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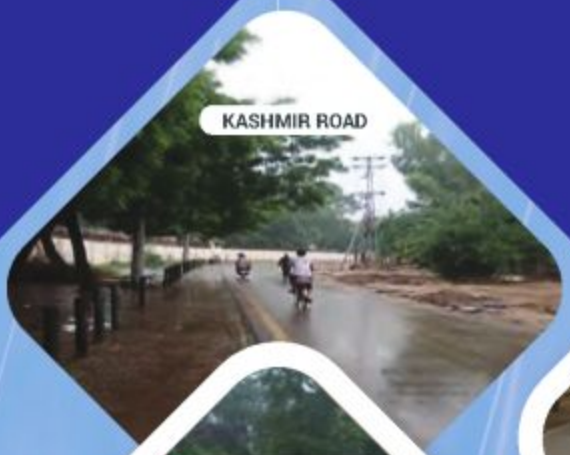
MANAGING URBAN FLOODING IN PUNJAB

A PIONEER STUDY ON RAINWATER STORAGE FACILITIES



HELP BUILD PMDFC HEALTHY CITIES

PUNJAB MUNICIPAL DEVELOPMENT FUND COMPA

Executive Summary

Punjab is the most populous and the 2nd most urbanized province of Pakistan. About 41 % of the population of the province which accounts to 51.97 million lives in urban centers. Most of the urban population is concentrated in the 5 urban centers of Lahore, Faisalabad, Multan, Gujranwala and Rawalpindi which accounts to 24.0 M approximately 46 percent of the urban population of Punjab. The remaining urban population of Punjab resides in 93 urban centers with a combined population of 27.97 M.

Punjab experiences highly seasonal rainfall, dominated by the monsoon season (July September) in which 60-80 percent of annual rainfall occurs.

Almost all urban centers in Punjab have experienced rapid urbanization. The rapid urbanization has altered the entire natural drainage pattern of the cities which existed prior to urbanization. Major changes are caused in the retention and infiltration capacity of the soil to serve as a natural means of storm water disposal which is lost with the construction of impervious roads, streets and houses causing the entire rainfall to turn into runoff on the city's streets and roads. The runoff accumulates at low points in the areas creating urban flooding.

The causes have been attributed to inadequacy of the drainage and a combined sewerage system with limited capacity to discharge rainwater.

The occurrence of urban flooding in Monsoon every year is not limited to larger cities like Lahore, Faisalabad, Multan, Rawalpindi and Multan but other cities with smaller population than major urban centers also experience similar situations.

Safe disposal of stormwater is one of the services delivery functions of WASAs and MCs managing water related urban services. In 2019 WASA Lahore introduced the novel idea of building a Storm Water Storage Tank in Bagh e Jinnah as a measure to eliminate inundation and ponding on Lawrence Road. The tank stores storm water that earlier caused flooding on the roads thereby keeping the roads free from inundation, traffic jams and risk to property. The intervention proved the success of Storm Water Storage Tank in eliminating urban flooding.

The success of Lawrence Road was followed by the construction of Stormwater Storage Tanks at several other locations in Lahore at: i) Kashmir Road ii) Sheranwala Gate iii) Nishter Park Sports Complex and iv) Tajpura to address urban flooding. WASA Lahore plans to build Storm Water Storage tanks at other locations to address urban flooding and eliminate sore points in Lahore.

The concept of 'Storm Water Storage Tanks' to manage urban flooding has gained traction and other WASAs and MCs are adopting it to manage urban flooding in their jurisdictions. WASA Faisalabad has built Stormwater Storage Tank on Dijkot Road.

Punjab Municipal Development Fund Company (PMDFC) is mandated to assist local governments / MCs in developing municipal infrastructure. PMDFC is building similar stormwater storage tanks in Burewala, Vehari, Khanewal and Wazirabad under a World Bank funded Punjab Cities Program (PCP). PMDFC plans to build 11 Stormwater Storage Tanks in different cities of Punjab to eliminate urban flooding.

The effectiveness of Stormwater Storage Tanks in the elimination of ponding has been assessed by observing the conditions prevailing in the area on rain events following the construction of the tanks in comparison to pre project conditions.

The analysis of site data comparing the ponding conditions before and after the construction of the Stormwater Tanks indicates the elimination of ponding in the area which was the main objective of building Stormwater Storage Tanks (Ref Tables 1-5 of the report). Besides, stakeholders' opinion was sought about the impact of the Stormwater Storage Tanks in eliminating urban flooding. The stakeholders are the people who have offices, shops and businesses near the ponding area or are regular passers-byes. The stakeholders gave a positive response and recognized that construction of stormwater storage tanks has relieved them from inundation of roads and traffic chaos that followed the rainfall events. Now they can reach their offices and shops without hassle of passing through the pond formed on the road on rainy days.

The combined sewerage system laid in the cities of Punjab has limited capacity to carry full stormwater flows, the provision of Stormwater Storage Tanks thus provides a good local solution for eliminating urban flooding. The reuse of stored water in the tank in non-potable applications like irrigation of parks, green belts is another benefit to reduce pressure on utilizing freshwater resources. Overall Stormwater Storage Tanks have contributed to improving the quality of life in the cities in Punjab by eliminating urban flooding.

Roof Top Rainwater Harvesting offers another option of managing stormwater at the household level by capturing rainwater from the roofs and diverting it to the recharge bores / wells. In this way rainwater is prevented from coming out of the houses to become surface runoff and cause urban flooding. Lahore Development Authority (LDA) has included rooftop rainwater harvesting in its Building Zoning Regulations, making it mandatory for all residential and public buildings.

Surface Rainwater Harvesting is currently implemented by WASAs in larger cities and PMDFC in 11 smaller cities by building stormwater storage tanks. It would be appropriate to include Roof Top Rainwater Harvesting in the Building Bylaws of MCs. The combination of Rooftop and Surface Rainwater harvesting has the potential to provide ultimate solution for the elimination of flooding in the urban centers of Punjab.

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1.0 Introduction

Punjab is the most populous and the 2nd most urbanized province of Pakistan. About 41 % of the population of the province which accounts to 51.97 million lives in urban centers. Most of the urban population is concentrated in the 5 urban centers of Lahore, Faisalabad, Multan, Gujranwala and Rawalpindi which accounts to 24.0 M approximately 46 percent of the urban population of Punjab. Lahore dominates among them with 25 percent of urban dwellers. The remaining urban population of Punjab resides in 93 urban centers with a combined population of 27.97 M.

The mandate of provision, operation, and maintenance of urban water supply, sewerage, and drainage services in major cities rests with WASAs. The management of water supply, sewerage and drainage services in other urban centers which constitute 54 percent of the urban population of Punjab rests with municipal authorities (MCs). It is only recently Government of Punjab has decided to create WASAs in 13 additional urban centers as a measure to improve water, sewerage and drainage services in the cities.

Beside WASAs and municipalities, Government of Punjab has initiated Punjab Cities Program (PCP) and Punjab Intermediate Cities Improvement Investment Program (PICCIP) assisted by World Bank and Asian Development Bank (ADB) for the improvement of water supply, sewerage and drainage services in the urban centers of Punjab.

Punjab Cities Program (PCP) is a world bank funded project being executed in 16 MCs of Punjab under the guidance of Punjab Municipal Development Funds Company (PMDFC). Under the Program several infrastructure projects for the improvement of water supply, sewerage, solid waste management, roads, streetlights and parks etc. have been implemented in the urban centers of Punjab including stormwater storage tanks for the prevention of urban flooding.

Punjab experiences highly seasonal rainfall, dominated by the monsoon season (JulySeptember). The rainfall varies greatly across regions, from the wetter north and northeast (e.g., Rawalpindi, Sialkot) to the drier southwest (e.g., Dera Ghazi Khan, Bahawalpur). The seasonal patterns followed are winter: Dec to Feb 10 -20 %, Pre monsoon: March to June (isolated events), Monsoon July to September 60-80 % of annual rainfall and Post Monsoon: October to November very little rainfall.

Almost all urban centers in Punjab have experienced rapid urbanization. The rapid urbanization has altered the entire natural drainage pattern of the cities which existed prior to urbanization. Major changes are caused in the retention and infiltration capacity of the soil to serve as a natural means of storm water disposal which is lost with the construction of impervious roads, streets and houses causing the entire rainfall to turn into runoff on the city's streets and roads. The runoff accumulates at low points in the areas creating ponding.

The causes have been attributed to inadequacy of the drainage and a combined sewerage system with limited capacity to discharge rainwater. The disposal of sewage in the drains meant to pass storm water further aggravates the situation by reducing their drainage capacity. The flooding prevails for several hours in the city until it recedes by dewatering the area using mobile pumps.

The occurrence of urban flooding scenes in Monsoon every year is not limited to larger cities like Lahore, Faisalabad, Multan, Rawalpindi and Multan but smaller cities also experience similar situations. Flood like situation occurs at the low lying areas making life difficult for the residents during heavy downpour.

Safe disposal of stormwater is one of the services delivery functions of WASAs and municipal authorities managing water related urban services. In 2019 WASA Lahore came up with the novel idea of building a Storm Water Storage Tank in Bagh e Jinnah as a measure to eliminate inundation and ponding on Lawrence Road. The tank stored storm water that earlier caused flooding on the roads thereby keeping the roads free from inundation, traffic jams and risk to property. Various independent studies proved the success of Storm Water Storage Tank in eliminating urban flooding.

The success of Lawrence Road was followed by the construction of Stormwater Storage Tanks at several other locations in Lahore at: i) Kashmir Road ii) Sheranwala Gate iii) Nishter Park Sports Complex and iv) Tajpura to address urban flooding. WASA Lahore plans to build Storm Water Storage tanks at 22 locations to address urban flooding and eliminate sore points in Lahore. Out of these, 4 have been built and 9 are under construction.

The concept of 'Storm Water Storage Tanks' to manage urban flooding has gained traction and other WASAs and municipalities are adopting it to manage urban flooding in their jurisdictions. WASA Faisalabad has built Storm Water Storage Tank on Dijkot Road which is a major ponding location in Faisalabad.

Punjab Municipal Development Fund Company (PMDFC) mandated to assist local governments / MCs in developing municipal infrastructure is building similar tanks in Burewala, Vehari and Kahnewal to eliminate urban flooding under a World Bank funded Punjab Cities Program (PCP). Another Storm Water Storage Tanks in Wazirabad is presently in the process of approval. PMDFC plans to build 11 Stormwater Storage Tanks in different cities of Punjab.

The objective of this assignment is to carry out study whether the 'Stom Water Storage Tanks' built in different cities of Punjab have achieved the objectives envisaged at the time of the approval of the projects. And to assess the extent of their contributions in mitigating urban flooding/ponding area, traffic jams and risk to the life and property of the people.

2.0 Methodology of Stormwater Storage Tanks Drainage Arrangement

Stormwater Storage Tank is strategically placed near the ponding area connected to a network of covered drains fitted with gratings to collect and store rainwater. The set of pumps provided in the tank releases water to thenearest drain for final disposal. The emptied tank then becomes ready to serve in the next spell of rain.

The tank is sized to temporarily store peak storm water from the catchment area until the rain has subsided and pressure on the sewerage / drainage network has reduced. The provision of stormwater storage tank depresses the formation of storm water flooding peaks, thereby eliminating urban flooding.

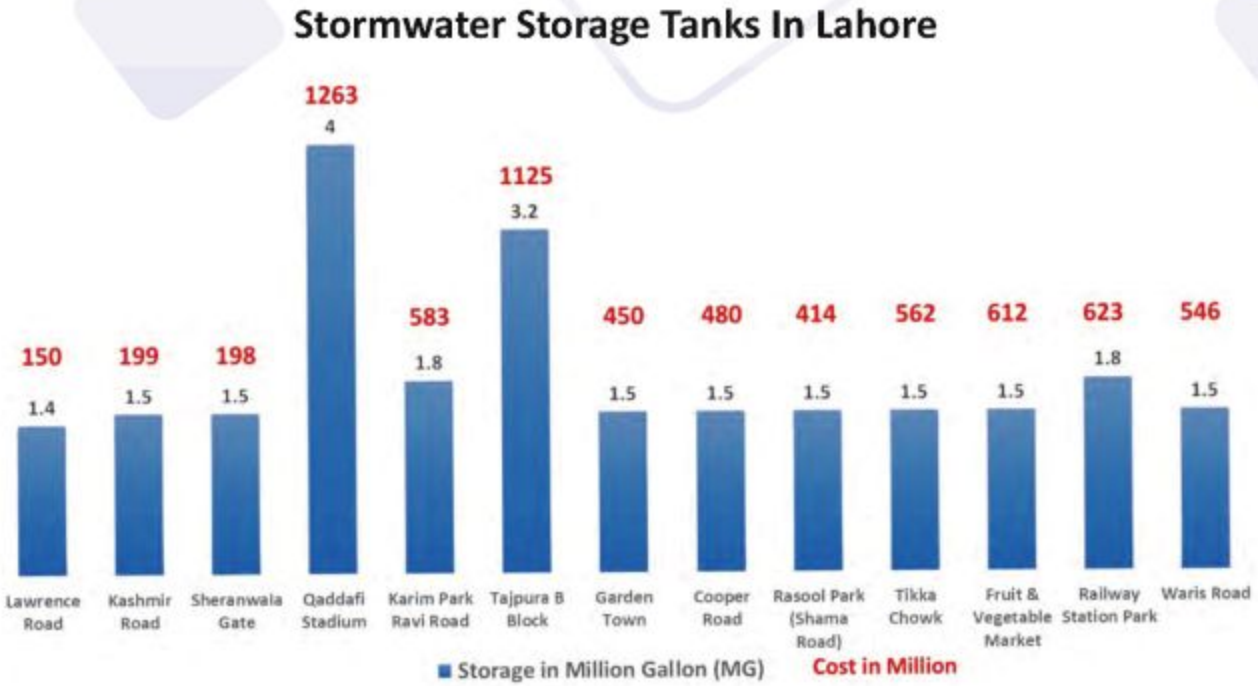
The entire system for storm water collection and disposal comprises of the following:

- Collection of Storm water through drains with Gully Gratings
- Collection of silt in the silt collector
- Coarse screen to remove floating material
- Storage Tank to store storm water
- Pumps and force main for pumping water to the nearest drain for final disposal
- Use of rainwater for horticultural purposes

3.0 Geographical Locations of the 'Stormwater Storage Tanks'

Among the 9 Stormwater Storage Tanks that form part of the study, 5 are already built and functional in Lahore and Faisalabad while the remaining 4 are under construction in Burewala, Vehari and Khanewal. The geographical location of the Stormwater Storage tanks is shown in Fig 1.

Fig 1: Location of Stormwater Storage Tanks in Punjab



4.0 Current Scenario of Sewerage and Drainage System in Urban Centers in Punjab

Punjab (Pakistan) is predominantly a flat alluvial plain, with only 17 - 20 percent of the area is hilly mainly in the northwestern and western parts of the province. Being flat land, a minimal natural slope is available for the wastewater to flow by gravity. Sewers and drains are designed with minimal gradient to maintain flow velocity and prevent stagnation. Despite providing minimal gradient, sewers and drains go deep requiring mechanical pumping stations to lift sewage and stormwater for final disposal in the water bodies.

The sewerage system provided in the urban centers of Punjab is combined, i.e the sewerage network is designed to carry the full sewage (dry weather flow) generated in the area and a part of the storm water. Because of the high rainfall intensities and duration of rainfalls which mainly occur in Monsoon (July to September), it is not possible to design sewers with full provision to carry rainwater and sewage being cost prohibitive. Therefore, a part of the storm water which normally ranges from 33 to 50 percent of the sewage (dry weather flow) is considered for the design of combined sewers. As a result, heavy rainfall quickly overwhelms combined systems because sewer pipes are designed to carry only a part of the stormwater.

Stormwater drains have been built to carry the rest of the stormwater, but the capacity of drains is kept limited to 2 years return period of rainfall to keep the cost within affordable limits. Dumping of solid waste in the drains is another issue which blocks the drains. The result is flooding of roads and streets when cloud burst occurs which has become a common phenomenon with the changing climate patterns. The situation becomes worse in low lying areas where runoff accumulates forming ponds creating issues of traffic jams and risk of damage to life and property of citizens. WASAs and MCs have identified critical inundation / ponding locations in their cities where they plan to build Stormwater Storage Tanks.

Alternative approaches such as 'Rooftop Rainwater Harvesting (RWH)' having the potential to manage rainwater at the household level has been realized by the regulatory bodies and included in their byelaws as mandatory but its practice has yet to gain wider acceptance. The construction of Stormwater Storage Tanks to manage urban flooding at depression points in the cities is gaining widespread adoption among WASAs and MCs. Smaller sized cities like Burewala, Khanewal, Vehari, Wazirabad and six other cities in Punjab have planned to benefit from the new approach of managing urban flooding by building Stormwater Storage Tanks under the Punjab Cities Program (PCP).

5.0 Stormwater Storage Tanks in various Urban Centers of Punjab

WASA Lahore has taken the lead in building Stormwater Storage Tanks in Lahore to address urban flooding issues in the city. WASA Lahore has identified 22 sore points in the city where ponding occurs in Monsoon disrupting traffic flow and normal life. Out of the 22 sore points 4 sore points have been rectified through the construction of Storm Water Storage Tanks at i) Lawrence Road ii) Kashmir Road iii) Sheranwala Gate iv) Nishter Park Sports Complex. WASA Faisalabad has built similar tank at Dijkot Road and PMDFC in Burewala, Vehari and Khanewal. PMDFC has plans to build 11 Stormwater Storage Tanks in different cities of Punjab.

5.1 Lawrence Road Lahore

The ponding occurred at Lawrence Road near Bagh-e-Jinnah, Lahore. The runoff from catchment area of 24.5 acres contributed towards the pondage spread over about 3 acres. The average depth at the deepest point in front of Lahore Zoo entry gate was about 18 inches forming a huge ponding during a rainfall event. It was a prac - tice to temporarily install dewatering sets to dispose of the Storm water. The clearance time of ponding area was about 2.5 to 3 hours which created havoc to the traffic and routine activities in the area.

The project has already been executed and comprises of a Storage Tank (120 x 80 x 17 Ft) built in the parking area of the Jinnah Garden with storm water sewer drains / sewer provided on the roads for the collection and conveyance of storm water towards the Storage Tank. Pumping Station has been built for evacuation of the stored water when stress on the adjoining drain (Birdwood Drain) has been reduced. Hydrant has been provided for the use of the stored water by Horticulture Authorities. The roof of Storage Tank has been utilized as Tennis Court. The tank has been functional since 2020. The scheme of stormwater storage tank at Lawrence Road is shown in Fig 2 .

Tennis Court on the Roof of the Stormwater Storage Tank on Lawrence Road, Lahore

Fig 2: Scheme of Stormwater Storage Tank on Lawrence Road, Lahore.

5.2 Kashmir Road Lahore

The Kashmir Road area was one of the worst aected areas during heavy rain. The topography was such that the storm water from the 26 acres of catchment area accu mulated over 2.25 acres and the water depth exceeded 2 ft. The accumulated storm water hampered the trac ow and caused inconvenience to public. The sewerage and storm water drainage system provided was inadequate to cope with the requirements of eective drainage system during rain. The frequent accumulation of water during Monsoon was a matter of great concern for the commuters and authorities responsible for the provision of sewerage and drainage facilities.

Ponding area at Kashmir Road that existed prior to the construction of Stormwater Storage Tank.

To address the situation and provide relief to the public from inconvenience, WASA Lahore built Stormwater Storage Tank of 1.5 million gallons capacity to accommodate a sizeable quantity of the stormwater runo of the area which caused urban ooding. The tank has been built at PHA Park adjacent to Kashmir Road near in front of Alhamrah to store surface runo.

Pumps provided in the tank, pump the stormwater collected in the nearby drain to empty the tank and make it ready to store water for the next spell of rain. Covered drains with gratings built along the Kashmir Road transfer the rainwater to the Storm water Storage Tank, thereby preventing accumulation of stormwater on Kashmir Road.

The area where stormwater storage tank has been built was a green area prior to the construction of tank. After the construction of tank, area was restored to its original form by proving green grass on the roof of the tank.

The construction of tank in 2023 has elimi nated another sore point in Lahore.

Fig 3: Scheme of Stormwater Storage Tank on Kashmir Road, Lahore Road, Lahore

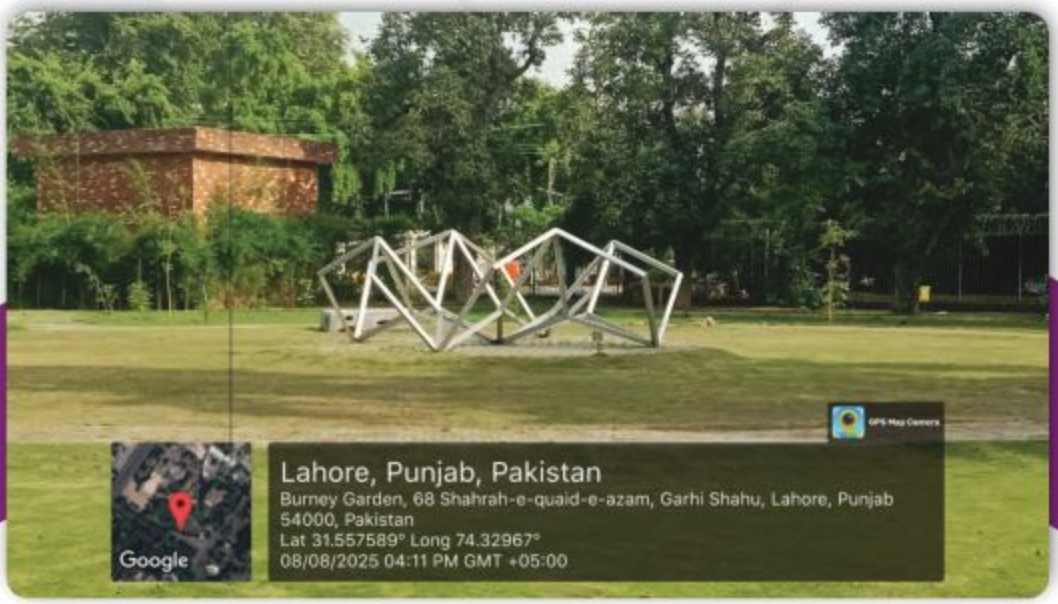


Fig 4: Green area on the Roof of the Stormwater Storage Tank on Kashmir Road, Lahore

5.3 Sheranwala Gate Lahore

Sheranwala Gate area was one of the worst affected areas during heavy rains in Lahore. The topography is such that the storm water from the 55-acre area accumulated over 07 acres on the circular road hampered the traffic flow and disrupted normal life in the area. The existing sewerage and storm water drainage system was inadequate to discharge the large volume of the stormwater. It took several days to clear the ponding area by means of dewatering pumps.

The estimated runoff from 55 - acre land area was 76.4 Cusecs which the existing sewerage and stormwater system in the area was unable to cope. To manage stormwater in Monsoon and to keep the roads clear of urban flooding, WASA built stormwater drainage tank of 1.5 MG capacity in the park near the flooding area. The tank was connected through a network of covered drains provided with gratings which carries the storm water from the catchment area to the Stormwater Storage Tank thus eliminating the pondage on the Circular Road and the surrounding area. The drains are of size 3 feet × 3 feet starting from ponding area upto the site of Stormwater Storage Tank at Sheranwala Gate. Screening chamber has been provided for the prevention of coarser material.

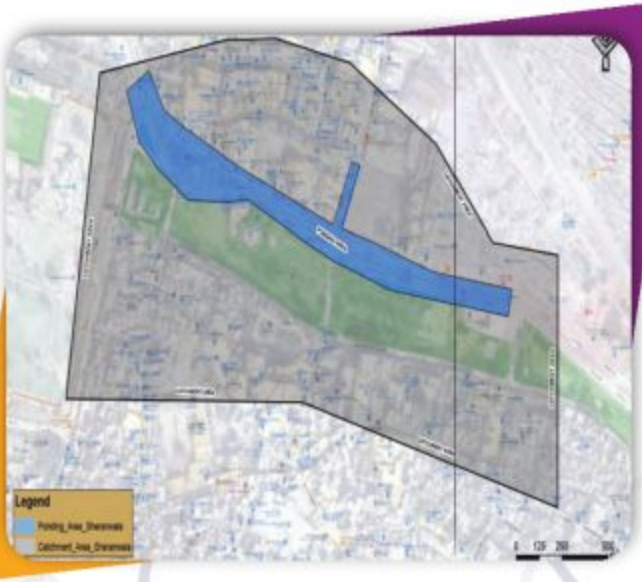


Fig 5: Catchment Area and Ponding area at Sheranwala Gate

from entering tank which can interrupt the functioning of pumps. The collection of storm-water in the tank and pumping is carried out simultaneously for the reduction of ponding depth. Thesystem of pumps and 400 mm dia. rising main provided on site discharges the stormwater stored in the tank away from the area.

The roof of the tank after completion was covered with green grass to restore the look of a park. The project was completed in 2023 at a cost of Rs 180.0 m.

Fig 6: Scheme of Stormwater Storage Tank and drains at Sheranwala Gate, Lahore

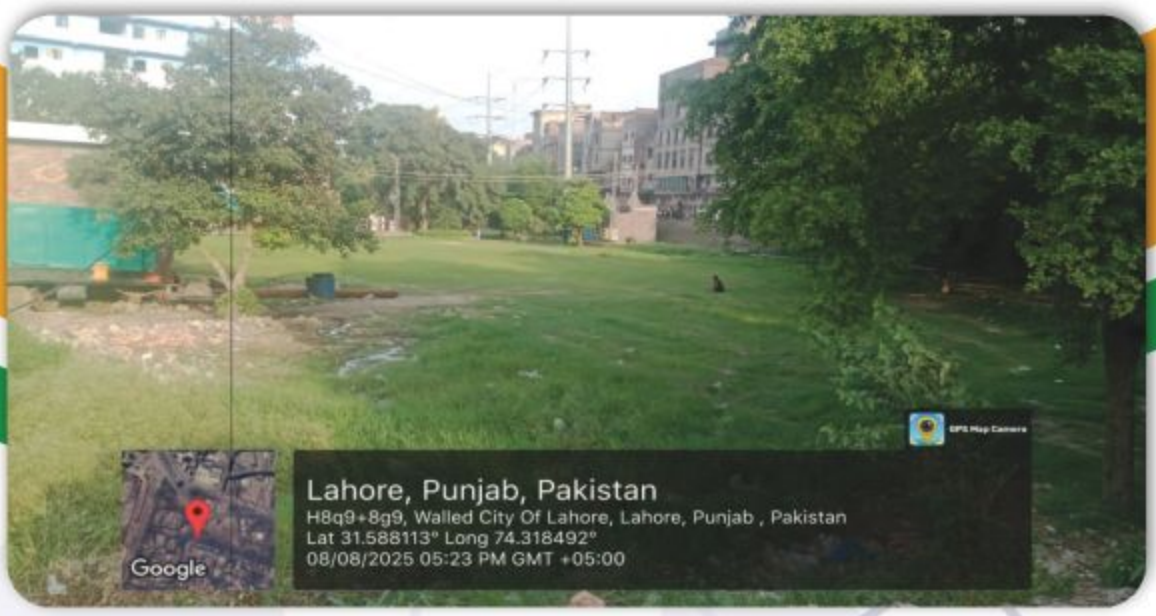


Fig 7: Green area on the Roof of the Stormwater Storage Tank at Sheranwala Gate, Lahore

5.4 Nishter Park Sports Complex Lahore

The Nishtar Park Sports Complex is one of Lahore's premier multi-sport venues, hosting numerous national and international facilities. The Nishter Park Sports Complex area was one of the worst affected areas during heavy rains. The topography is such that the storm water from 135 acres catchment area accumulated on 6 acres forming pond with depth of water exceeding 2.5 ft. The accumulated storm water hampered traffic flow and caused complete suspension of life activities in the area. Some people reported that water depth during the rain was so much that their vehicle started floating.

Around Nishter Park Sports Complex, there did not exist any specific drainage and sewerage system for the drainage of accumulated water around the Stadium.

Fig 8: Catchment Area and Ponding area at Nishter Park Sports Complex Lahore

WASA Lahore built massive stormwater storage tank with a capacity of 2.4 MG under the road of Nishter Park Stadium Complex. The tank was designed to eliminate extreme ponding that existed in the area. The tank is located below the existing road and Control Room for the operation of Pumps has been built on the roadside green area. Submersible Pumps installed in the tank have adequate capacity to readily pump out stormwater stored in the tank making the tank empty and available to store stormwater of the next spell of rain. A network of covered drains provided with opening and grating in its roof has been provided to catchstormwater and transport to the Stormwater Storage Tank. The ultimate disposal of the stormwater stored in the tank is the Nullah (Drainage Channel) flowing near Home Economics University Lahore. A 5 km long rising main of 600 mm dia has been laid from Nishter Sports Complex to the Nullah (Drainage Channel). The project was completed in 2024 at a cost of Rs 550 M.

Fig 9: Scheme of Stormwater Storage Tank and drains to eliminate urban flooding at Nishter Park Stadium Lahore.

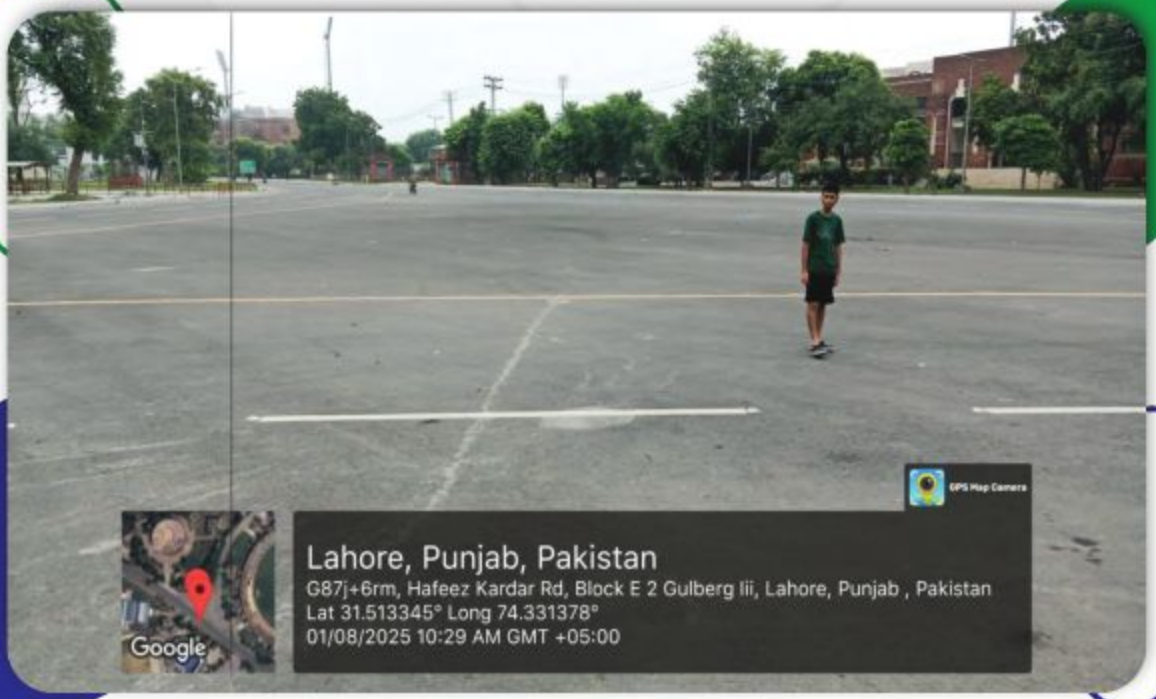


Fig 10: Road built above the Stormwater Storage Tank at Nishter Park Sports Complex, Lahore

5.5 Dijkot Road Faisalabad

Faisalabad city experiences annual rainfall of about 480 mm, a rain duration of 1 or 2 hours for 40 days per year, and rain events with more than 10 mm of daily rainfall on 13 days per year. During rainy season, inundations are often caused in low lying areas and even on main roads of the city.

Storm water drainage in densely populated areas of Faisalabad has been a major environmental hazard and civic problem. The situation becomes worse in the monsoon season which normally extends from July to September every year. Due to rainfall events the runoff rushes along the roads towards the relatively depressed areas and gets accumulated speedily to form ponding areas. The impounded runoff is ultimately drained through the sewerage system provided by WASA in the area. However, due to limited capacity of sewers the impounded water takes long time to drain out from the area. This situation becomes problematic for the public movement and creates unsolicited traffic hazards for hours. Dijkot Road is one of the major problematic areas in Faisalabad which WASA Faisalabad addressed by building Stormwater Storage Tank. The site was a scene of urban flooding every year in Monsoon during the rainy season causing disruption of traffic and normal life.

Fig 11: Stormwater Storage Tank at Dijkot Road, Faisalabad

WASA Faisalabad has built Stormwater Storage Tank of 1.0 MG capacity provided with Pumps and Rising Main 350 mm, 1500 Ft in length for the disposal of the collected stormwater in tank in the nearest canal. The project has been completed in 2024 at a cost of Rs 374.0 M. Layout of the Stormwater Storage Tank scheme is shown in Fig 12.

Fig 12: Scheme of Stormwater Storage Tank on Dijkot Road, Faisalabad

5.6 Stormwater Storage Tank in Khanewal

Kacheri Road, Yousaf Park are the major chronic depression areas in Khanewal. During the incidents of heavy rains which go up to 80 mm, the areas remain in-undated resulting in disruption in human activities and obstruction in smooth flow of traffic. The areas are identified as critical and significantly important sore points with respect to inad - equate drainage arrangements. Keeping in view this critical drainage situation, PMDFC planned to construct under - ground storage tank to reduce the inundation at the sore point.

The catchment area contributing runoff to the depression point is 33 acres, comprising of Block 8 and 4, Kacheri Road and surrounding areas in the Khanewal city. The storm and wastewater are collected through 9'' dia. lateral sewers and discharged in the 12'' dia. sewer at Kacheri Road. These sewers fall into Trunk sewer of 33" dia. trunk sewer at Sir Syed Road for onward disposal into Tariqabad disposal station. The pipes are of inadequate size to cater for this peak stormwater flow of 40 cusecs. As a result, water accu mulates on the streets of the areas causing inconvenience to the residents. In order to work out the stormwater runoff, the rainfall of 05 years return period was adopted. The Stormwater Storage Tank is of 0.8 million Gallons capacity connected through a network of stormwater drains. Pumping machinery has been provided to pump water through a 0.72 FT dia rising main. The total cost of the project is Rs 169.53 M. The tank is presently under construction.

Fig 13: Scheme of Stormwater Storage Tank on Kacheri Road, Khanewal

5.7 Stormwater Storage Tanks in Burewala

There are two chronic depression points identified in Burewala causing ponding during heavy rains. Stormwater Storage Tanks for the elimination of urban flooding have been proposed i) Arif Bazar Burewala & ii) Z Block Burewala.

5.7.1 Arif Bazar Burewala

The location of Arif Bazar area of Burewala City is identified as critical sore point because of inadequate drainage arrangements. Arif Bazar lies at low level and remains flooded with surface runoff for several hours when the rain occurs. Keeping in view the critical drainage situation, PMDFC planned to construct underground storage tank to reduce inundation at the sore point. With the construction of Storm Water Storage Tank, the runoff will flow into the tank from the ponding area, and the road/streets will be clear for traffic movement. Storm water collected in the tank will be pumped out for disposal and the tank becomes ready to receive runoff of next rain.
ponding area, and the road/streets will be clear for traffic movement. Storm water collected in the
tank will be pumped out for disposal and the tank becomes ready to receive runoff of next rain.

The catchment area, contributing flow to the pond - ing area is 35 acres. The stormwater runoff generated during 01 hour of 5 - year return period rainfall from the catchment area is of about 20 cusecs which cannot be carried by 33" dia. outflow sewer which carries both waste and stormwater from the whole drainage zone in which Arif Bazar is located.

The Stormwater Storage Tank is of 1.0 million Gallons capacity connected through a network of stormwa - ter drains for discharging stormwater in the storage tank. Pumping machinery has been provided to pump water through a 250 mm dia rising main. The collected water will be pumped to the Larri Adda Disposal Station. The total cost of the project is Rs 149.60 M. The tank is presently under approval stage.

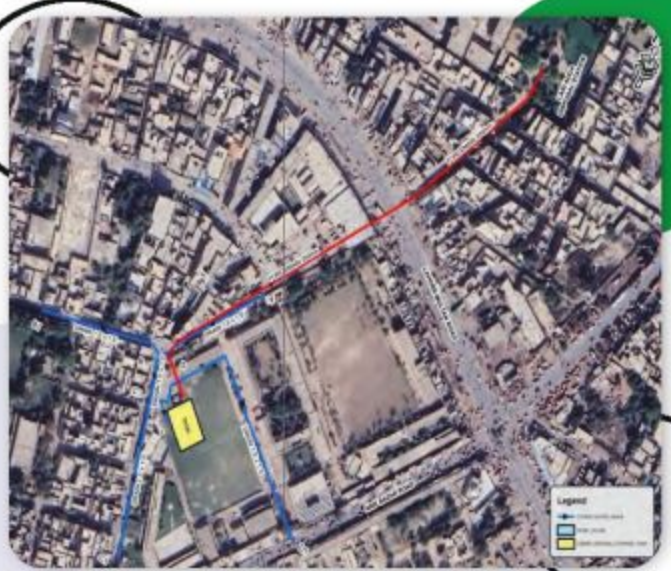


Fig 14: Scheme of Stormwater Storage Tank in Arif Bazar, Burewala

5.7.2 Z Block Burewala

The sewerage system laid is combined, which carries sewage and limited amount of stormwater. Drains exist but they are being used for carrying both sewage and stormwater. Z Block area has a flat topography, and the surround - ing area is 2 Ft higher.
During rains stormwater accumulates in the Z blockarea and remains stagnant for a long period, sometimes for more than 24 hours.
The accumulation of stormwater creates unhealthy environment and massive traffic jams, disruptingroutine activi - ties of the public, particularly for the residents living in these areas. The catchment area, contributing stormwater flow to the ponding area is 40 acres. A peak stormwater flow of 30 cusec is generated during 1 hour of five years

return period. The accumulated storm - water on the roads and streets of the Z Block becomes a cause of inconvenience to residents and risk to their property. The existing sewerage and drainage system comprising of sewers network of 9" to 42"dia becomes inadquate to discharge this large amount of water.

The Stormwater Storage Tank of 1.0 MG capacity has been proposed connected through a network of stormwater drains for discharging stormwater in the storage tank. The collected water will be pumped through a 250 mm dia. rising main to the 2 R minor at controlled pumping rate due to the limited capaci - ty of the receiving water body. The total cost of the project is Rs 152.07 M. The tank is presently under approval stage.

Fig 15: Scheme of Stormwater Storage Tank in Z Block, Burewala

5.8 Stormwater Storage Tank in Vehari

Gol Chowk area near MC Office on Jinnah Road is identified as the critical point in the Vehari city where ponding occurs during heavy rainfalls. The exist- ing sewerage system is combined with limited capacity to carry stormwater results in the formation of pond causing inconvenience to public. The accumulat - ed water remains stagnant for a long period of time for more than 24 hours. At present, the accumulated stormwater is discharged into a drain which conveys water to a Wet Well of the Disposal Station located 1 km away from the Gol Chowk. The pumping arrangement at disposal station pumps water into the fields.

Fig 16: Scheme of Stormwater Storage Tank in Gol Chowk, Vehari

The catchment area, contributing stormwater flow to the ponding area is 30 acres. A peak stormwater flow of 43 cusec is generated during 1 hour of five years return period which is beyond the carrying capacity of the existing drain. Resultantly, water accumulates in the Gol Chowk area.ponding area, and the road/streets will be clear for traffic movement. Storm water collected in the tank will be pumped out for disposal and the tank becomes ready to receive runoff of next rain.

The Stormwater Storage Tank of 0.75 million Gallons capacity has been proposed in the MC library premises connected through a network of stormwa - ter drains for discharging stormwater in the storage tank. The collected water will be pumped through a 250 mm dia. rising main. A lorry hydrant has been provided to fill the water tank of MC for use of water in gardening or horticulture. The total cost of the project is Rs 152.07 M. The project is presently under construction.

Fig 17: Under construction Stormwater Storage Tank at Gol Chowk, Vehari

6.0 Pre and Post Project Scenarios

Land use in the catchment areas where ponding occurs in Lahore or other cities during rain is characterized by the building roofs, roads, streets, foot paths and parking areas with very limited infiltration spaces left such as open spaces, parks and lawns. The consequences are major part of the rainfall in the area is converted into runoff. Ponding forms on the road due to the inadequate capacity of the sewers and drains to pass stormwater.

In the past Stormwater management tools available to utility organizations were: i) disposal of storm water through existing gravity sewers ii) existing Storm water drains and iii) use of mobile dewatering pumps to dispose of run off. Despite the use of all these resources, formation of ponding on road could not be eliminated, indicating deficit in the storm water management infrastructure. The deficit was filled by building a Storm Water Storage Tank in the catch - ment area at appropriate location of adequate capacity to temporarily store peak storm water in the tank. The stored water is gradually released into the sewerage and drainage system as the storm recedes or disposes of into the near - est water body.

The effectiveness of Storage Tank in the elimination of ponding has been assessed by observing the conditions prevailing in the area on rain events following the construction of the tank in comparison to pre project conditions.

6.1 Elimination of Ponding on Lawrence Road, Lahore

The analysis of site data by comparing the ponding conditions before and after the construction of the Stormwater Tank indicates the elimination of ponding in the area which was the main objective of building Stormwater Storage Tank. Analysis is depicted in the table below:

Table 1: Analysis of the Rainfall data shows 'No Ponding' on Lawrence Road after the construction of Stormwater Storage Tank in 2020

LAWRENCE ROAD PONDING FROM 2016 - 2021										
	6	6	7	7	8	8	9	9		
Sr. No.	201	201	201	201	201	201	201	201	0 202	1 202
	Date	Max Ponding (Inches)	Date	Max Ponding (Inches)	Date	Max Ponding (Inches)	Date	Max Ponding (Inches)		
1	16.06.16	16	26.01.17	6	03.07.18	24	06.07.19	8	No Ponding	No Ponding
2	22.06.16	16	08.06.17	18	19.07.18	16	14.07.19	4		
3	02.07.16	8	17.06.17	10	20.07.18	3	16.07.19	10		
4	12.07.16	6	19.06.17	5	22.07.18	16	25.07.19	10		
5	14.07.16	5	21.06.17	2	09.09.18	26	-	-		
6	17.07.16	18	27.06.17	4	-	-	-	-		
7	24.07.16	15	28.06.17	10	-	-	-	-		
8	27.07.16	18	06.07.17	6	-	-	-	-		
9	05.08.16	16	11.07.17	10	-	-	-	-		
10	08.08.16	12	14.07.17	14	-	-	-	-		
11	10.08.16	5	27.07.17	7	-	-	-	-		
12	16.08.16	8	28.07.17	12	-	-	-	-		
13	25.08.16	18	06.08.17	5	-	-	-	-		
14	27.08.16	17	25.08.17	7	-	-	-	-		
15	29.08.16	21	30.08.17	3	-	-	-	-		
16	01.09.16	36	01.09.17	9	-	-	-	-		
17	20.09.16	6	06.09.17	11	-	-	-	-		

Fig 18: Accumulation of Rainwater on Lawernce Road before the construction of Stormwater Storage Tank

Fig 19: View of Lawernce Road after the construction of Stormwater Storage Tank

6.2 Elimination of Ponding Conditions on Kashmir Road, Lahore

Table 2: Analysis of the Rainfall data shows 'No Ponding' on Kashmir Road after the construction of Stormwater Storage Tank in 2022

KASHMIR ROAD FROM 2020 TO 2025																							
2020				2021				2022				2023				2024				2025			
Sr.No	Date	Rain	Maximum Ponding	Sr.No	Date	Rain	Maximum Ponding	Sr.No	Date	Rain	Maximum Ponding	Sr.No	Date	Rain	Maximum Ponding	Sr.No	Date	Rain	Maximum Ponding	Sr.No	Date	Rain	Maximum Ponding
1	6-Mar	31	4"	1	6-Jun	56	10"	1	5-Jan	24		1	25-Mar	47		1	30-Apr	27		1	5-Jul	72	
2	29-Jun	26	4"	2	13-Jul	32	6"	2	7-Jan	69		2	3-Apr	97		2	5-Jul	105		2	6-Jul	35	
3	12-Jul	28	6"	3	20-Jul	48	8"	3	22-Jan	24		3	10-Jun	78		3	12-Jul	42		3	8-Jul	78	
4	16-Jul	38	6"	4	21-Jul	75	14"	4	17-Jun	44		4	25-Jun	104		4	18-Jul	29		4	9-Jul	143	
5	17-Jul	40	7"	5	1-Aug	60	12"	5	20-Jun	40		5	26-Jun	171		5	20-Jul	170		5	10-Jul	53	
6	21-Jul	37	8"	6	2-Aug	27	4"	6	13-Jul	22		6	5-Jul	291		6	28-Jul	28		6	12-Jul	28	No ponding
7	2-Aug	69	11"	7	6-Aug	92	18"	7	14-Jul	106		7	6-Jul	58		7	30-Jul	95		7	14-Jul	133	
8	10-Aug	121	20"	8	21-Aug	30	6"	8	15-Jul	18	No Ponding	8	8-Jul	55		8	1-Aug	65	No ponding	8	18-Jul	94	
9	20-Aug	207	32"	9	10-Aug	101	18"	9	21-Jul	143		9	15-Jul	39		9	7-Aug	248		9	1-Aug	72	
10	16-Nov	25	4"	10	11-Aug	198	30"	10	29-Jul	103		10	19-Jul	44		10	15-Aug	56		10	3-Aug	89	
				11	12-Aug	45	8"	11	31-Jul	29.5		11	22-Jul	181	No ponding	11	16-Aug	67		11	10-Aug	100	
				12	21-Aug	53	10"	12	29-Aug	172		12	24-Jul	45		12	20-Aug	41					
				13	2-Oct	81	12"	13	8-Aug	38		12	26-Jul	141		13	23-Aug	55					
								14	23-Aug	69		14	29-Jul	101		14	6-Sep	18					
												15	10-Aug	46		15	7-Sep	89					
												16	25-Aug	75									
												17	19-Sep	112									
												18	23-Sep	138									
												19	9-Oct	58									
												20	14-Oct	77									
												21	17-Oct	66									

Fig 20: Accumulation of Rainwater on Kashmir Road before the construction of Stormwater Storage Tank

Fig 21: View of Kashmir Road after the construction of Stormwater Storage Tank

6.2 Elimination of Ponding Conditions on Kashmir Road, Lahore

Table 3: Analysis of the Rainfall data shows 'No Ponding' at Sheranwala Gate after the construction of Stormwater Storage Tank in 2022

SHERANWALA GATE FROM 2020 TO 2025																							
	2020			2021				2022				2023				2024				2025			
Sr.No	Date	Rain	Maximum Ponding	Sr.No	Date	Rain	Maximum Ponding	Sr.No	Date	Rain	Maximum Ponding	Sr.No	Date	Rain	Maximum Ponding	Sr.No	Date	Rain	Maximum Ponding	Sr.No	Date	Rain	Maximum Ponding
1	6-Mar	25.00	3"	1	6-Jan	43.50	6"	1	5-Jan	43		1	3-Apr	46		1	30-Apr	24		1	26-Jun	20.5	
2	29-Jun	28.00	4"	2	13-May	20.00	3"	2	7-Jan	46.5		2	10-Jun	41		2	6-Jul	45		2	27-Jun	31	
3	12-Jul	39.00	6"	3	13-Jul	32.00	5"	3	20-Jun	40		3	25-Jun	106		3	12-Jul	151		3	6-Jul	74	
4	16-Jul	27.00	4"	4	20-Jul	56.00	8"	4	13-Jul	27		4	26-Jun	82		4	23-Jul	30		4	9-Jul	74	
5	17-Jul	46.00	6"	5	21-Jul	71.00	10"	5	14-Jul	108	No Ponding	5	29-Jun	167		5	26-Jul	89		5	10-Jul	175	No Ponding
6	21-Jul	39.00	6"	6	1-Aug	132.00	16"	6	21-Jul	158		6	6-Jul	268		6	28-Jul	71		6	14-Jul	32	
7	2-Aug	63.00	10"	7	6-Aug	106.00	14"	7	29-Jul	83		7	8-Jul	66		7	1-Aug	324	No ponding	7	15-Jul	171	
8	10-Aug	68.00	11"	8	21-Aug	29.00	4"	8	29-Aug	157		8	24-Jul	176	No Ponding	8	10-Aug	55		8	18-Jul	35	
9	20-Aug	160.00	20"	9	10-Sep	66.00	10"	9	23-Sep	33		9	26-Jul	51		9	11-Aug	57		9	23-Jul	99	
10	27-Aug	24.00	4"	10	11-Sep	176.00	20"					10	27-Jul	140		10	17-Aug	53		10	10-Aug	100	
11	28-Aug	47.00	6"	11	12-Sep	29.00	4"					11	29-Jul	33		11	19-Aug	53					
12	31-Aug	70.00	10"	12	21-Sep	50.00	6"					12	1-Aug	147		12	26-Aug	42					
13	4-Sep	135.00	18"	13	22-Sep	28.00	4"					13	14-Sep	52		13	Sep-02	50					
				14	2-Oct	69.00	7"					14	9-Oct	109									
												15	14-Oct	24.5									
												16	16-Oct	33									

Fig 22: Accumulation of Rainwater on Circular Road / Sheranwala Gate before the construction of Stormwater Storage Tank

Fig 23: View of Sheranwala Gate area after the construction of Stormwater Storage Tank

6.4 Elimination of Ponding Conditions at Nishter Park Sports Complex, Lahore

Table 4: Analysis of the Rainfall data shows 'No Ponding' at Nishter Park Sports Complex after the construction of Stormwater Storage Tank in 2024

NISHTER SPORTS COMPLEX PONDING FROM 2020 TO 2025																							
2020				2021				2022				2023				2024				2025			
Sr. No.	Date	Rain	Maximum Ponding	Sr. No.	Date	Rain	Maximum Ponding	Sr. No.	Date	Rain	Maximum Ponding	Sr. No.	Date	Rain	Maximum Ponding	Sr. No.	Date	Rain	Maximum Ponding	Sr. No.	Date	Rain	Maximum Ponding
13	6-Mar	30	5"	2	6-Jan	56	8"	1	7-Jan	42	7"	10	3-Apr	39	6"	15	5-Jul	76	8"	26	5-Jul	52	No ponding
48	12-Jul	29	6"	27	13-Jul	20	4"	2	22-Jan	26	4"	23	25-Jun	42	6"	18	12-Jul	31	4"	27	6-Jul	43	
51	17-Jul	30	6"	30	20-Jul	23	4"	6	17-Jun	49	8"	24	26-Jun	47	6"	25	30-Jul	65	7"	28	8-Jul	69	
55	21-Jul	49	8"	31	21-Jul	64	8"	7	20-Jun	44	7"	25	29-Jun	31	5"	26	1-Aug	40	5"	29	9-Jul	153	
59	2-Aug	30	6"	34	1-Aug	49	8"	16	14-Jul	61	8"	26	3-Jul	111	14"	29	7-Aug	214	18"	32	14-Jul	82	
60	9-Aug	45	8"	39	6-Aug	43	7"	19	21-Jul	76	12"	28	6-Jul	33	4"	39	20-Aug	41	6"	35	18-Jul	59	
61	10-Aug	51	8"	43	21-Aug	28	4"	24	29-Jul	42	6"	29	8-Jul	308	28"	41	23-Aug	49	6"	42	3-Aug	45	
64	20-Aug	95	12"	47	2-Sep	29	4"	36	29-Aug	47	6"	34	26-Jul	113	16"					43	9-Aug	100	
66	28-Aug	57	8"	53	11-Sep	71	9"					39	2-Aug	35	5"								
67	4-Sep	100	14"	61	2-Oct	40	5"					48	18-Sep	34	5"								
												51	9-Oct	158	18"								
												52	14-Oct	122	16"								
												54	17-Oct	43	6"								

Fig 24: Accumulation of water at Nishter Park Sports Complex, Lahore before the construction of Stormwater Storage Tank

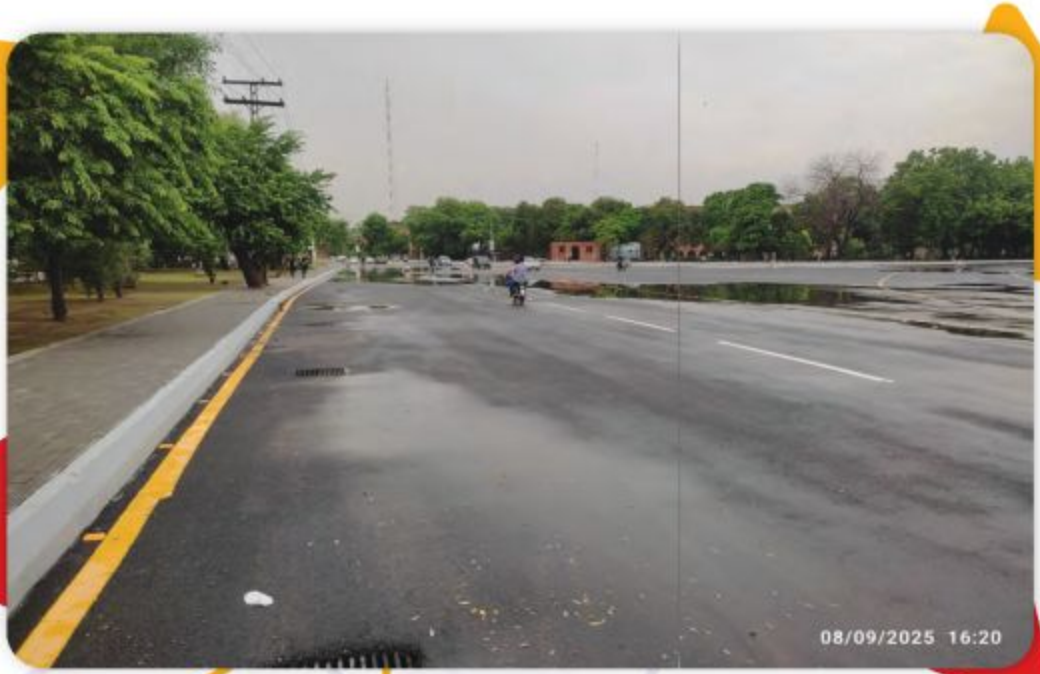


Fig 25: View of Nishter Park Stadium Complex Road after the construction of Stormwater Storage Tank

6.5 Elimination of Ponding Conditions on Dijkot Road, Faisalabad

Table 5: Analysis of the Rainfall data shows 'No Ponding' on Dijkot Road after the construction of Stormwater Storage Tank in 2024

DIJKOT ROAD PONDING FROM 2020 - 2025																							
2020				2021				2022				2023				2024				2025			
Sr.No	Date	Rain (mm)	Maximum Ponding	Sr.No	Date	Rain(mm)	Maximum Ponding (inches)	Sr.No	Date	Rain(mm)	Maximum Ponding (inches)	Sr.No	Date	Rain(mm)	Maximum Ponding (inches)	Sr.No	Date	Rain(mm)	Maximum Ponding (inches)	Sr.No	Date	Rain(mm)	Maximum Ponding (inches)
1	23.02.2020	13.8	3	1	05.01.2021	50.2	18	1	17.06.2022	14.8	4	1	30-03-2023	26.8	3	1	1/2/2024	20	2	1	11/4/2025	15	No Ponding
2	05.03.2020	20.2	3	2	23.03.2021	12.6	10	2	20.06.2022	37	18	2	31-05-2023	9.4	1	2	20-06-2024	33	2	2	11/5/2025	25	
3	06.03.2020	14.4	4	3	23.04.2021	7.4	18	3	21.06.2022	13.2	7	3	10/6/2023	17.4	1	3	5/7/2024	47	3	3	24-05-2025	7	
4	11.03.2020	22.8	4	4	11.07.2021	5.8	6	4	10.07.2022	10.2	12	4	15-07-2023	20.4	1	4	6/7/2024	56	16				
5	12.03.2020	13.4	8	5	14.07.2021	35.4	20	5	21.07.2022	82.8	12	5	29-07-2023	22	1	5	10/7/2024	10	2				
6	17.04.2020	11.8	8	6	20.07.2021	132	28	6	22.07.2022	10.2	3	6	15-03-2023	48	2	6	12/7/2024	89	12				
7	30.05.2020	14	6	7	31.07.2021	22.8	21	7	24.07.2022	42.2	18	7	23-03-2023	26	1	7	25-07-2024	77	12				
8	04.06.2020	3.6	7	8	21.09.2021	6.6	10	8	25.07.2022	18.6	6	8	24-09-2023	86	6	8	4/8/2024	142	14				
9	25.06.2020	3.2	3					9	29.08.2022	13.64	3					9	16-08-2024	127	8				
10	26.06.2020	7.2	3					10	23.09.2022	11.36	8					10	17-08-2024	23	2				
11	29.06.2020	12.4	12													11	29-08-2024	53	12				
12	12.07.2020	16.4	10													12	30-08-2024	36	20				
13	21.07.2020	25.2	12													13	3/9/2024	60	12				
14	31.07.2020	21.4	12													14	28-09-2024	59	12				
15	20.08.2020	55	18																				
16	21.08.2020	9.8	8																				
17	26.08.2020	10	12																				
18	27.08.2020	24	16																				

7.0 Views of Local Stakeholders

Disposal of stormwater is one of the service delivery functions of Utility Organizations (WASAs & MCs) which must be carried out without creating any disturbance on roads and streets of the city. Recurring events of inundation of road and consequent disruption of normal life during the storm indicated a critical service delivery gap on the part of utility organizations.

In 2019 WASA Lahore came up with the novel idea of building a storage tank in Bagh e Jinnah as the measure to eliminate inundation and ponding on Lawrence Road. The aim was to maintain life normalcy in the area during stormwater events. The construction of Stormwater Storage Tank at Lawrence Road was followed by the construction of similar tanks on Kashmir Road, Sheranwla Gate and at Nishter Park Sports Complex Lahore. WASA Faisalabad built Stormwater Storage Tank on Dijkot Road to manage urban ooding there. Based on the success of stormwater storage tanks in Lahore and Faisalabad, PMDFC planned similar tanks to manage urban ooding in Vehari, Burewala, Khanewal and Wazirabad. The tank in Vehari is under construction while tanks in Burewala, Khanewal and Wazirabad are under various stages of the approval process.

Now, when tanks built in Lahore and Faisalabad have been made functional and seen some Monsoon seasons, it is pertinent to approach the local stakeholders to assess how far their lives have been relieved of the ponding and urban ooding experienced in the past.

In this regard a questionnaire was developed, and local stakeholders were approached to answer various aspects of the impacts of the stormwater storage tank on ponding in the area. The gist of responses is presented here.

The stakeholders were interviewed individually butthey were unanimous in their opinion that theyhave got the relief. In the past water ponding was 1- 2 Ft which is not experienced now, and the water is drained quickly. One of the stakeholders who owns a shop in the area reported that 2 years before it was not possible for him to cross the road and reach his shop on the day of rain due to ponding, which is possible now.

Another stakeholder who owns a Hotel on Larence Road reported that in the past water used to enter their entrance gate and shops on the front, but now there is no accumulation of water, and the road remain clear.

A laboratory technician who works in one of the famous medical laboratories of Lahore located on Lawrence Road reported they could not move on the road due to the accumulation of water and now they face no such trouble.

Trac warden responsible for the control of trac on Lawrence Road reported that there is no more ponding on the road on rain events and trac moves uninterrupted.

An auto rickshaw driver who passes through Lawrence Road several times a day, reported that now there is no pond ing in Monsoon and he passes without any traffic hurdle.

Some stakeholders recommended replication of the project in other parts of the city as a means to eliminate flooding.

The survey has revealed the perception of the local stakeholders about the project and its impacts on their lives. All believed that storage tanks have eliminated ponding on Lawrence Road and the problems associated with it.

Stormwater Storage Tank on Kashmir Road, Lahore

The construction of stormwater storage tank has provided relief now, water does not stand on the road, and we can easily pass through the road during the rainy days. In the past the water reached up to 1.5 Ft depth even on a smaller magnitude of rain event which took days to clear. People inter viewed worked in oces located on Kashmir Road.

Stormwater Storage Tank on Sheranwala Gate, Lahore

Stormwater Storage Tank on Sheranwala Gate has provided relief to the passers-by and shop owners of Circular Road Lahore. Water used to enter their shops on rainy days, which does not happen now. The situation has signicantly improved, now water instead of standing on the road goes into the tank in minutes.

Stormwater Storage Tank at Nishter Park Stadium Complex, Lahore

There has been a remarkable improvement, now we can come to oces without any mental pres sure. Roads during rainy days remain clear and trac can easily pass. In the past it was all ooded during rain, vehicles used to get stuck in the storm-water standing on the road and we remained wor ried about how to reach oce. Now there is a huge dierence, water does not stand on the road. The people interviewed worked in oces and restau rants located on Stadium Complex Road.

Stormwater Storage Tank on Dijkot Road, Faisalabad

The area around Dijkot Road is all commercial where shops are located.

We used to keep our shops closed on rainy days because the approach road remained flooded which we could not cross to reach our shops. About 200 shops used to remain closed on rainy days. Some time water entered our shops causing damage to the merchandize and floor. Now water does not stand on roads, and we can reach our shops. In the past vehicles used to be stuck in water.

Our business has also improved due to the elimination of flooding on the roads.

8.0 Managing Stormwater Sustainably

Sustainability is defined in terms of its three pillars: i} Social ii} Economic & iii} Environment. When the three pillars are strong people live in world where excellent quality of life is standard. Conceptually the framework of sustainability is defined in Fig 26.

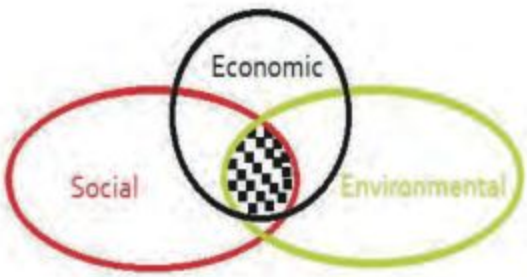


Fig 26: Conceptual Framework of Sustainable Development

The shaded area in Figure 26 represents sustainable development. In the context of Storm Water Management Projects, three pillars can be defined as:

i} Social: Stakeholder's / User satisfaction & improvement in the quality of life by eliminating urban flooding
ii} Economics: Spending resources efficiently on a technically most feasible project
iii} Environment: Rainwater harvesting / aquifer recharging to protect environment has been made part of the project

The existing sewerage system in Punjab is combined, which carries sewage from homes and stormwater from the paved roads and streets. The Stormwater storage system allows on - site stormwater storage where the excess storm water beyond the carrying capacity of combined sewerage system flows on the roads and streets until it slowly discharges into the combined sewers and drains.

With the increase in the imperviousness of the city terrain accompanied by inadequate capacity of the combined sewerage / drainage infrastructure, the storm water stays on the roads for a longer period of time before it recedes. The flooding of roads, traffic interruptions, impairing automobile access, and the risk to property during very heavy rainstorms are the characteristics of this system. Several approaches to sustainable stormwater management currently practiced worldwide are discussed below:

8.1 Shifting to Separate Sewerage System

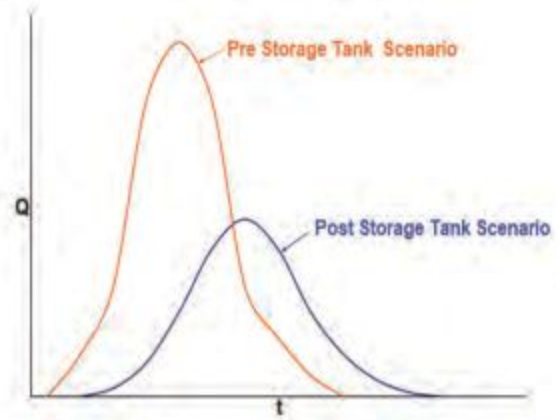
One approach to managing storm water is to shift to separate sewerage system providing separate pipes to carry sewage and storm. This will involve tearing up the roads and streets of the city, digging up the old, combined sewers and replacing them with separate stormwater and sewerage system. The high cost of retrofitting the new separate sewerage system and widening of existing drains is prohibitively expensive. Moreover, the extensive traffic disruption involved in replacing most roads and streets will not make this a popular choice.

8.2 Stormwater Storage Tank

The second approach is to provide local solution for temporarily storing the peak storm water from the catchment area in the Storage Tank through a network of local drains built for this purpose as a measure to eliminate urban flooding. The concept involves delaying the discharge of storm water in the combined sewerage / drainage system until the rain has subsided and pressure on the sewerage / drainage system has reduced. It depresses the formation of storm water flood peaks, thereby eliminating urban flooding. The system has the capacity to keep the roads free from flooding. The stored water can either be released into combined sewerage / drainage system or can be brought into other beneficial usages such as horticulture and ground water recharge. The solution is less resource intensive and more cost effective involves lesser disruption of traffic during construction and provides a means of recharge of the groundwater hence more sustainable. Moreover, in the urban context the use of the area is restored to its original form e.g in case of Lawrence Road Storage Tank, the roof of the Storage Tank has been utilized as Tennis Court. Such a development for stormwater management is classified as "Low Impact Development" and most suitable for the already developed areas.

Tennis Court on the top of Lawrence Road Storage Tank

Low Impact Development allows storm water to be managed at a lower cost than the conventional Combined or Separate Sewerage Systems with least disturbance to normal life in storm water management infrastructure development.



Stormwater Peaks in Pre & Post Storage Tank Scenario Q= Flow Rate, t = Time

8.3 Permeable Pavements & Rain Gardens

The third method decreases the stormwater runoff by increasing its infiltration into the soil. The technique involves the use of permeable pavements and use of rain gardens. Permeable pavements use materials with void in it that allow water to seep into the soil beneath the pavement. Another way is the use of precast porous pavers designed with holes in the surface allowing water to flow through the pavement and infiltrate into the soil beneath. Permeable pavements need periodical maintenance because the pores in porous pavement or the holes in precast pavers get clogged by the soil and dust which reduces the infiltration drastically. In the context of urban centers of Punjab, use of porous pavement is yet to be introduced in the market, therefore this arrangement does not provide any readily implementable solution to resolve the storm water management issues of Lahore.

Permeable paving Drains used in to vegetated swale used in Parking lot, Elmhurst, Illinois, USA

Similarly, the use of Rain Gardens which reduce surface run off by enhancing rainwater evaporation and infiltration into the soil is not a feasible option because of the space constraint in the already developed land in urban centers of Punjab. The aim of the rain gardens is to retain water in the land scape & reduce runoff. The solution can be implemented by providing green spaces in the concrete dominated urban area. The solution is commonly classified as "Green Infrastructure" which can be implemented in the development of new areas.

Green Streets with Infiltration swales

8.4 Green Roofs

Another form of Green Infrastructure is the "Green Roof" which uses soil material above a layer of water proofing material on its surface to allow shallow rooted plants to be planted. The Green Roof stores water in the pores of the soil before it is discharged on the ground by the roof gutters and drainpipes. The soil of a green roof can capture and temporarily store stormwater precipitation as the pores between the soil particles fill up with rainwater. Green roofs will cost more than conventional roofs, because of the additional cost of structural engineering that might be necessary to accommodate the weight of the green roofs soil and plantings.

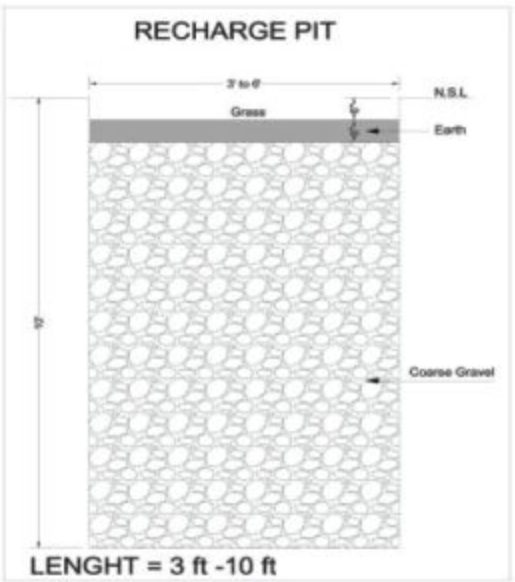
Green Roof in Villa Park, Illinois, USA

8.5 Rainwater Harvesting Tank at the Household level

This is a decentralized harvesting approach using rain barrels, cistern or storage tank at the individual house level for capturing and re-using rainfall for watering plants or flushing toilets. The captured water can be used for all other purposes than drinking. Lahore Development Authority (LDA) has adopted this approach and made it mandatory for houses and buildings to be constructed in future in Lahore to have a roof top rainwater harvesting tank commensurate with its plinth area.

The capacity of rainwater harvesting tanks proportionate to the plinth area has been provided in the LDA regula tions. LDA regulation also prohibits the connection of the roof drainpipe directly with the sewerage system or with the street / right of ways which will be diverted towards the landscape, natural areas and to groundwater recharge bores / wells. In order to raise the aquifer level in the city, it has been made mandatory for every house of above 15 Marla to construct recharge well / recharge pit as shown in Fig 27.

Rainwater capturing from Roof Top



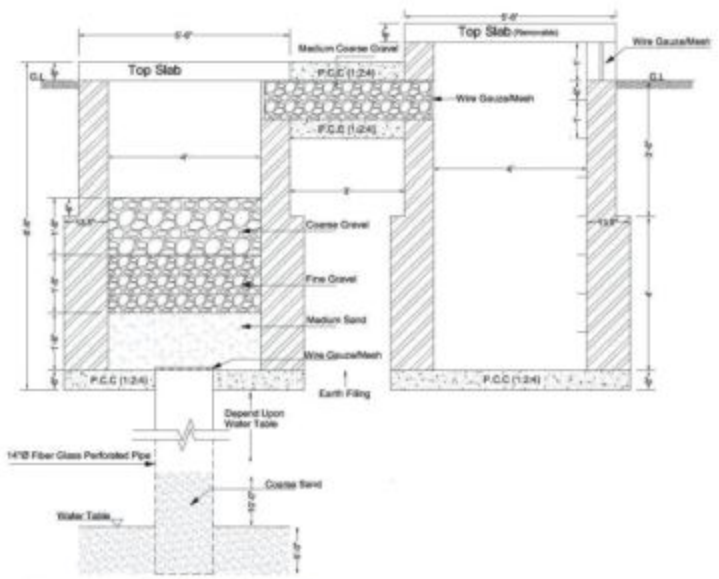


Fig 27: a) Recharge Pits adopted by LDA

b) Recharge Wells adopted by LDA

LDA regulations have also made it mandatory for Parks and Garden owners to adopt rainwater harvesting tech - niques for aquifer recharge by using spread basins, recharge pits, recharge trenches, dug wells, recharge shafts, injection wells.

9.0 Conclusions

The preceding sections have discussed the impacts of storm water storage tanks in eliminating urban flooding. The documentation on pre-and-post project scenarios and views of the stakeholders affected by urban flooding show that Stormwater Storage Tanks have been beneficial in preventing accumulation of stormwater in the low-lying areas and in maintaining interrupted traffic flow on roads during rainfalls. By eliminating urban flooding, Stormwater Storage Tanks have prevented damage to roads, building and critical infrastructure. Besides, the risk of damage to residential and commercial properties has been eliminated. The citizens in the area can carry out their normal activities and businesses during rain because of the diversion of stormwater towards the Stormwater Storage Tanks instead of accumulating on roads. The tanks have been beneficial in economic terms by eliminating dewatering pumps and the need for repairs of roads and other infrastructure damaged by urban flooding.

In environmental terms, the roof of the tank is provided with a grassy green cover giving the tank an environmentally friendly look. The collected stormwater in the tanks can be reused for nonpotable applications like irrigation of parks, green belts thus reducing utilizing of freshwater resources. Overall stormwater tanks have contributed to improving the quality of life in the cities in Punjab by eliminating urban flooding.

Since the combined sewerage system laid in the cities of Punjab is limited by its capacity to carry full stormwater flows, the provision of stormwater storage tanks provides a good local solution for eliminating urban flooding.

Another option of managing stormwater and urban flooding is Rainwater Harvesting. Among the two types of Rainwater harvesting, Roof Top Rainwater Harvesting offers managing stormwater at the household level by capturing rainwater from the roofs and diverting it to the recharge bores / wells. Lahore Development Authority (LDA) has included rooftop rainwater harvesting in its Building Zoning Regulations, making it mandatory for all residential and public buildings. The other method of managing stormwater and urban flooding is Surface Rainwater Harvesting currently implemented by WASAs in larger cities and PMDFC in 11 smaller cities by building stormwater storage tanks. It would be appropriate to include Roof Top Rainwater Harvesting in the Building Bylaws of MCs. The combination of Rooftop and Surface Rainwater harvesting has the potential to provide ultimate solution for the elimination of flooding in the urban centers of Punjab.

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