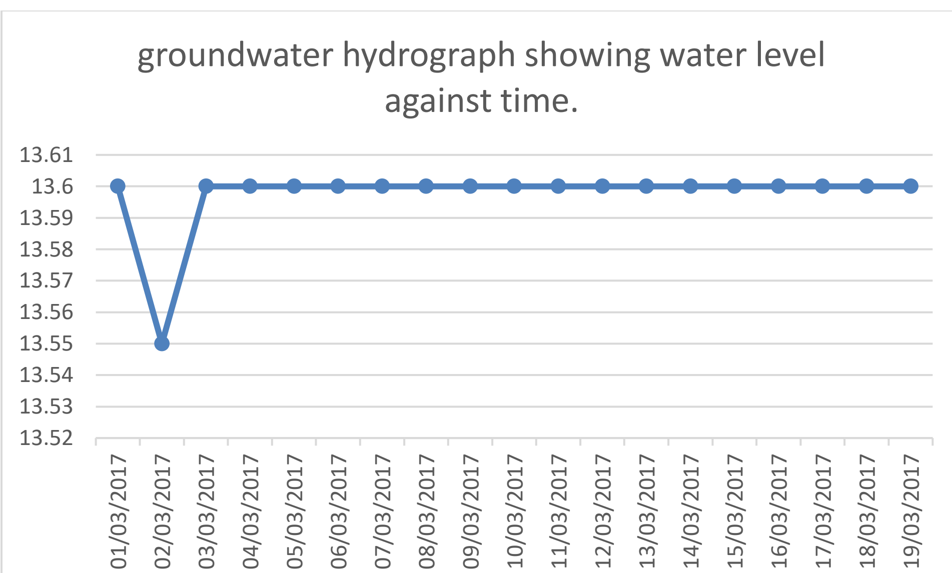
Putting in mind that January is a lean month, ground water fluctuation is expected to be very low due to low amount of precipitation received in the area. According to the report on the groundwater level fluctuation in the area, during the period of no rainfall in the area, the ground water level is always very low. During the baseline study that was conducted before undertaking this research study, two people who had dug their shallow wells had dried up immediately after two months. This is a good indicator of low recharge in the area.



For the second month, the groundwater level rose sharply from 13.74 to 13.78m.thereafter, the groundwater level maintained at 13.78m for ten days. During this time, water withdrawal from the well reduced from six hundred liters to four hundred liters.it was also during this time that water level in the dam reduced considerably to high rates of evaporation. But then, the water level was high compared to the level in February despite the fact that there was no rainfall received in the area.

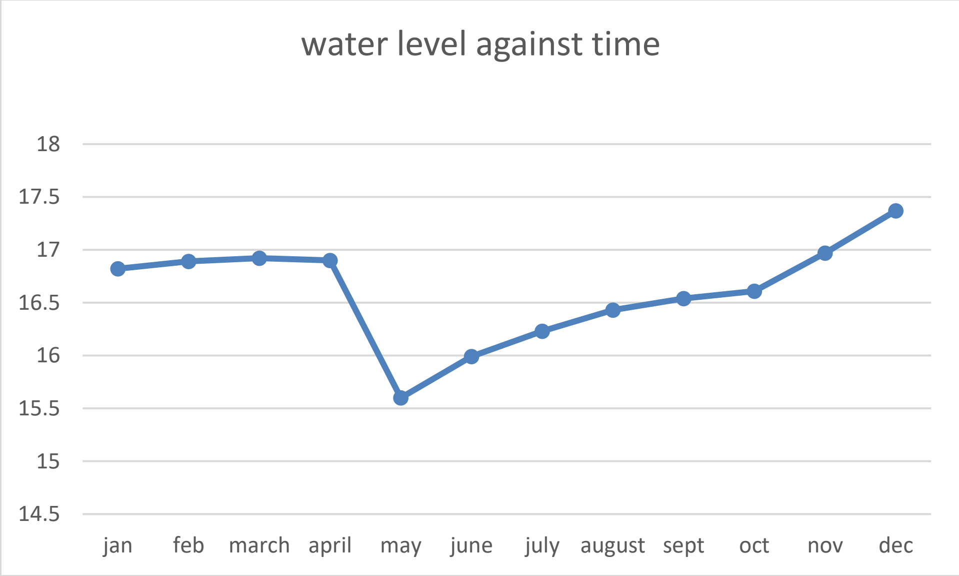


Towards the end of February, the groundwater level was dropping. There was a drop from 13.75m to 13.65. Also during this period, there was no water withdrawal from the shallow well. During this period, recharge was recorded the lowest. This phenomenon can be explained in the sense that there was so much evaporation from the soil thus very little water reached the groundwater aquifers.



This was the last period of monitoring. On first march, precipitation was received in the area. The rainfall was of low intensity and since there was no or less antecedent soil moisture, the amount of rainfall received in the areas had less impact to the subsurface soil layers.as the rains continued to be experienced in the area, the water level in the shallow well rose from 13.55m to 13.6. Also during this period, water was withdrawn from the shallow well daily until the end of the monitoring period. From the graph above, it is evident that there was constant groundwater level. This can be well explained by the persistent amount of rainfall that was occurring in that region. Precipitation is the main groundwater system replenishment; therefore we can conclude that the constant groundwater level was as a result of both direct rainfall and seepage from the earth dam.

5.3: Findings of groundwater fluctuation of the borehole whose recharge is not influenced by road runoff.



The trend line above shows the water level fluctuation in Nyumbani village borehole.it is evident from the graph that during the months of April and December recorded the highest water level in the borehole. This can be explained basing on many factors such as the effect of rainfall amount received in the region, surface water available, and demand of groundwater and over abstraction of groundwater.

According to www.worldweatheronline.com historic rainfall data record, the below table shows the average variability of rainfall depth received in kitui region in millimeters.

month	rainfall depth
January	38
February	39

march	144
April	232
May	47
June	6
July	2
August	7
September	9
October	87
November	330
December	127

From the above table, we can conclude that there is a high rainfall variability ranging from 330 millimeters to 2millimeters. The long periods of rain in kitui is experienced in the months of march to October with peak being in april.it is also evident in the above table. The region receives short rains between Octobers to December with peak rainfall amount occurring in November. This can also be seen from the above table.

Now the relationship between the amount of rainfall and groundwater recharge using the trend line above and the documented rainfall depth can be explained.

When the precipitated water is not able to completely infiltrate into the ground, the water is pounded and surface runoff occurs.accordily, the runoff provides a mass loading that adds to the ground surface. The loading leads to changes in pore pressure and in turn render variations in groundwater level. Conversely, evapo-transpiration causes a decrease in surface loading so that the groundwater level would fall. However because the effect of runoff and evapotranspiration on groundwater level variation is difficult to be specified for groundwater flows, the effect is lumped to the accumulated rainfall amount. According to Wu et al (2009) not only the accumulated rainfall amount but also the rainfall distribution can affect groundwater level.

It is evident that the water level fluctuation in the dam is influenced by the precipitation. During the periods of short and long rains, groundwater level in the borehole is the highest. Groundwater level is lowest during the dry month’s period. Also it is noted that the streams in this lower Tana catchment are seasonal, therefore during the periods of heavy rainfall, these streams get filled with water but after a short period of time, i.e. two weeks after precipitation, a large percentage of water infiltrates into the ground since the streambed is composed of sands which are highly permeable. Almost eighty percent of the infiltrated water is found just below the sand, therefore during the lean months, the communities living along the river usually scoop the sand out using tins or even sticks thus forming a shallow pool which water fills and becomes available to water vendors.it is a very small percentage that percolates to the aquifers from the rivers. Therefore, we can argue out that a large portion of water that is stored in the aquifers is from direct precipitation.

5.4: Estimation of runoff from katangi road

The volume of water running off from 8 kilometer along the katangi tarmac road from a rain shower of 30mm can be estimated as

Road area=8000m*20m

Road surface =tarmacked

Runoff coefficient=90%

Rainfall depth=30mm

Therefore, the estimated volume of water generated that day is;

(8000*20*90*30)/100

=1140m^3

Average annual rainfall in a season is about 300 mm

Total annual volume is

(8000*20*90*300)/100=**523,200m^3**

Assuming during the rainy months, 1140m^{3}volume of water is collected on that road, due to the gravity, this volume of water runs down, a quantity percentage is lost through seepage due to pervious surfaces on the shoulder edges of the road. Along katangi road, the several culverts aligned along the road assists in channeling the water collected to the water pan through a large box culvert. Assuming during the months of April it rained twenty days, with rainfall depth being constant(30mm),using the formula and calculation above, the 1140m^3 multiplied by 20 days we arrive at a figure of estimated monthly runoff collected during the months of April. According to the residents of the katangi area, the water pan does not dry up. This means water collected during the rainy season is usually in large volume. The water loss from the pan is either through evaporation or seepage to the ground. According to the kerra engineer in Machakos County, Eng. Muthembo, the pan was constructed in 1974 during which the katangi road was constructed. Since then, the pan usually is the main water supply to the people of katangi. They use that water for brick making, washing, and spate irrigation and construction activities.

5.5: Estimation of water collected in the earth dam

Length of the earth dam =660m

Width of the earth dam=495m

Depth=20m

Therefore, the total volume of water the pan can hold as per the time of study period, 6,534,000m^3 but then due to siltation, depth across the pan is not uniform, near the embankment of the pan, depth is less compared to depth at the Centre. This is due to siltation that is carried along with the runoff from roads. This can be seen by the locals who use the water in the pan for their various uses. Children as well as adults usually wade up to a few meters upstream of the pan to collect clean water. But then during the periods of heavy rainfall, the pan usually overspills, this eventually becomes difficult for people to collect water from it.again, during this period of time, the local usually practice rain water harvesting from roof catchment. Therefore, water demand reduces.

6.0: Conclusion and recommendations.

This chapter deals with conclusion from the results and recommendations on adaptation of road water harvesting.

6.1 Key findings

Earth dams can be used as a reservoir for groundwater storage. This is evident in the findings of this research paper. The katangi earth dam was purposely constructed to collect water from the road during construction of machakos-kitui road and since then it has never failed thus it has proved to be a good reservoir.

i. Road water harvesting has an impact on groundwater recharge but then, the research has not exactly quantified the magnitude of the impact since there was no use of groundwater software in analyzing the data.

ii. Lower eastern part of Kenya receives very little amount of rainfall therefore most of the boreholes and shallow wells have very little quantities of usable water. Therefore, majority of the shallow wells which were dug in the area dried up.

iii. Roads can serve as a good catchment for runoff collection. The runoff coefficient for tarmacked road is higher as compared to marram roads. Diverting the collected water to a pond or marram pits can be useful to the community around.in this case, the runoff collected from the katangi road is used by the local community for spate irrigation, domestic purposes and brick making.

iv. When water is collected from the roads and stored in reservoirs, there are many losses due to evaporation and seepage. The evaporation loss can be mitigated by covering the pond with geomembranes fabricated from durable plastic geotextiles. Seepage losses can be minimized by compacting the earth materials. Also one may sprinkle the bentonite on the entire water surface. These particles settle on the pond bottom and penetrate the soil pores as the water seeps through.

6.2 Conclusions of the study

This study found out that road runoff has an impact on groundwater system. This impact can be seen after a long period of time since groundwater recharge is majorly by direct precipitation. Quantifying the exact amount is the main knowledge gap which should be filled.

6.3: Recommendations of the study.

Road runoff collection is a good technique which should be incorporated in Kenya. Since Kenya is a water stress country, adopting rain water practices will reduce the water stress to certain scale. Although rooftop catchment is a common practice in Kenya, road runoff harvesting is not commonly practiced. Since water harvested from roads can be used for many uses, living conditions at household levels will improve due to generation of extra cash through spate irrigation, brick making.

There is large scope to optimize the design of road bodies .pans development for the extraction of construction material is one of the major activities in road construction.it is advisable that the size of the pan to be developed is identified during or even before the final design of the road is made. Based on this, the location of the culverts and even the road alignment could be designed in such a way that water from roads is channeled into the pan and they are shaped accordingly. Using earth dams for surface water as well as groundwater recharge is one of the best options in road design and construction.

Water harvesting from roads involves multi-stakeholders. For water harvesting from roads to be implemented effectively, there should be strong linkages and cooperation among the sectors through a more powerful body but with clear tasks and responsibilities for each stakeholder

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