Stormwater Management in Monwabisi Park: C-Section

Existing Conditions, Interventions and Proposed Solutions

Compiled by the 2010 WPI Stormwater Management Team

Kaylyn Button, Elisabeth Jeyaraj, Rodrigo Ma, Edwin Muniz

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2010 WPI Stormwater Team

Meet the Team

The 2010 WPI Stormwater Team is made up of four students, Kaylyn Button, Elisabeth Jeyaraj, Rodrigo Ma, and Edwin Muniz, from Worcester Polytechnic Institute (WPI), a University in the United States. Each student brings a different background of knowledge to this project, as they are focusing their studies on different aspects of engineering. Button is studying Biomedical Engineering and Pre-Health, Jeyaraj is studying Biomedical Engineering, Ma is studying Chemical Engineering, and Muniz is studying Civil Engineering. This group prepared for seven weeks prior to arriving in Cape Town, and they have spent seven weeks in Cape Town researching and reporting aspects of their project: Stormwater Management in Monwabisi Park.

Left to right: E. Jeyaraj, E. Muniz, K. Button, R. Ma

Mission of the Project

Dr. Kevin Winter

Thabo Gulwa, co-researcher

As part of an interdisciplinary project program sponsored by WPI (advised by Professors Scott Jiusto and Robert Hersh), these students are integrating technology with social issues found within Monwabisi Park, an informal settlement in Cape Town, South Africa. This team has specifically researched and identified the most important issues related to stormwater on the main road found within C-Section. With assistance from the Violence Protection Through Urban Upgrading Program (VPUU), a city funded organization working on aspects of urban upgrading, co-researchers from Monwabisi Park and Dr. Kevin Winter, a professor at the University of Cape Town, this team has identified four problem areas along the road (hot spots). They have researched how to successfully incorporate Sustainable Urban Drainage Systems (SUDS) methods into the informal settlement, while taking into consideration local solutions that have worked effectively with time. By taking precise measurements of road and analyzing different social conditions, the team has assessed the feasibility of implementing an effective stormwater management system in the roads. By preparing this guidebook, they hope to create a plan for future implementation of various methods they have researched to help prevent damages and other issues in these areas that are commonly caused by excessive stormwater runoff and flooding.

This Guidebook

Purpose of this Book

The team has created this book to assist the VPUU and other interested organizations determine appropriate methods to be implemented in Monwabisi Park to help control stormwater runoff and prevent flooding. This guidebook has been organized to outline the existing conditions of each identified hot spot along the C-Section road. The team has specifically identified physical and social conditions found within these areas and have documented the existing interventions already in place by residents. These interventions are explained in great detail and are then referred to as they relate to sections in different areas. The team has also researched many stormwater methods and techniques that have been used throughout other projects (Sustainable Urban Drainage Systems (SUDS)) and they have determined which methods would work best in Monwabisi Park by taking into consideration the available resources and unique conditions of the settlement. These solutions are described in depth and are also referred to as needed throughout the respective hot spot pages.

Even though this guidebook is specific to Monwabisi Park, this book can be used as a guideline for stormwater management in other informal settlements with similar physical and social conditions.

Limitations

During the duration of the project, the team encountered several limitations that did not allow their plan to fully develop. These obstacles varied from political issues to a range of time restrictions, and their summation resulted in a shortcoming of the original concept of the project. The two main, and most limiting constraints were:

Violence Protection through Urban Upgrading Program (VPUU)

One of the major obstacles the team had to work around was the various policies put in place by the VPUU. Through discussions with the team's project advisors and the VPUU liaison, it was determined that the VPUU's methods are very conservative. The team fully understood and respected these views, but unfortunately, the approach of the WPI Project Centre towards redevelopment is much more experimental. The team had prepared for the implementation of a stormwater management plan as the final aspect of their project, but without approval from their sponsoring agency, the team was advised to hold-off on any forms of experimental implementation.

Time Constraints

Another big detriment in the project's goals being completed was due to time constraints. The team only had seven weeks in Cape Town to fulfill the various facets of the project. This provided for a tight schedule, considering their plans for implementation and factoring in the various social, political and economic aspects. Nonetheless, the team felt that if given the opportunity of physical implementation, they would have been able to leave a meaningful legacy for the future development of Monwabisi Park.

Regulations

Spatial Reconfiguration Plan

The Spatial Reconfiguration Plan is a document that has been created by the members of the VPUU, and is currently being improved and completed. It outlines the placement of roads, infrastructural services and major public buildings, in order for them to be developed to eventually create an improved living area that will have the potential to grow and prosper over time. The VPUU is currently working on delineating a logical plan related to how spatial constraints encourage and discourage various social aspects present in areas within informal settlements. These social aspects are focused on promoting positive relations, reducing violence, and improving community-wide interactions. The team's work along the C-section road will be regulated by this plan, and it will assist in determining appropriate solutions that will be accepted by both the residents of Monwabisi Park as well as city officials.

For further information, refer to:
http://www.capetown.gov.za/en/sdf/Pages/default.aspx

Regulations

Biodiversity Regulations

CITY OF CAPE TOWN | ISIDEKO SASEMAPA | STAD KAAPSTAD

THIS CITY WORKS FOR YOU

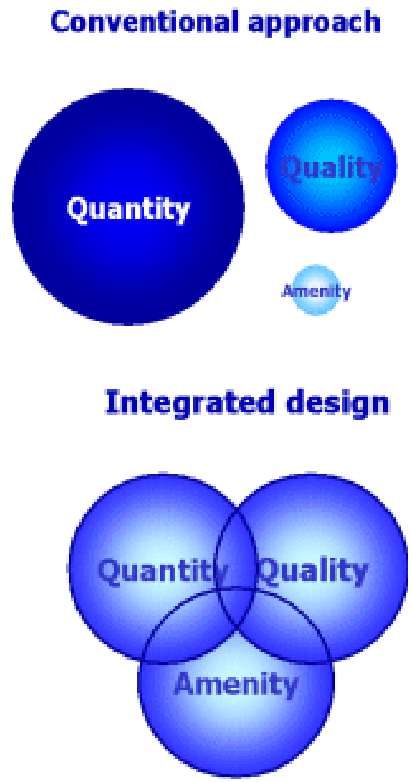
Even though the City of Cape Town is home to one of the most biodiverse areas in the world, the City has struggled in finding a sustainable balance between environmental protection and the economic and social development of the growing population. In reference to this project, the team must be sure to adhere to the different policies that protect the City of Cape Town's unique ecological environment.

Some of the main threats towards biodiversity that the City has recognized include urbanization, invasive species, and agriculture. All of these are relevant to this project given that some of the stormwater management interventions include vegetation as a means of biofiltration and water pollution removal. The team has carefully planned to work within the City constraints by being particularly careful not to use any alien plant species, but instead, use plants that are native to the Western Cape. In this way, the team will be working within the City's legal framework to improve residential life in Monwabisi Park while using plant species that do not interfere with the unique ecosystem that the City of Cape Town harbours (City of Cape Town, 2003).

Sustainable Urban Drainage Systems

What is "SUDS"?

The idea of Sustainable Urban Drainage Systems (SUDS) was developed during the UN Earth summit at Rio de Janerio in 1992 and later adopted in the United Kingdom in 1999. This method came about when crowded areas were facing problems related to draining rainwater, which created a chain of additional, including a reduction of water quality caused by pollutants on the ground. SUDS have taken a more integrated design approach in which the all aspects of water drainage, including the quantity, quality and amenity (such as water resources and community facilities), are treated with the same importance (*SUDS: Background,* 2005). While one of the goals of sustainable drainage systems is to manage the stormwater runoff rate so that it reduces its damaging impact on the environment, sustainable drainage systems also encourage protecting and treating the water from pollutants. Moreover, the overall goal of SUDS is to get community involvement in order to increase the commitment of the community to take care of all the stormwater measures (*SUDS: Background,* 2005). The methodologies of SUDS have already been successfully implemented in England and Scotland, and are now being revised to be used in informal settlements such as Monwabisi Park.



http://www.ciria.com/suds/background.htm

Applying "SUDS" to Informal Settlements

The implementation of SUDS in informal settlements requires much preparation in order to identify all of the technical, institutional, economical, and social factors that may affect the development objectives of the proposed systems. Land constraints and potential interferences caused by preexisting conditions and systems need to be recognized before beginning the project, so that resources can be mapped out and the overall cost can be minimized to the greatest extent (Micou, 2006). A series of oral surveys and field studies can aid not only in the identification of these physical restraints, but also in the generation of maps that lay out which areas are suitable for new drainage systems and methods. These maps can take into account the topography of the area by looking at the varying depressions and elevations. Upon review, an analysis of these land features can determine which areas will be able to successfully accommodate specific methods and systems. Due to the low-income environment within informal settlements, these restrictions are crucial to the implementation of the project. If they are not correctly defined, the proposed costs could be too high and the sustainability of the proposed systems could be negatively affected.

Overview of Methodology

The team followed a systematic methodology in order to gather information and analyze the data. This was divided into five different sections:

Identifying "Hot Spots"

In narrowing down the focus of the project, the team identified 4 major "hot spots" of flooding along the C-section road and recorded their exact location using a Global Positioning System (GPS) as well as the software, Google Earth. These "hot spots" were identified as the areas that are most prone to flooding and had the greatest potential for improvement.

Interviewing of Residents

Realizing that successful implementation was based not only on technical aspects, the team visited Monwabisi Park to gather raw data on the physical and social attributes from the local community members. The information gathered by the team included the overall frequency of flooding, current interventions put in place by residents and the reasoning behind their implementation, insights into collaborations between neighbours and feedback on their proposed solutions.

Overview of Methodology

Spatial Conditions of "Hot Spots"

To accurately depict the sizes of the "hot spots" and the features included within them, the team decided that taking measurements, such as the width and length of the road, the distance of the houses from the road and the slopes of the road, would be beneficial. This data was collected and inputted into a modeling software program, AutoCAD, where floorplans of each "hot spot" were produced.

Generating alternative designs

Having surveyed the four different "hot spots", the team proceeded to evaluate the current interventions for effectiveness. They used this information to determine which SUDS solutions would be the most appropriate for each spot; concluding that soakaways, swales, infiltration trenches and wetlands would be the most suitable.

Guidebook, Poster and Brochure

The team's final product varied for each audience they addressed. A guidebook and a poster were produced for the VPUU's usage in future redevelopment endeavors, while a brochure was created for the residents of Monwabisi Park. This brochure contained information on how to prevent flooding using simple, basic, widespread techniques.

Resident Brochure

The team created a brochure to be used by the residents of Monwabisi Park, to give them ideas on how they can prevent flooding at an individual level. Providing insights into other interventions already in place, they used pictures and diagrams to show the residents how to implement a successful solution.

In collaboration with this guidebook, the brochure incorporates the main aspects of flooding prevention in Monwabisi Park. Using the current interventions described in this book, as well as the proposed solutions, the brochure enables the residents to gain a better understanding of how to manage stormwater runoff.

Resident Brochure

Who we are

We are students from Worcester Polytechnic Institute, a University in the United States. We have been working in collaboration with the VPUU in researching flooding conditions in Monwabisi Park, along the C-section road, and identified "hot spots" of flooding.

We recorded local interventions, cataloged them, and noted their pros and cons. The most efficient solutions are displayed in this brochure, for all residents of Monwabisi Park to use.

Worcester Polytechnic Institute

E-mail: ct10stormwater@wpi.edu

Worcester Polytechnic Institute & VPUU

Flooding in Monwabisi Park: Causes, Prevention and Solutions

Eliminating Flooding, one intervention at a time

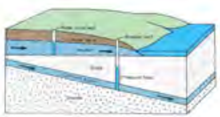
Resident Brochure

Stormwater Management plan

Why do you get flooding?

The major reason for flooding in Monwabisi Park is due to its lowlying topography. Water will naturally flow downhill, and Monwabisi Park is located at the lowest point in its surrounding area.

The lack of proper drainage is also an issue, as the water that stagnates in Monwabisi Park cannot be channeled away without a proper drainage grid. This becomes especially challenging during winter, when the water capacity of the soil becomes easily saturated.



What are residents doing?

There are many simple techniques that residents are presently using to avoid flooding. You may have seen some of these methods and if you use them correctly, they can be efficient in preventing water from entering your house.

Fences

Fences act as a physical barrier for water runoff. Use a layer of cloth and some vegetation to effectively prevent flooding.

Vegetation

A patch of vegetation along the perimeter of a house acts as a physical barrier and absorbent for water runoff.

Tyres

Tyres are used to stabilize sand and they also act as barriers. If tyres are properly placed and secured, they can reduce flooding significantly.

Ditches

Artificial and temporary channels help redirect water away from houses, which work effectively to prevent flooding.

Community Co-op

Collaboration between neighbours results in better preventative methods, quicker implementation and increased social stability.

For example, at the end of C-section road, there is a small community that gathers with communal spades to build a ditch that helps prevent flooding for the stretch of 8 to 10 houses.

Further efforts

The local solutions displayed in this brochure are partially effective, but are not permanent. There are better ways to manage flooding issues, but will need city help to be created:

Swales: culverts with vegetation, that help control water run off velocity and volume

Infiltration trenches: trenches filled with varying sized stones, that filter and redirect the water.

Soakaways: similar to trenches, but with a top layer of grass that helps filter the water.

Wetland: natural or artificial land depressions were water is redirected.

Key Terms

Throughout this guidebook, many "key terms" that will be used to characterize and organize the material presented. These "key words" were chosen by the team because they felt that they were the most appropriate and universal terms to be used with regards to stormwater management. These words have been broken down into four categories to help keep this guidebook informative and organized. These categories include:

1. **Existing physical conditions**

   Characteristics and features of the preexisting landscape of the C-section road and its surrounding areas

2. **Existing social conditions**

   Interactions between the residents along the C-section road that affect the overall interest and motivation for stormwater management plans

3. **Current interventions**

   Present methods and techniques used throughout the C-section road (implemented by residents) to minimize excess water flow and flooding

4. **Possible solutions**

   SUDS methods (adapted to the conditions of Monwabisi Park) identified by the team that are appropriate for implementation and easy to maintain along the C-section road

These categories help develop a more in depth understanding of the environment and current situations present in these areas.

Key Terms: Physical Conditions

Existing Physical Conditions

Low-lying: The topography of these areas is flat and does not contain any hills or depressions. These areas are often found at the base of a hill or in between two hills, making them very susceptible to high amounts of flooding and standing water.

Uphill slope: These areas are characterized by an increasing slope, determined by the direction they are being observed at*. This increase in slope can vary, ranging from a slight raise of ~15˚ to a steep incline of ~50˚. The areas that are most prone to flooding in uphill regions are the areas toward the bottom end of the slope, where water is naturally directed by gravity.

Downhill slope: These areas are characterized by a decreasing slope, determined by the direction they are being observed*. This decrease in slope can vary, ranging from a small drop of ~15˚ to a sharp decline of ~50˚. The areas that are most vulnerable to flooding in downhill regions are the areas on the lower end of decline, where water naturally flows as a result of gravity.

In this guidebook, the team will be observing all areas from Mew Way, viewing the road from north to south.

Key Terms: Physical Conditions

Existing Physical Conditions

Uneven Surface: Sections along the length of the road are comprised of protrusions caused by rocks and small divots. These varying levels throughout the width of the road disturb the natural flow of water, causing it to pool and eventually spread to nearby side roads and houses.

Vegetation: Grasses, small plants, and shrubs are found alongside the road, bordering the yards of houses. They are found in small clumps and are sporadically spread along the length and width of the road. Some grasses are found within ditches, and they help to capture excess runoff from both rainwater and communal tap water.

Key Terms: Social Conditions

Existing Social Conditions

Tension: As a result of miscommunication and misperceptions regarding problems arising from stormwater between neighbours and community members, uncertainty and frustration occur. There are different levels of tension with regards to issues related to stormwater management and this guidebook will define them using a scale of 1-10. "1" defines minimal frustration and lack of acceptance of other residents' ideas, while "10" demonstrates a sense of aggravation and annoyance between neighbouring residents. These scales were determined based on responses from interviews of the local residents.

Low Tension (1-5): Verbal disagreements are a very common result of stormwater management concerns along the road. At this level, community members put forward an effort to work with each other, but their ideas may conflict with one another, and a lack of trust begins to form. This level of tension is usually characterized by controlled criticism and slightly apprehensive conversations.

High Tension (6-10): Disagreements between neighbouring residents result from many issues related to stormwater. Personal interventions to prevent water from entering houses may conflict with other interventions put in place by other residents. This leads to verbal conflicts and arguments and can sometimes escalate into physical conflict, which only occur on a rare occasion.

Key Terms: Social Conditions

Existing Social Conditions

Awareness: With regards to stormwater management, the wealth of knowledge varies throughout the residents. Contributing factors to the overall awareness include knowing how the water effects the roads and houses, knowing how to cope with excess water runoff, and understanding how to effectively work with existing conditions to benefit the community in a way that helps to prevent excessive flooding. On a scale from 1-10, the awareness of stormwater management can be defined as "1" identifying minimal knowledge and background of the subject, and "10" demonstrating an in depth and profound understanding of the subject. These scales were determined based on responses from interviews of the local residents.

Low Awareness (1-5): The lack of understanding stormwater management is very common along the road. Residents who do not have the knowledge and appropriate information regarding this subject often do not understand the benefits that preventative measures can bring. This results in dysfunctional personal interventions and a lack a interest towards providing a community-wide preventative method that has the ability to decrease the overall amount of flooding within an area.

High Awareness (6-10): A deep understanding of stormwater management practices is mildly prevalent throughout the road. Residents who hold this level of knowledge are often characterized by a community leader who is supported by a close and tight community. These areas possess a variety of preventative techniques against stormwater both at personal levels and at community-wide levels.

Key Terms: Social Conditions

Existing Social Conditions

Cooperative Collaboration: The will to work together as a small community is witnessed in various areas along the road. The organization of a small group of residents by one or two "leaders" results in neighbours sharing their knowledge and ideas to work as a team to implement a stormwater management intervention that benefits the entire community. Residents not only share their knowledge, but they share tools and other materials to eliminate costs and minimize overall labour time.

Voluntary Isolation: The lack of enthusiasm and, incorporated with conflicts between neighbouring residents results in people working alone to implement a personal stormwater management intervention. These personal interventions may or may not be successful due to the shortage of labour and resources. The detached attitude that these residents possess is a direct cause of this condition and it is often hard to change. This situation leads to increased levels of tension and greatly effects the ability of the surrounding community to work together and benefit as a whole.

Key Terms: Current Interventions

Current Interventions

Water Barrier: To prevent standing water and water runoff from spreading across the road and into houses, hurdles have been implemented to block the water from travelling further and into unwanted areas. These blockades serve as an obstruction to both the movement and relevant flow of water.

Water Redirection: Interventions that are strategically designed to change the direction of the flow of water assist in eliminating the amount of water that enters houses. These redirection techniques allow residents to form paths during the dry season to prepare for the large amount of water encountered during the heavy rain season. Paths can be created on either a personal level, which relocates the water into a neighbouring yard, or on a community level, which redirects the water along the side of the road toward the end of the road or into a highly vegetated area.

Key Terms: Current Interventions

Current Interventions

Functional: Interventions that successfully prevent water from entering a designated, unwanted area (either a yard or a house), can be classified as functional.

Dysfunctional: Interventions that do not successfully prevent water from entering a designated area (either a yard or a house), can be classified as dysfunctional. In this guidebook, this term will be used to identify any intervention that allows any amount of unwanted water, whether it is a large or small amount, into an unwanted area.

Unsuitable: Interventions are often duplicated along the road by various residents. Some residents create a fully functional design, while others who try to repeat the design, create an intervention that does not primarily serve to prevent flooding. These interventions will be referred to as unsuitable throughout this guidebook due to their improper construction and misunderstanding of the original, appropriate intention of the design.

Key Terms: Current Interventions

Current Interventions

Personal: Interventions that are implemented by individual community members are prevalent along the road. These designs are put into practice to protect a specific resident's yard and/or house from both standing water and flooding. They are designed to benefit a specific person or family, and they often effect neighbouring houses and yards.

Collaborative: Interventions that are implemented by multiple residents working together are not commonly found alongside the road. These preventative methods are designed to benefit an entire area and small community, and they usually are implemented in the proximity of four to five houses that neighbour each other.

Proposed Solutions

Long-term: Solutions that will require at least six months of preparation will be classified as "long-term." This preparation may involve the procurement of appropriate materials (through contractors), the approval of various organizations (local government, provincial government and street committees), and the obtainment of community involvement (both local residents and city officials).

Short-Term: Solutions that will require less than six months of preparation will be classified as "short-term." This preparation my involve the procurement of materials (local, readily available), the agreement of organizations involved (local government and street committees), and the obtainment of community involvement (local residents).

Material/Resource Intensive: Solutions that require numerous materials and resources (more than five different items) or large amounts (anything that requires outside assistance to transport/move) of specific materials and resources will be classified as "material/resource intensive." These materials and resources may be obtained from local vendors or contractors throughout neighbouring areas.

Key Terms: Proposed Solutions

Proposed Solutions

Water Redirection: Solutions that are strategically designed to change the direction of the flow of water serve to direct the water away from the houses, eliminating the amount of water that enters the houses. These redirection techniques allow residents to form paths during the dry season to prepare for the large amount of water encountered during the heavy rain season. Paths can be created on either a personal level, relocating the water into a neighbouring yard, or on a community level, redirecting the water along the side of the road toward the end of the road or into a highly vegetated area.

Water Catchment: Solutions that are designed to trap and hold excess water can be used to collect runoff from both stormwater and communal taps. These interventions allow residents to redirect water into a designated and contained area that can be maintained and monitored to accumulate the greatest amount of water in the most efficient manner.

Key Terms: Proposed Solutions

Proposed Solutions

Management: Solutions will require both maintenance and monitoring to ensure optimal use of the intervention. Depending on the level of management the solution requires, maintenance will entail proper care, knowledge and understanding of the intervention by various people. This level will be determined by a scale of "1-10", where "1" will demonstrate limited involvement of different people, and "10" will demonstrate a collaboration of multiple people to ensure that the solution stays functional and usable. These scales were determined based on responses from interviews of the local residents.

Low Management (1-5): Solutions that will require the involvement of only a select number of people at the local level to ensure that the intervention is well maintained and the community is properly informed on how to use it are classified as "low management." The individuals involved may include members from local street committees or local residents who live alongside the road.

High Management (6-10): Solutions that will require the involvement of representatives from various organizations to ensure that the intervention is well maintained and the community is properly informed on how to use it are classified as "high management." These organizations may include both local and provincial governments, street committees, and local residents.

Map of the C-Section Road

(Hot Spots identified in red)

Current Interventions

Throughout the entirety of the C-section road, residents have implemented both individual and community-wide interventions to assist in controlling stormwater runoff and minimizing household flooding. The following section details the numerous existing interventions found along the road and provides a concise explanation of why residents use these techniques.

Each intervention is briefly described, providing details of how it works to prevent the damages caused by stormwater. This description is followed by a "Key Features" segment that emphasizes the important aspects and attributes of each intervention.

Current Interventions

Fences

There are a variety of fences found along the C-section road. These fences serve as a barrier against both rainwater and communal tap water runoff and are designed to prevent household flooding. They are commonly built around the perimeter of individual yards and they are often incorporated with other interventions to reinforce their stability and functionality. Due to them being built directly into the sandy ground, over time they sink into the sand and become lowered.

Dimensions: Height: 1 meter – 1.5 meters
Width: Typically the same width as the house

Key Features of Fences

Varied Materials

Most fences found within the C-section road are made out of a variety of materials. Thin boards of wood are used commonly as poles to hold the fences up, while the materials that hold these poles together vary from house to house. Some people use strands of wire to hold the wood together, while others use scrap pieces of metal siding to keep the poles standing. In some rare cases, both metal wiring and metal siding was used. With regards to stormwater management, the fences that are the most successful in preventing water from entering yards and houses are the ones that are metal. They create a barrier against the water, and help to redirect it around the yard. However, it usually directs it into another near by, neighbouring yard.

Another material that is commonly integrated into the design of a fence is a shadecloth. Shadecloths are large pieces of materials with a dark green tint that serve to help block the sun and provide privacy to the residents who reside in that area. Shadecloths are commonly not used as a method of stormwater management, but some people do consider this technique, and claim that it does help to create a small barrier against the water. In most cases it allows water to enter yards, but it helps to debilitate the overall flow of water.

Current Interventions

Tyres

Old automobile tyres that are made out of a sturdy, rubber material and that are found along the main road (Mew Way) and throughout the settlement are used in various ways to help prevent household flooding. When incorporated with the sand found along the road, they can be very useful in producing a stable road surface that is able to withstand the pressures of water runoff. Tyres are used to stabilize the sand and prevent it from moving and shifting during a rain storm. They can also be used to form a barrier against water by being stacked on top of one another, ultimately forming a wall-like structure that is similar to a fence.

Dimension: Height: 1 – 3 tires
Width: usually the width of the house

Key Features of Tyres

Incorporation with Sand

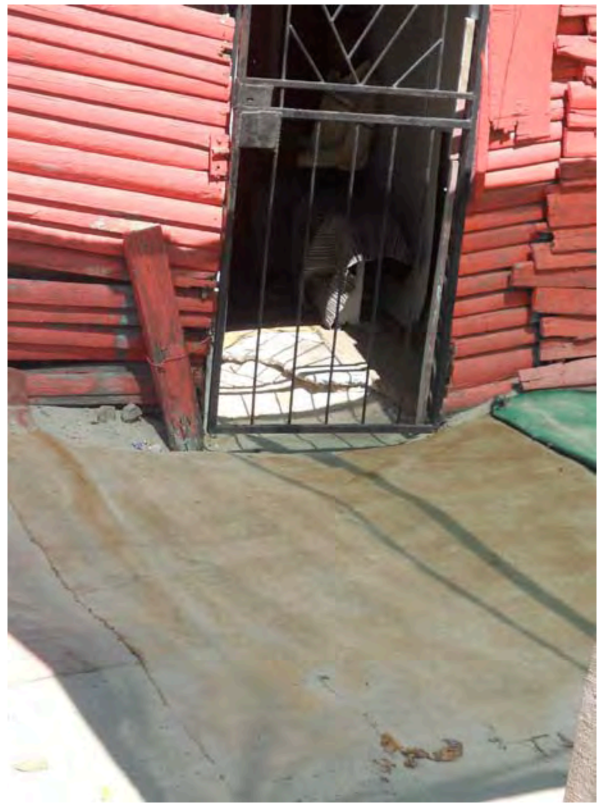
The two main designs that residents use to manage stormwater involve either burying the tyres into the sand or stacking the tyres on top of one another and then filling them with sand. Burying the tires into the sand stabilizes the sand and help to reinforce the ground by providing enough extra support to keep the sand from moving around and creating unwanted natural paths and channels that redirects water into houses and shacks. The other design that involves stacked tyres allows the tyres to form a barrier against the water, and the sand inside of the tyres creates a sturdier base for the tyres to stand upon. Without the sand in the tyres, they would not be strong enough to redirect the water, as the flow would be too powerful and would begin to move the tyres and knock them over.

Accessibility

Tyres are very abundant in Monwabisi Park and can be easily obtained from the sides of roads and in abandoned areas or can be bought cheaply. Due to their convenience, many people accumulate tyres over time and use them to create barriers against the water during the rainy season. Unfortunately, the ease of access of tyres is not always a positive thing. When the rainy season arrives and certain community members are unprepared for it, they tend to steal tires from other people who are using them to help protect their yards and houses. This causes conflict between neighbours and results in the lack of trust between numerous community members.

Culverts/Holes

Throughout the C-section road, many residents have begun to dig out small areas around their yards and in front of their doorways to help capture the rainwater and prevent it from entering their houses. These culverts can also be found alongside the road to help redirect water away from houses and into a communal area where no one currently resides. Some of these culverts work very well, as they are built along a sloped area, allowing them to work with gravity to aid the proper direction of water. However, there have also been culverts dug along the perimeters of various residents' yards that redirect the water into the yards of neighbouring residents.



Similarly to culverts, some residents dig different sized holes in front of their doorways in hopes of creating a trap for the water. The goal of these holes is for them to be deep enough so they can lower the height of water when it comes in contact with the house, but shallow enough to not create a dangerous environment (one that someone may trip on, or fall in). These holes are very common, and usually help to prevent a large portion of flooding.

Current Interventions

Key Features of Culverts/Holes

Varied Size

The sizes of the ditches and holes vary depending on their location along the C-section road. These interventions are very adaptable to different conditions, and can be created in numerous, varying areas. Some ditches are approximately a half meter in width, and are commonly found alongside the road, while other ditches are only a quarter of a meter wide and are found in smaller, narrower areas (between houses, along yards). The ability of these interventions to vary in size allows them to be used very commonly by residents who live in different areas and in different conditions. The sizes of holes, most generally the ones found in front of doorways, range from a quarter of a meter in diameter, all the way to a meter in diameter. These larger holes are less commonly found within individual yards, and are located at the ends of side roads to help prevent flooding for numerous residents.

Dimensions: Height: 15 centimeters -30 centimeters
Width: 0.5 meters – 1 meter

Current Interventions

Accumulation of Sand

Residents have strategically piled up sand both along the perimeter of their yard and at the base of their house, which helps create a barrier against stormwater flowing into the houses. The residents who build up the sand along the perimeter of their yard commonly do so by incorporating it into an existing fence to cover up any holes in the fence. This also stabilizes the fence. The other method of using sand around the base of a house serves to reinforce the foundation, and provides a shield between the water and the walls of the house. This helps to keep water from coming in contact with the house, eliminating the amount of damage seen by floors and furniture, that is caused by water.

Dimension: Height: 15 centimeters – 30 centimeters
Width: Length of the side of the house

Current Interventions

Key Features of Accumulation of Sand

Temporary Nature of Sand Piling

The use of sand as a preventative method against stormwater is often seen as counter productive. The build up of sand is much stronger than loose sand found within the road, but it is still not strong enough to form a barrier against powerful stormwater flows. Over time, the sand begins to shift, and the barrier that the residents had formed with it eventually breaks down and begins to allow water to push through it.

Incorporation with Other Current Interventions

Due to the unreliability of sand, many residents have realized that by incorporating it into other interventions, it can be more useful and beneficial. The main intervention that sand is incorporated with is tyres and this method is frequently found along the C-section road. Sand is also commonly incorporated with fences, used mostly as a stabilizer to ensure that the fence will stay intact during rain storms and wind storms.

Current Interventions

Vegetation

Small patches of vegetation, such as grass and small shrubs can be found throughout the C-section road. The grassy areas are commonly located alongside the road, bordering the fronts of residents' yards, and serving to help catch excess water to direct it to various places both on and off the road. Some residents have vegetation in their yards and around the base of their houses, which serves as small, commonly useless, barrier between the house and excess water, but it also helps to catch the water and encourages it to soak into the ground.

Another form of vegetation that is commonly found along the road in this area is small shrubs. Commonly, they resemble a small fence, but they have much greater open space throughout them, which allows water to easily flow through.

Dimensions for grasses: Height: 15 centimeters – 30 centimeters
Width: along the side of the house

Dimensions for shrubs: Height: 1 meter – 1.5 meters
Width: along the side of the house

Current Interventions

Key Features of Vegetation

Grass

Many types of grass are found along the C-section road and in Monwabisi Park. The most common grass is referred to as Buffalo Grass (*S. secundatum*), which is indigenous to Cape Town. This grass is found sporadically alongside the road and throughout residents' yards. Unfortunately, the grass is not well maintained, so there are only a few prominent strips while the rest is found in small patches. This grass helps to soak up and catch the rainwater as well as excess water that runs the length of the road.

Shrubs

The shrubs found along the C-section road are most commonly used as fences and barriers against the water. They are placed along the bordering section of yards with the road, and they also serve to provide privacy and isolation to many residents.

Current Interventions

Rocks

Rocks and stones are found throughout and along the entire length of the C-section road. They are buried both completely and partially in the sand. They serve to help stabilize the sand and help to prevent it from shifting and moving around. Unfortunately, the rocks that are only buried partially create an uneven surface and disrupt the natural flow path of water, resulting in spreading and flooding in unwanted areas (off of side roads, and into yards and houses). Residents have taken some of these rocks and incorporated them into their yards to prevent flooding. In some cases, large rocks have been used and lined up across the perimeter of the yard to create a barrier against the water. These rocks serve a similar purpose as fences, but they are often hard to acquire, so the barriers have open spaces and large gaps enabling the water to flow through into the yards.

Key Features of Rocks

Varied Size (Dimensions of the different rocks)

Depending on the size of the rock used along the road, the purpose that it serves can vary greatly. Within the road itself, both small stones, as well as medium sized rocks can be found. The small stones, approximately two to three centimeters in diameter, help to keep the road level and provide the sand with a slight amount of stability. The medium sized rocks, roughly fifteen to twenty centimeters in diameter, serve to keep the sand in certain areas of the road from moving around and shifting. These medium rocks are successful in doing this when they are completely buried, but when they are protruding from the surface of the road, they begin to redirect the water and enable it to spread to areas where the water is unwanted (yards and houses).

Alongside the road, there are rocks that are much larger in size, about half a meter in diameter, that are used at a more personal, individual level. These rocks, due to their size, are placed above the ground and are located directly next to one another to form a barrier against the water.

Current Interventions

Wooden Ledges/Boards

Many houses along the C-section road are located in valleys and low-lying areas. This predisposes these houses to a greater amount of flooding, and it has resulted in many residents building small interventions, such as wooden ledges in front of their doorways and around their yards to help block the water. These ledges are made from long, thin scraps of wood (mostly frequently found along Mew Way) and are positioned either along the perimeter of yards, or directly in front of doorways. They serve not only to block the water from entering the unwanted areas (yards and houses), but they also assist in redirecting the water into either neighbouring yards or central areas where water accumulates and pools.

Dimensions: Height: 10 centimeters – 20 centimeters from the ground
Width: Length of the door
*It is buried 10 centimeters – 15 centimeters into the ground

Key Features of Wooden Ledges/Boards

Permanency

Wooden ledges and boards are built securely into the ground, so that they are able to stand upright and endure the forces of water witnessed during the heavy rain seasons. Due to these slabs of wood being positioned deeply into the ground, they are often hard to remove. This is often seen as an added benefit, because they do not need to be replaced after each rainstorm, except for when the wood rots and decays overtime. The elimination of constant management with these interventions is very beneficial to the residents. Unfortunately, some see this permanency as an obstacle and problem. If the ledge is not working properly, or it was placed in the wrong area, the time and labour that must go into removing and relocating it is sometimes excessive.

Current Interventions

Raised Platforms

To prevent stormwater and communal tap water runoff from entering houses, some residents have designed raised platforms that enable their yards and houses to sit above the road level. These houses are often found at the bottom of hills and in low-lying areas, where flooding is the most prominent. The raised platforms incorporate scrap pieces of wood found throughout the settlement to create a border along the entirety of the yards, primarily composed of excess sand. The boards provide an outline for the sand and a barrier against the water. The risk of flooding is highly decreased since the whole house is raised above the ground.

Key Features of Raised Platforms

Permanency

Similar to wooden ledges and boards, raised platforms are very permanent. They are often time consuming to initially implement, but once they are in place, they are very hard to remove. The wood pieces need to be dug into the ground, and need to be strategically placed so that they form a complete enclosure. The inner layer of sand also contributes to the permanent nature of this intervention because it becomes packed down over time and forms a raised layer within itself. The boards primarily act as a support to keep the sand in one area, but after the first rainfall, the sand becomes saturated and compacted, creating a firm and sturdy layer.

Aesthetic Appeal

Raised platforms are not common along the C-section road. Due to the large amount of time and labour that goes into designing and building such an intervention, many residents choose to implement a smaller plan to manage stormwater. Even though they are not frequent in this area, the raised platforms that have been built are often well maintained and cared for. Many residents who put the time and effort into implementing and maintaining a raised platform often incorporate other aspects of design into their overall intervention, such as vegetation and shrubs.

Plastic

Incorporated with sand and other select materials (metal siding, scrap wood), plastic is used to help stabilize the sand and protect houses from coming in direct contact with water. The plastic is intended to create a barrier between the sand and the walls of the houses, to eliminate the amount of damage caused by stormwater. The plastic can be located either between a layer of built up sand and the outside walls of houses, or it can be placed between the outside walls and inside walls, including the floors of houses. When placed between the sand and walls, the primary purpose of the plastic is to stabilize the sand and assist in preventing it from shifting around and breaking down around the houses. When located on the inner portion of the houses, the plastic serves to block the water from entering. When the water comes in contact with the walls, it often seeps through small cracks and holes, but with the extra layer of plastic in place, the water is unable to proceed any further, severely decreasing the amount of household flooding.

Key Features of Plastic

Thickness

Different types of plastic are used throughout Monwabisi Park to assist in the management of stormwater. These plastics range from thin, garbage bag-type consistency, to thick, unbendable forms of plastic that are commonly used in high-strength industrial products. The thick plastics perform better overtime when it comes to forming a steady, reliable barrier against water, but they are often more expensive and harder to find. The thin plastics are much more assessable, and they are consistently less expensive. Unfortunately, these plastics tend to disintegrate with time, and they begin to break down, preventing them from creating a sturdy, reliable barrier.

Proposed Solutions

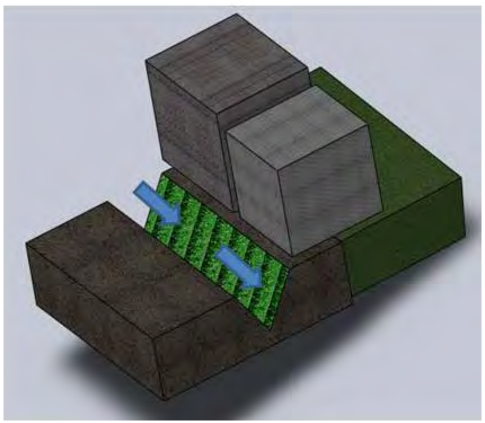
After analyzing and compiling the data that the team gathered from interviews and field studies conducted along the C-section road, they identified four stormwater management solutions that would be appropriate for implementation in this area. Incorporating ideas from past projects using SUDS methods in formal settlements, the team created specific interventions that could properly adapt to the existing conditions of Monwabisi Park. The following section details these four proposed solutions and provides a concise explanation of why each intervention would be beneficial if placed in an informal settlement.

Each proposed solution is briefly detailed, providing a short description of how it works to prevent the damages caused by stormwater. This description is followed by a "Key Features" segment that emphasizes the important aspects and attributes of each intervention and method.

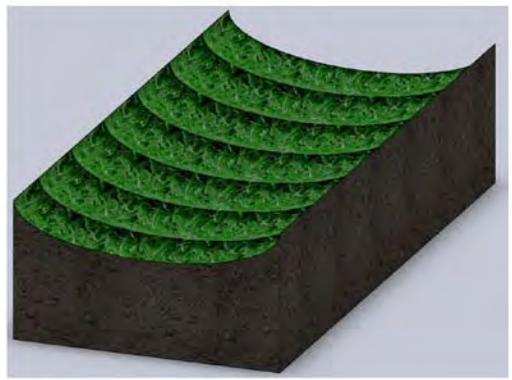
Proposed Solutions: Swales

Artificial Swales

Artificial swales are narrow ditches dug into the ground, often into a low-lying area along a preexisting, natural water flow path. These ditches are covered with vegetation and are designed to help promote the spread and directed flow of rainwater and other sources of runoff. They can range in size, but commonly they are approximately **five to ten meters in length, a quarter of a meter to a half of a meter deep (measured at the center of the ditch), and roughly one to two meters wide**. By spreading the water runoff, artificial swales are able to slow the rate at which the water flows as well as capture the water, so it can be managed and concentrated into a certain area.



Computer generated (SolidWorks) model of an artificial swale



Cross-sectional view of an artificial swale

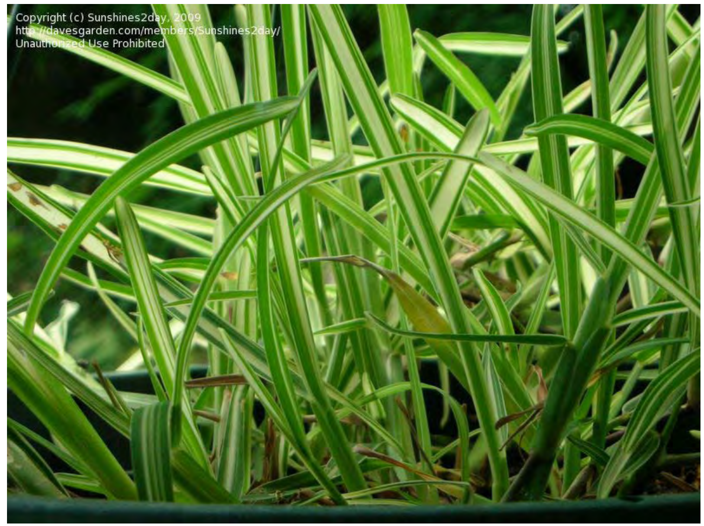
Proposed Solutions: Swales

Key Features of Artificial Swales

Vegetation

The layer of vegetation that covers the ditch in an artificial swale is strategically comprised of specific plants that assist in both the catchment and direction of water. Grasses are commonly used in these designs, as they are easy and fast to grow, easy to manage, and are small enough to stay contained within the boundaries of the overall swale.

Dr. Kevin Winter from the University of Cape Town has been studying a variety of indigenous grasses and plants to be used within Monwabisi Park. Specifically for artificial swales, he suggests to use small grasses that are very accessible in Cape Town. These grasses can be found alongside roads, as well as in populated residential areas. The proposed grass to be used in an artificial swale in Monwabisi Park is an indigenous grass, *Stenotaphrum secundatum* (Buffalo Grass).



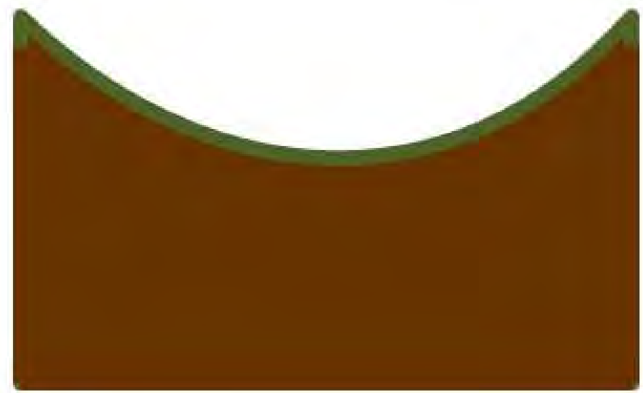
S. secundatum
(Buffalo Grass)

Key Features of Artificial Swales

Dish-shaped ditch

The design of an artificial swale is crucial to its functionality and rate of success. Ideally, a swale should be created in such a way that the ditch forms a dish-like shape. This allows for a greater amount of water to be redirected in a shorter period of time and it provides a greater surface area in which water can be captured.

For an artificial swale to be successful in Monwabisi Park, it will need to be built on a small slope, no greater than 15°, and it must be designed to incorporate a shallow, wide, dish-shaped channel. By being built on a gentle slope, the water will naturally flow into the shallow trough and spread across the dish-shaped area, allowing it to be redirected toward the end of the swale.



Ideal shape of ditch

Proposed Solutions: Artificial Swales

Proposed Implementation of Artificial Swales

In order to have successful implementation of swales in an informal settlement like Monwabisi Park, there are different factors that need to be addressed:

- **Planning:** Before breaking any ground, a thorough study of the road itself is needed. In this way, all of the engineering solutions can be calculated, which are important in determining the speed and volume of the runoff flowing through the swale. It is also important to get the community involved so that they can replicate these solutions in the future.

- **Materials:** Securing all of the necessary materials is also a crucial step in the implementation process. The raw materials, such as soil and vegetation, have to be funded, which in Monwabisi Park's case, will almost certainly translate to government or external aid. Building tools, such as spades and tape measures, can most likely be obtained from within the community.

- **Human Labour:** In terms of who would physically build the swales, the implementation team would follow the SUDS philosophy closely and empower the community by allowing them to build it. Community leaders would be appointed and they would rally other members into action, hence producing a result that is significant to the residents.

Proposed Maintenance of Artificial Swales

Swales are considered a low-maintenance SUDS solution. The short-term management aspect will require supervision in specific areas only, including interval cutting of the vegetation that controls the velocity of the water runoff, and the monitoring of the swale to clean blockages or prevent them.

The swale, being a low-maintenance solution, would only require local community organization in order for it to be properly maintained. Community boards can be created in rather small stretches along the road, which will assist in making the supervision more personal, and thus more significant to the residents.

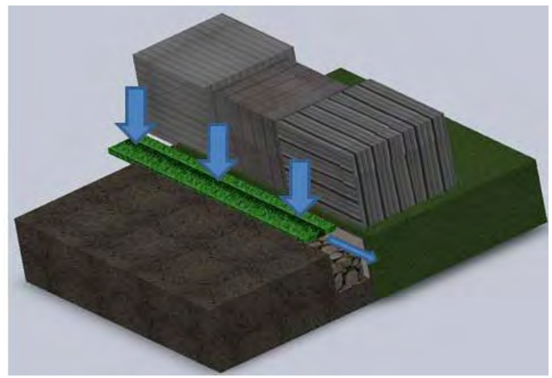
The long-term management aspect will include the education of residents living around the swale to enhance their understanding of the overall function of the intervention, as well as its benefits and how to make it keep it functioning in the most efficient manner.

Proposed Solutions: Soakaways

Soakaways

Soakaways are ditches dug into the ground, **approximately one meter deep by one and a half meters wide and approximately four to six meters in length,** that are filled with a layer of rocks and covered in a layer of vegetation. The main goal of a soakaway is to capture water runoff from the ground level and allow it to soak into the ground and be redirected to a specified area that is designed to manage large amounts of water. The layer of rocks act as a filtration system, and they help to cleanse the water and soak up the nutrients, which in return, are used to promote the growth of the plants within the layer of vegetation. The layer of vegetation serves to capture the rainwater and runoff, and also plays an important role in cleansing and filtering the water as it is soaked into the ground.

Cross-sectional view of a soakaway



Computer generated (SolidWorks) model of a soakaway

Proposed Solutions: Soakaways

Key Features of Soakaways

Vegetation Layer

The proposed plants to be used in the vegetation layer include a variety of indigenous plants found and grown in Cape Town. These plants are currently being researched at the University of Cape Town by Dr. Kevin Winter, to determine their ability to filter certain nutrients from water. The plants that will be the most beneficial to Monwabisi Park are the ones that can absorb a variety of nutrients, including phosphates, nitrates, and ammonia, and those that are easy to manage.

As per Dr. Winter's suggestions, the three most valuable plants to be implemented in a soakaway for use in Monwabisi Park would include:

1. *Zantedeschia aethiopica* (Arum Lily)
2. *Nymphaea nouchali* var. *caerulea* (Blue Lily)
3. *Strelitzia juncea* (Crane Flower)

http://www.milliwaysnurseries.com/Zantedeschia%20aethiopica.html

Z. aethiopica (Arum Lily)
- 30% absorbency of nutrients
- Highly prevalent in Western Cape, easy to obtain

N. nouchali var. *caerulea* (Blue Lily)
- 50% absorbency of nutrients

http://www.plantzafrica.com/plantnop/nymphnouch.htm

http://www.plantzafrica.com/plantqrs/strelitzjun.htm

S. Juncea (Crane Flower)
- 60% absorbency of nutrients
- Reeds can be used to make mats and matted shacks

Proposed Solutions: Soakaways

Proposed Implementation of Soakaways

In order to have a successful implementation of soakaways in an informal settlement like Monwabisi Park, there are different factors that need to be addressed:

- **Planning:** Before any construction takes place, a in-depth study of the road itself is needed to determine the capacity of the soakaway, its spatial dimensions, the varying sizes of stones and the type of vegetation used. It is also necessary to look into the City of Cape Town standards to make sure that native vegetation, rather than alien plants, is used. It is also necessary to gain community involvement.

- **Materials:**. The raw materials, such as stones and vegetation, have to be funded, which in Monwabisi Park's case will almost certainly translate to government or external aid. Building tools, such as spades and tape measures, can be obtained from within the community.

- **Human Labour:** In the actual building of the soakaways, the implementation team would follow the SUDS philosophy closely and allow the community to build it themselves. Community leaders would be appointed and they would take the lead on the final product.

Proposed Solutions: Soakaways

Proposed Maintenance of Soakaways

Soakaways are considered a low-maintenance SUDS solution. The short-term management aspect will require supervision in select areas only, including interval cutting of the top layer of vegetation that controls the velocity of the water runoff and creates an initial filter, and the monitoring of the trench to remove blockages and prevent them.

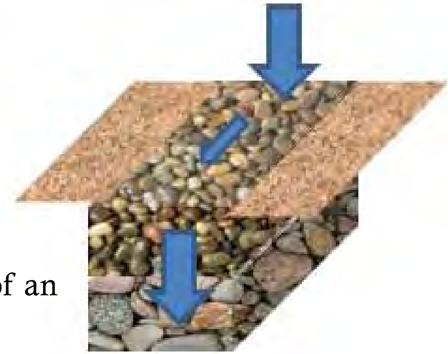
Being a low-maintenance solution, infiltration trenches will only require local community organization for proper maintenance. This can include community boards, that can be created along small stretches of the road, which would make the supervision of this intervention more personal, and thus more significant to the residents.

The long-term management aspect of this solution will include the education of residents living in close proximity of the soakaways, so that they can learn and fully understand the proper function of it, its benefits and how to efficiently ensure that is works and stays functional over a long period of time.

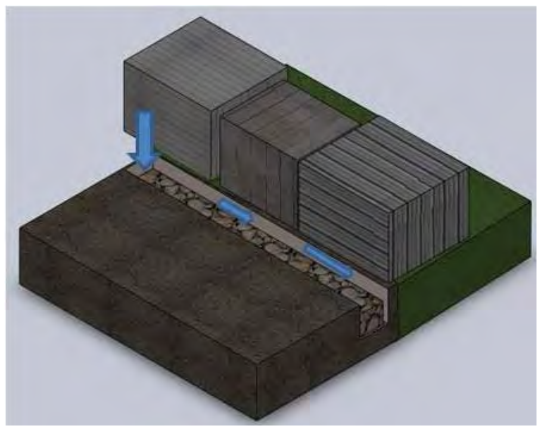
Proposed Solutions: Infiltration Trenches

Infiltration Trenches

Infiltration trenches are ditches dug into the ground covered in layers of various types of rocks (depending on their size). The bottom most layer is comprised of large rocks and is topped with a layer of smaller stones. The third layer is made up of small pebbles, which is approximately even with the level of the ground. The purpose of these three levels is to create a filtration system that allows water to travel through the layers while being filtered and cleansed of pollutants. **These trenches are approximately a meter deep, between three quarters of a meter and a meter wide, and range anywhere from four to eight meters in length.**



Cross-sectional view of an infiltration trench



Computer-generated (SolidWorks) model of an infiltration trench

Proposed Solutions: Infiltration Trenches

Key Features of Infiltration Trenches

Rocks, Stones and Pebbles

The three layers found within an infiltration trench are comprised of different sized components to enable the trench to efficiently filter the water that runs through it. The top layer is made up of the smallest pieces, most commonly pebbles, and acts as an initial filter to rid the water of large particles such as rubbish and other waste products. The next layer, the middle layer, contains slightly larger components such as stones. This layer cleanses the water as well and helps to eliminate potential pollutants and other small elements. The bottom layer, comprised of larger rocks, serves as a final filter and helps to remove any remaining small particles, pollutants and other matter that was not filtered out by the first two layers.

Layer 1: Pebbles

Layer 2: Stones

Layer 3: Rocks

Proposed Solutions: Infiltration Trenches

Proposed Implementation of Infiltration Trenches

In order to have a successful implementation of infiltration trenches in an informal settlement like Monwabisi Park, there are different factors that need to be addressed:

- **Planning:** Similar to planning the building of artificial swales, analysis of the selected area and a study of the proposed literature is required. It is also important to obtain community involvement.

- **Materials:** Securing all of the necessary materials is also a crucial step in the implementation process. The raw materials, such as varying sized stones, and plastic covers, have to be funded, which in Monwabisi Park's case will most likely translate to government or external aid. Building tools, such as spades and tape measures, can possibly be obtained from within the community.

- **Human Labour:** In terms of who would physically build the trenches, the implementation team would follow the SUDS philosophy closely and empower the community by allowing them to build it. Community leaders would be appointed and they would rally other members into action, hence producing a result that is significant to the residents.

Proposed Solutions: Infiltration Trenches

Proposed Maintenance of Infiltration Trenches

Infiltration trenches are considered a low-maintenance SUDS solution. The short-term management aspect of this solution will require supervision in select areas only, such as the monitoring of the trench to remove blockages and prevent them, and ensuring that the stones in the ditch are not removed or stolen.

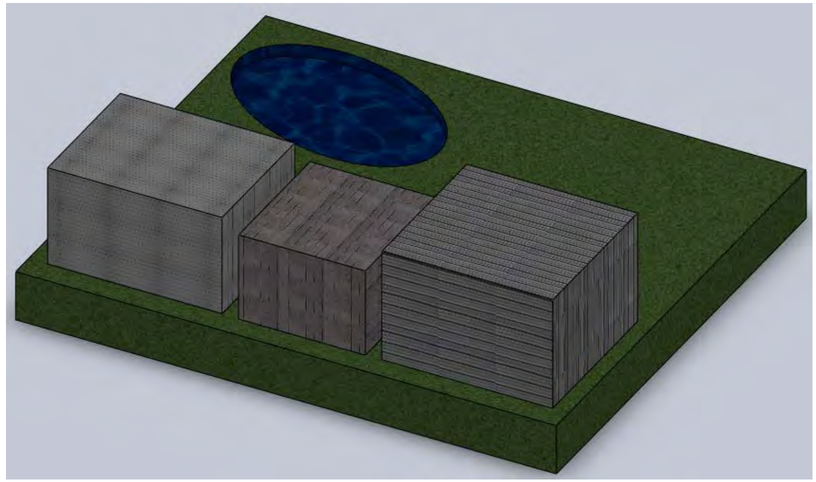
Being a low-maintenance solution, infiltration trenches will only require local community organization for proper maintenance. This can include community boards, that can be created along small stretches of the road, which would make the supervision of this intervention more personal, and thus more significant to the residents.

The long-term management aspect will include the education of the residents living around the trench, allowing them to learn about the proper function of the solution, its benefits regarding both the individual and community-wide levels, and how to ensure it will successfully function overtime.

Proposed Solutions: Wetlands

Wetlands

A wetland is an area of land that is used to maintain and hold large amounts of water. It is often found in a low-lying area in a vegetated and marshy environment. The soil of this area is very moist, and often completely saturated, which creates small pools of water. They are characterized by minimal standing water, which is used to promote and assist the growth of seasonal plants. Wetlands help to capture and gather water, from rain and runoff, and they incorporate it into a natural environment. They are areas of rich biodiversity (see biodiversity regulations), as they are home to a variety of plants and animals, such as lilies, cattails, amphibians and insects.



Computer-generated (SolidWorks) model of a wetland

Proposed Solutions: Wetlands

Key Features of Wetlands

Plant Life

Wetlands rely heavily on the plants that grow within them. Due to the marshy environment that they are comprised of, there are only specific plants that can thrive and successfully live in them. The soil is often very saturated, and this condition contributes to the limitations defining what plants can be found in these areas. Plants that are commonly found in wetlands include a variety of tall grasses and reeds, as well as lilies and other small flowering plants.

For a wetland in Monwabisi Park, conservation and biodiversity regulations need to be taken into consideration. As per Dr. Kevin Winter's (UCT) recommendations, the plants that would be the best suited for a Monwabisi Park wetland include:

1. *Zantedeschia aethiopica* (Arum Lily)
2. *Typha capensis* (Bullrush)
3. *Phragmites australis* (Common Reed)

Z. aethiopica (Arum Lily)

T. capensis (Bullrush)

P. australis (Common Reed)

Proposed Solutions: Wetlands

Proposed Implementation of Wetlands

In order to have a successful implementation of a wetland in an informal settlement like Monwabisi Park, there are different factors that need to be addressed:

- **Planning:** Determining the capacity of the wetland, its most appropriate location, and developing an appropriate management program is crucial to the planning process of implementation. It is also important to get the community involved so that they can reproduce the management systems without outside assistance. Another aspect of planning requires the careful consideration of the City of Cape Town's regulations and codes.

- **Materials:** Securing all of the necessary materials is also a crucial step. In the case of a wetland, it can be artificial or natural. Ideally, it would be natural, meaning that no work is necessary to construct it. If it is artificial, labour and different plants are needed. Nonetheless, the city should be prepared to supervise to make sure that everything runs smoothly. Spades and other materials could be supplied by the community, although other more heavy machinery might be needed (refer to the cost analysis on page 133).

- **Human Labour:** It is important for the community to participate in the building process, but at some point, some level of city involvement will be needed to construct the wetland.

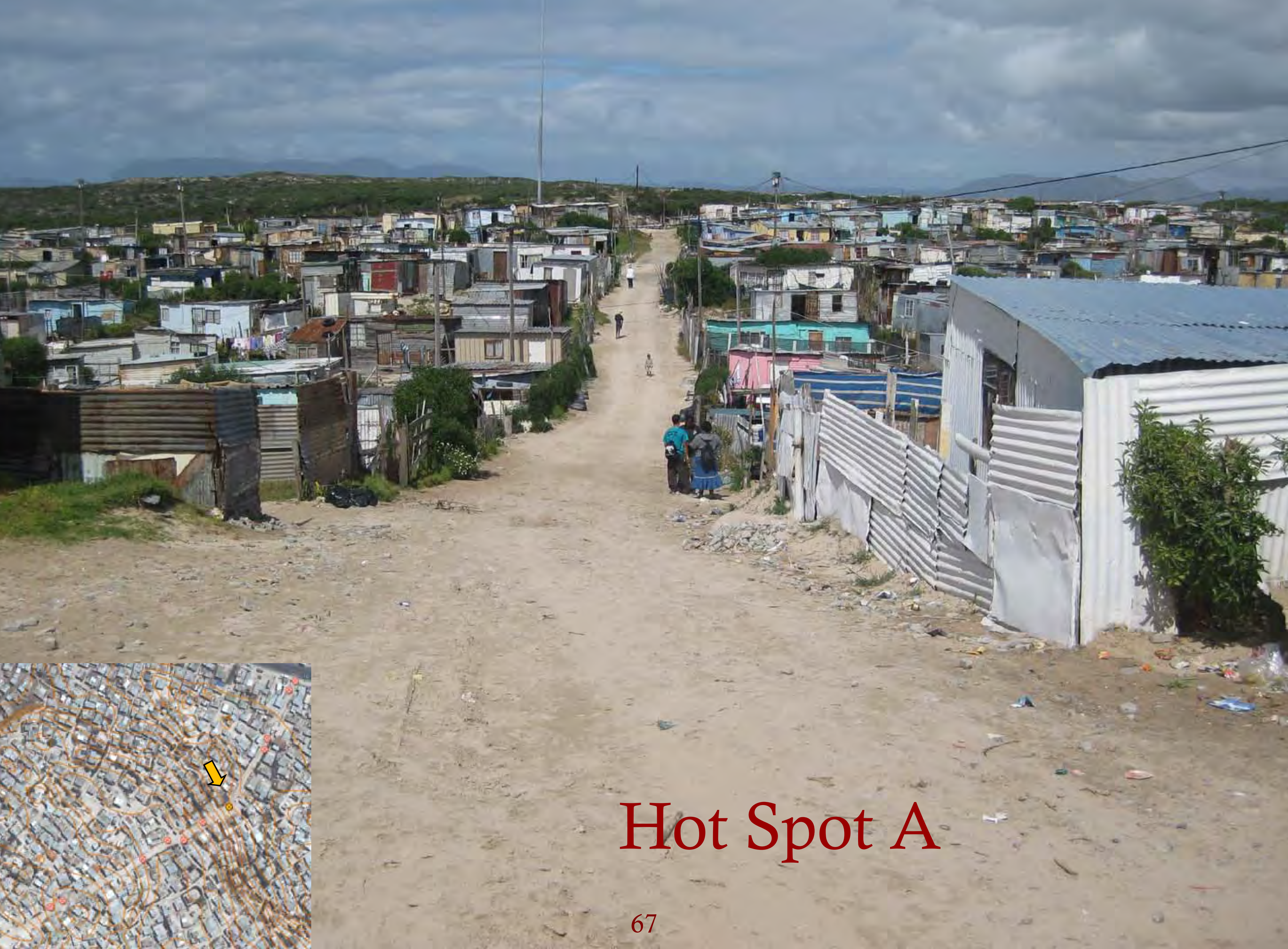
Proposed Solutions: Wetlands

Proposed Maintenance of Wetlands

Wetlands are considered a medium-maintenance SUDS solution. The short-term management aspect of this solution will require supervision in select areas only, such as regular cleaning of the wetland and constant supervision to assure the facility is not abused.

Being a medium-maintenance solution, wetlands can work closely with local community organizations, such as a community boards and street committees, but some form of government involvement would be beneficial, especially towards the process of creating the committee.

The long-term management aspect will include the education of the residents living around the wetland, so that they can understand the proper function of it, its benefits and how to ensure that it works efficiently and effectively overtime.



Hot Spot A

Hot Spot A

Existing Physical Conditions

- Downhill Slope
- Uneven Surface
- Potential Ponding

Existing Social Conditions

- Low Tension
- Cooperation
- Environmental Adaptation

Current Interventions

- Fences
- Ditches
- Accumulation of Sand
- Minor Vegetation
- Wooden Ledges/Boards

Possible Solutions

- Artificial Swales
- Soakaways

Residents' Point of View

"We do not get flooding, but all of the water is redirected from around our house into our neighbor's house"

"We put a wooden board in the doorway to create a barrier, it didn't work as well as we had hoped."

"Neighbors do not complain, they just continue the redirection cycle as well."

Existing Physical Conditions

Downhill Slope

From the north to south end of this section, the road encounters a steep decline, forming approximately a 45° angle with the flat, ground level. Over a roughly 30 meter span, the road begins to level out, and it turns into a low-lying area. Due to this natural topography, water flows at a high rate along this slope. Gravity works to direct the water down this decline and enables it to accumulate at the bottom, forming a small pond that has the potential to spread to nearby yards and houses.

Uneven Surface

This portion of the C-section road is characterized by numerous holes, divots and protruding rocks. Holes are created by a relatively high flow of traffic, and the inability of the sand to stay in place, both when traveled on and when saturated during and after a rainstorm. These holes are scattered throughout the road and are characterized by a variety of shapes, including circles and long, rectangular shapes. Water is attracted to these areas, and over time it accumulates and eventually spreads to side roads and nearby yards and houses (increasing the risk of flooding). The small divots and bumps caused by rocks and other objects found within the road, such as rubbish and small household items, result in not only a dangerous path to walk along, but in a new path for the water to flow along, directing it to unwanted areas (yards and houses).

Potential Ponding

As a result of the natural topography of this section of road, and the lack of a smooth, level surface, water has an increased potential to accumulate in specified areas and form ponds. Specifically at the bottom of the hill, in the low-lying area, and in areas where there are large holes (ranging between half a meter to three quarters of a meter in diameter), excess water is captured and builds up, forming a large puddle. Depending on how deep the hole is, or how accommodating the low-lying is for gathering water, the water will eventually reach a point where it cannot be contained any longer and it begins to spread to nearby areas, such as side roads and houses alongside the road, resulting in higher flood potentials and risks.

Existing Social Conditions

Low Tension

The residents in this section are very close with one another, as many of them are related. They understand that stormwater causes many problems in their area, and there are only a limited number of things that can be done to fix them. Unfortunately, many interventions that are put in place by residents at an individual level have negative effects on neighbouring houses. These interventions often reinforce the redirection of water into nearby yards and houses, which in most areas, would result in verbal and potentially physical conflicts. Due to the nature of the relationship of these residents, they realize that this redirection of water is something that cannot easily be fixed. One resident explained, **"Neighbors do not complain, they just continue the redirection cycle as well."** Instead of getting upset with neighbouring residents, they simply work with the current conditions and situations and redirect it to the next house, until it is no longer their problem. (Level of tension: "3")

Existing Social Conditions

Cooperation

Due to the low tension in this area, many residents find it easy to work collectively with one other. They understand that not all residents are capable of implementing a functional stormwater management system to protect their house, so they reach out to these people and assist them creating an intervention. A community member explained, **"We put a wooden board in the doorway to create a barrier, it didn't work as well as we had hoped."** He added that other members of the community who lived nearby helped him rebuild his barrier so that it was more functional and able to prevent a large amount of water from getting into his house. This collaborative cooperation results in a greater number of houses having interventions, and it helps to eliminate the overall risk of flooding in individual houses.

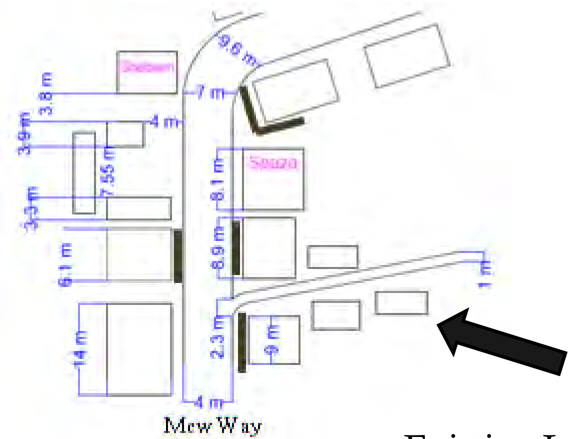
Existing Social Conditions

Environmental Adaptation

Many of the residents in this area have a concrete understanding of the philosophy behind stormwater management. They have lived in conditions similar to these for a large portion of their lives, and over time, they have gained an in-depth perception of how stormwater affects yards and houses (Level of awareness: "8"). These residents realize that existing conditions play an important role in the level of damage that stormwater can cause, and they have used this knowledge to their advantage when designing various management plans. One resident stated that he had to take into consideration both the slope and curve of the road when he was building a fence around his yard, to ensure that it would form a proper barrier against the path of water with the greatest amount of flow. By considering these aspects of the environment and becoming aware of specific surroundings, the process of determining appropriate interventions becomes much simpler, and in the future, much more beneficial.

Fences

The fences found along this portion of the C-section road are commonly incorporated with the use as sand. Residents gather sand at the bottom of these fences to assist in stabilizing the main supports, enabling them to withstand more water pressure and last longer. These fences are made primarily out of wood, as the residents live fairly closely to Mew Way, where there is an abundance of scrap boards. The wood boards are incorporated with a variety of other materials in this area, including wire, shade clothes, metal siding, and shrubs. The functionality of these different materials varies greatly, as the wire and shade clothes do not provide enough substance to create a firm and solid barrier. Shade clothes are easily penetrated by the water, and the wire is too thin to form a completely, enclosed fence. The use of metal siding and shrubs work very well in this area to prevent flooding in yards and houses. They both enable the fence to create a fully enclosed wall, that acts as an obstacle against the water flowing along the road.

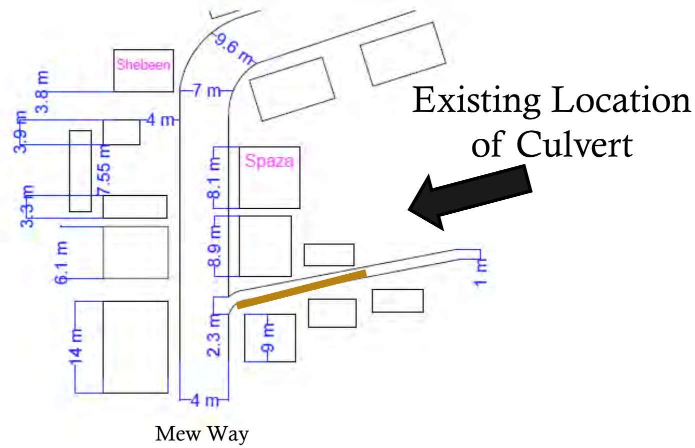


Existing Locations of Fences

Current Interventions

Culverts

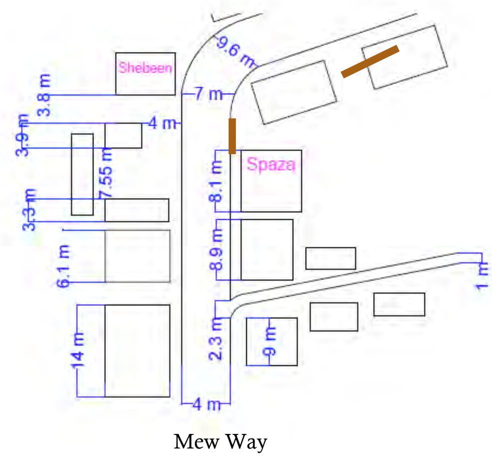
Residents living in this area have built culverts along the perimeter of their houses to help redirect the water away. These ditches are very small, and are approximately twenty to thirty centimeters in depth, twenty to thirty centimeters in width and range from a meter and a half to three meters in length. These interventions serve to provide a channel for the water to run along, creating an alternative path directed away from houses. The culverts in this area are specifically designed to redirect the water along side roads, incorporating the downhill slope, so that the water will take on a partial natural flow. By directing the water along the side roads, the residents are able to keep the water from entering their yards, but they do not take into consideration the houses located on the side roads. As a result, these houses get bombarded with stormwater, and they witness an unfair amount of flooding.



Current Interventions

Accumulation of Sand

The use of sand to create a barrier against water has been implemented by a select number of residents in this area. Specifically, one resident who's house is located directly across from the spaza shop used large amounts of sand to create a ridge in front of his doorway to prevent water from flowing into his house. After speaking with this resident, it was determined that the build up of sand is not a reliable intervention. When the sand becomes wet and saturated, it becomes heavy and when built up, it begins to disperse and crumble. As the sand shifts around and moves away from the house, the barrier that it was intended to form becomes no longer effective.

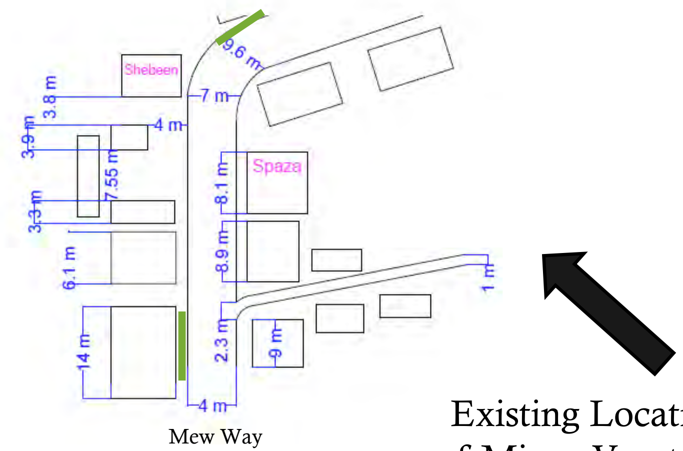


Existing Locations of Accumulation of Sand

Current Interventions

Minor Vegetation

Found along the edges of the road, small patches of grass are used to soak up minimal amounts of water to assist in limiting the amount of standing water found throughout the road. Some residents use vegetation (small grasses) along the perimeter of their yards to capture water as it flows into their property, hoping that it will cut down the amount of water that eventually comes in contact with their houses. The use of shrubs along the perimeter of yards also serves to prevent water from entering houses, but they do so in a slightly different way than the small grasses do. Shrubs are much taller than patches of grass, so they function similarly to a fence, creating a blockade against the water, disabling it from penetrating into unwanted areas, such as yards and houses.



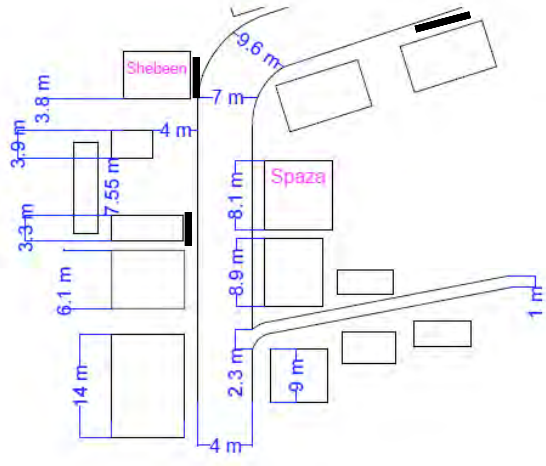
Existing Locations of Minor Vegetation

Current Interventions

Wooden Ledges and Boards

Residents have taken small pieces of wood, approximately a meter in length and about twenty five centimeters in height and placed them into the ground, so that roughly ten centimeters protrudes. These pieces of wood are located in front of doorways to create an extra obstacle for the water to overcome when entering houses. The ledges in this area are not very useful, as they are often not built high enough off the ground, and they do not provide a tall enough barrier for the water to come in contact with. Due to the lack of a functional barrier, the water simply flows over the board and enters the house with great ease.

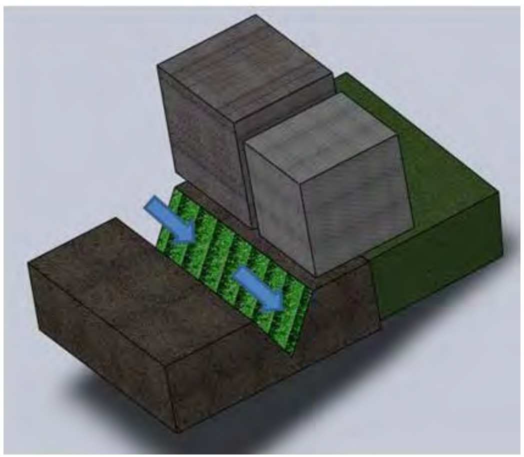
Existing Locations of Wooden Ledges and Boards



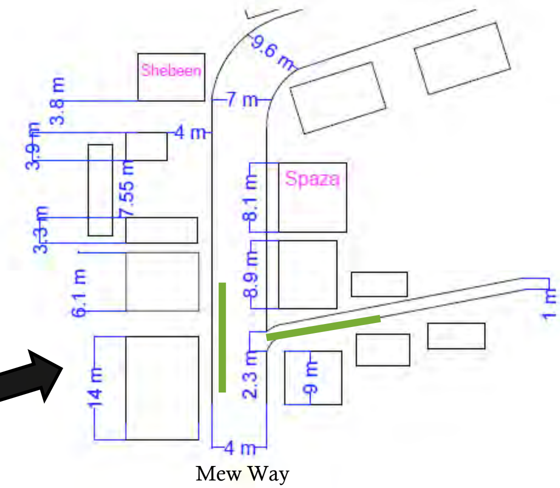
Proposed Solutions

Artificial Swales

In this area of the C-section road, artificial swales can be implemented alongside both the main road and along the side roads to assist in directing the water to a designated, well contained area. Specifically, they can be implemented along the east side of the main road which will enable the water that flows down the slope to be directed towards the bottom of the hill in a uniform path, eliminating the spreading of water across the road and into unwanted areas (yards and houses). This swale would be roughly ten to twelve meters in length, a meter wide and between a quarter of a meter and half a meter deep.

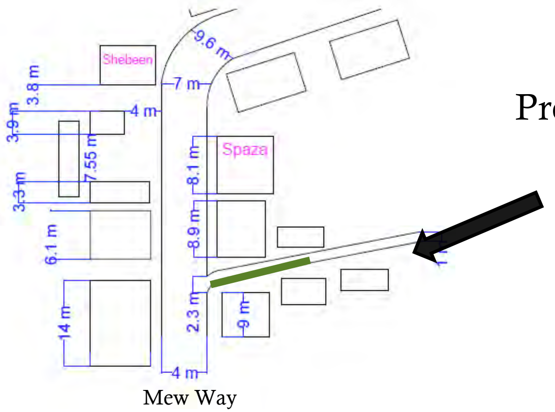


Proposed Location of an Artificial Swale

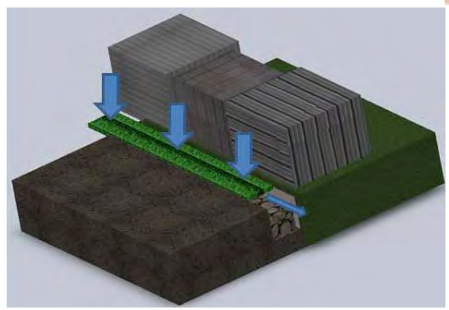


Soakaways

Along this portion of the C-section road, soakaways can have a highly beneficial effect on the overall management of stormwater. If placed along the side road that branches off of the west side of the main road, this intervention will serve to capture water that naturally runs down the slope and spreads into this area. The soakaway, measuring approximately half a meter in width, three quarters of a meter in depth, and three to five meters in length, will act to gather excess water that accumulates along the sloped section of the road, and encourage it to soak into the ground, eliminating its ability to runoff into neighbouring yards and houses. If incorporated with other interventions, such as artificial swales, it can help to redirect water away from houses and direct it into a specified, well controlled area.

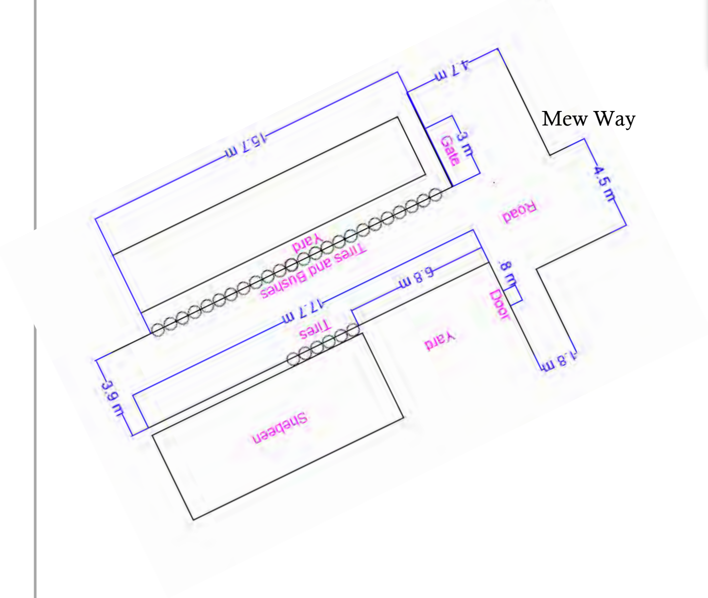


Proposed Location of a Soakaway



Hot Spot B

Hot Spot B



Existing Physical Conditions

- Low-lying
- Uneven Surface
- Potential Ponding

Existing Social Conditions

- Conflict
- Lack of Cooperation
- Individual Efforts

Current Interventions

- Tyres
- Ditches
- Raised Platform
- Buildup of Sand
- Vegetation

Proposed Solutions

- Artificial Swales
- Soakaways

Residents' Point of View

“After putting in a platform around my yard, my neighbour complains that his flooding is caused by me.”

“We dug a ditch to help redirect the water, but every time it rains, we have to re-dig it.”

“Every man is for himself when it comes to dealing with stormwater.”

Existing Physical Conditions

Low-Lying

This section of the road is located at the base of two hills, one downhill and one uphill. Due to the topography of this area, the road forms a slight valley, and fairly flat surface. This stretch of road, measuring roughly eighteen meters in length, is prone to a high amount of standing water. Water is naturally directed along the slopes of the hills into this area, and the houses located alongside the road witness large amounts of flooding and water damage.

Existing Physical Conditions

Potential Ponding

As a result of this area falling between two hills, water is naturally directed to this section of the road. This area is relatively flat , and the water is attracted small divots and holes that are naturally found throughout the road. This water accumulates over time and begins to forms small puddles and pools. When the sand beneath this water becomes oversaturated, the standing water quickly builds up and starts to spread across the road. As it extends to nearby areas, the potential for flooding increases, and it travels along the slightly sloping side roads (both on the northwest and southeast sides) round in this area. As a result, the houses along these side roads receive high quantities of water and large amounts of stormwater and flooding damage.

Existing Physical Conditions

Uneven Surface

Located in a fairly flat section of the road, this area is characterized by numerous divots and bumps, caused by erosion (mainly from water), and small rocks scattered throughout the road. Due to the amount of excess water found in this section, the inconsistencies within the road disrupt the path of the water, and enable it to pool, and eventually spread into neighbouring yards and houses, resulting in high amounts of flooding.

Conflict

Residents in this area have implemented many interventions on an individual level. Unfortunately, these interventions often have negative effects on others and verbal arguments arise between neighbours (Level of Tension: "7"). Residents claimed that their interventions would upset their neighbours, and specifically, on resident stated, **"After putting in a platform around my yard, my neighbour complains that his flooding is caused by me."** As a result of the high amount of flooding witnessed in this area, the level of frustration is presumably higher than that found in other areas of the C-section road. When the residents become bombarded with problems arising from stormwater, such as uncontrollable flooding, and property/infrastructure damage, they cope with their aggravation by blaming neighbours and other members of the community.

Existing Social Conditions

Lack of Cooperation

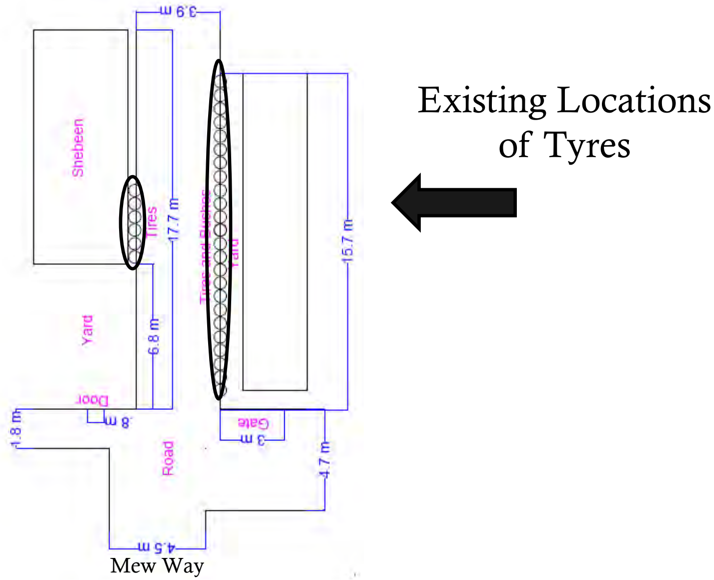
The widespread attitude of "Every man for himself" in this area results in the unwillingness of residents to work together. Numerous residents expressed the high level of tension between neighbours (Level of tension: "7") and added that people are better off working alone. The isolation that arises in this area creates an unfriendly atmosphere, and with regards to stormwater management, it leads to a greater number of problems rather than solutions. With the lack of community-wide efforts, the awareness of stormwater management practices is very low (Level of awareness: "2"). The residents who do have a strong understanding for the philosophies behind different preventative techniques are unable to share them with other residents, resulting in individual interventions that are highly inefficient. This area is prone to a high amount of flooding, especially along the road itself, and without an appropriate community-wide intervention, the proper containment of the water will never occur.

Individual Efforts

As discussed in the "Lack of Cooperation" section, the residents who live in this area do not work well together. Many of these people have brilliant ideas when it comes to designing stormwater management systems, but they keep these ideas to themselves, in fear that another resident might take advantage of what they have in mind. This competitive atmosphere leads to a variety of personal interventions, both successful and unsuccessful. Fortunately, the residents who take the time to implement a well thought out plan, have the motivation to ensure that these methods work. While often simple ideas, these techniques flourish into time-consuming annoyances, in which the residents must constantly manage**. "We dug a ditch to help redirect the water, but every time it rains, we have to re-dig it."** This community member expressed his frustration with his intervention, but he also made certain that the success of this ditch was well known. Even though it requires constant management, he exclaimed that the extra work is worth the effort, both in the near and far futures.

Tyres

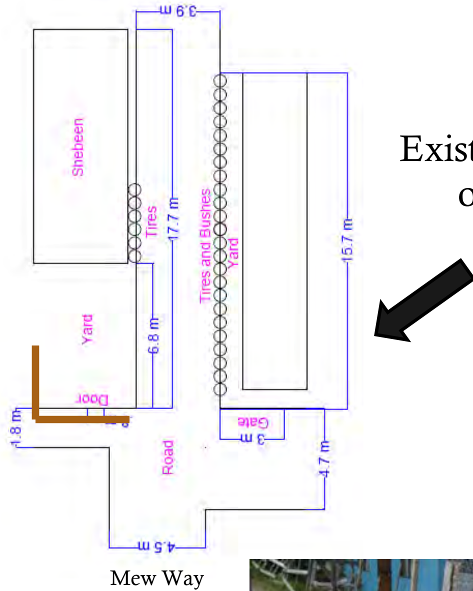
Alongside the main road, residents have partially buried tyres and filled them with sand to create a border between their yards and the road. On both the northwest and southeast sides of the road, multiple tyres have been lined up next to each other, in such a manner that they protrude about twenty five centimeters from the ground. This minor protrusion allows this intervention to form a small barrier against the flow and potential spread of ponded water. In this area, these tyres are incorporated with other interventions, such as shrubs and fences, and when filled with sand, they create a reliable, sturdy base to build upon. By placing sand inside these tyres, the residents create a stronger barrier, and more permanent intervention, making it more difficult for others to move or steal them for use in their own interventions.



Current Interventions

Culverts

Along the side roads branching from this area, specifically on the southeast side, residents have built a ditch to help channel the water that flows down the two adjacent hills. The high amount of water that travels along this path requires a deep ditch, approximately half a meter, as well as continual management. After each rain storm, residents, primarily the two who live directly next to this intervention, need to restore the ditch by re-digging it. Residents have begun to adapt to this challenge, and they have placed tires along one side of the ditch to help stabilize the stand and prevent it from filling in the conduit. Community members have mentioned that these tyres do provide assistance, but during the heavy rain storms, the sand from the main road gets pushed toward the low lying area and shifts into the ditch. Despite the extra labour and time that this intervention requires, it is very successful in redirecting the water from the main road into an area where it can be appropriately stored.



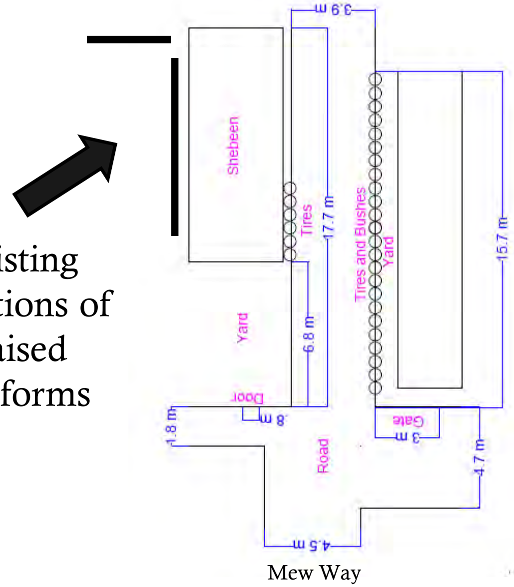
Existing Locations of Culverts

Current Interventions

Raised Platforms

On the southeast side of the C-section road, off of a small side road, residents have used wood boards to create an elevated surface in which their houses are placed upon. These platforms, approximately twenty five centimeters above ground level, help to block water from entering houses and causing infrastructure damage. The wood boards are placed along the entire perimeter of the yards, and they form a discrete enclosure. One resident designed a raised platform on his property and incorporated a small ledge in front of his door as well to ensure that the amount of water entering his house would be minimal. These platforms are slightly time consuming to implement, but once in place they are functional for a significant amount of time. In this area, it was noted that the enclosure formed by the wooden boards also serve to redirect water into neighbouring yards. This has lead to a greater number of residents building ledges and platforms around their yards, and eventually redirecting the water into remote areas far from the main C-section road.

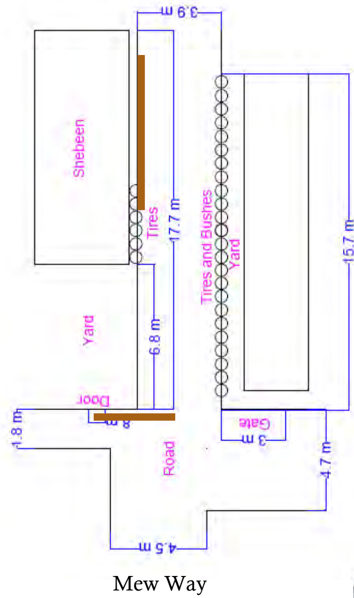
Existing Locations of Raised Platforms



Current Interventions

Accumulation of Sand

Throughout the flat, low-lying stretch of road in this area, residents have gathered sand from the adjacent hills and piled it up against the sides of their houses and along the perimeters of their yards. Incorporated with fences, many people have pressed large piles, roughly a half meter in height, of sand against the bases of wood and metal fences. The purpose of this sand build up is to reinforce barriers already in place, and to help prevent the spread of standing water into yards and nearby houses. The topography of this area predisposes this section to a large amount of standing water, and the creation of built up ridges is a simple method and solution that can be easily implemented by the residents.

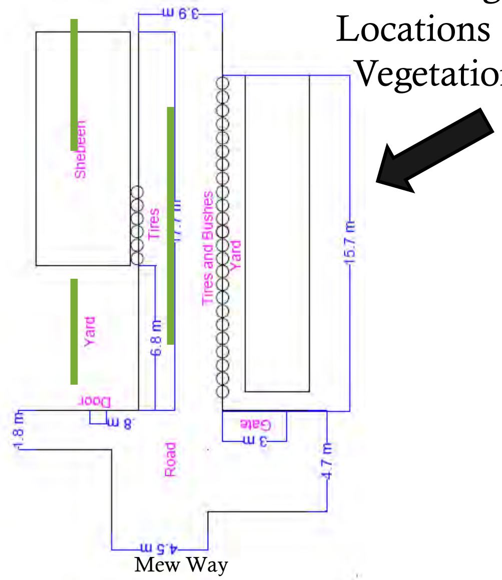


Existing Locations of Accumulation of Sand

Current Interventions

Vegetation

Incorporated with both tyres and fences in this area, vegetation is commonly used as a simple intervention to prevent stormwater from entering unwanted areas (yards and houses). Alongside the road, on the southeast side, large shrubs are supported by wooden posts (from fences) and create a thick barrier against the water that pools in this section of the road. These shrubs are about a meter and a half tall, and range from half a meter to a meter in width, covering a large portion of land. Due to their size, residents commonly only place one to three shrubs in their yard, eliminating costs and management. In collaboration with these shrubs, smaller forms of vegetation are scattered throughout the road to help soak up extra water and provide small barriers (commonly ineffective) against the water. On the northwest side of the road, small patches of grass have been incorporated into the use of tyres. These grasses are placed inside the open portion of the tyre that is filled with sand, providing a potential catchment area for both rain water, and high flood waters.



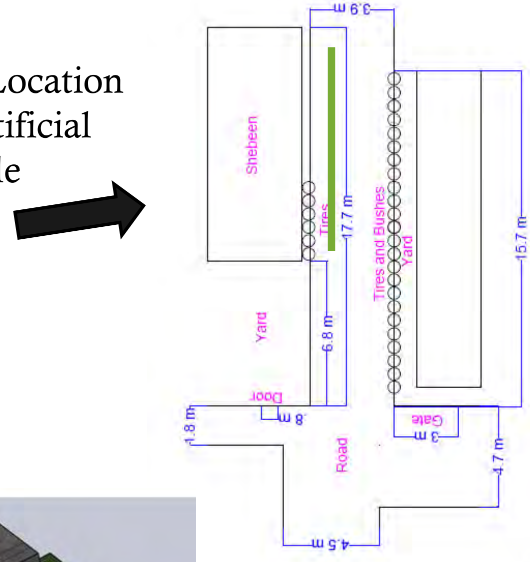
Existing Locations of Vegetation

Proposed Solutions

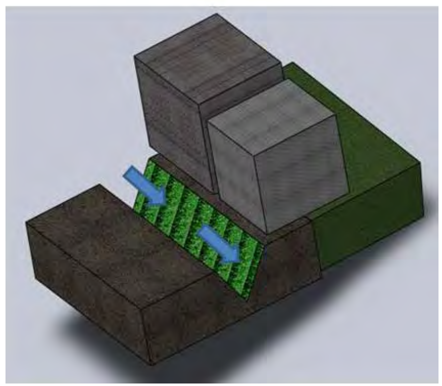
Artificial Swales

To assist in the redirection of water, artificial swales can be implemented along the southeast region of the road. Following the path which comes directly down from a downhill slope and runs past a low-lying side road, this intervention will encourage excess water to flow alongside the road. This specific area of the road will benefit the greatest from an artificial swale because it will incorporate the natural flow of water that is caused by gravity (from the downhill slope topography, northeast of this area). The swale will help to capture water from areas of ponding and it will be incorporated with the patches of existing vegetation. By integrating existing conditions with this proposed solution, the residents will have a better understanding of how to manage it, and keep it well maintained.

Proposed Location of an Artificial Swale



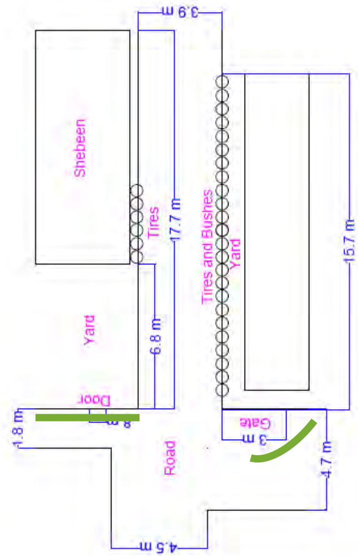
Mew Way



Proposed Solutions

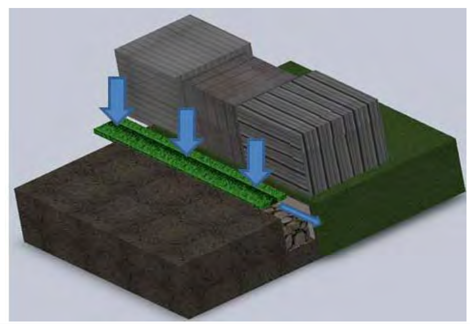
Soakaways

Along the two main side roads, one on the northwest and one branching off of the southeast side of the C-section road, soakaways would be very beneficial if implemented in these regions. A large amount of water runs off onto these roads because they sit slightly lower than the main road. The water flows directly from both hills flanking this vicinity, and when it meets at the bottom, in the low-lying, flat area it begins to pool. Soakaways would help to capture this excess water and would prevent the spreading of it into yards and houses located along the side roads. Due to gravity, the water flow is naturally directed down the length of these roads, and it has no place to drain. With a soakaway in place, the runoff would not only be captured and infused into the ground, but it would also be directed into an area that can withstand these excessive amounts of water. The proposed soakaways would be approximately three to four meters in length, a meter in width, and about a meter deep. Implementing them on these two side roads would be ideal because they would easily fit into these specified spaces while leaving room for footpaths and common transportation/travel.



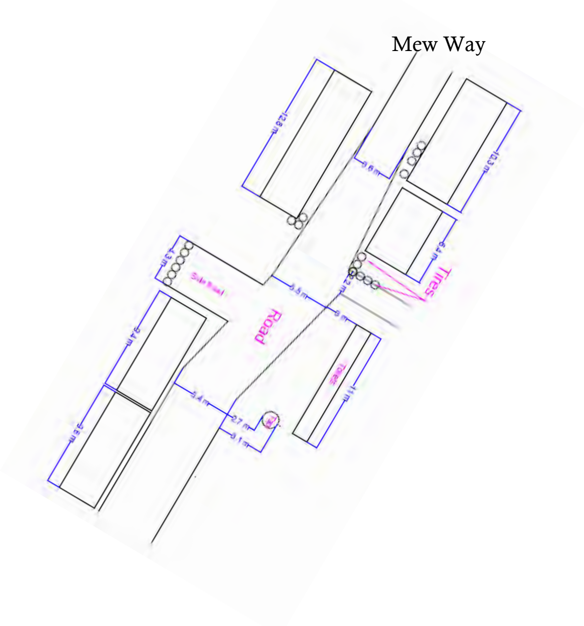
Mew Way

Proposed Locations of Soakaways



Hot Spot C

Hot Spot C



Existing Physical Conditions

- Broken Tap
- Potential Ponding
- Elevated Road

Existing Social Conditions

- High Tension
- Low Awareness
- Lack of Cooperation

Current Interventions

- Tyres
- Fences
- Raised Platforms

Proposed Solutions

- Soakaways
- Infiltration Trenches

Residents' Point of View

"We experience a fair amount of flooding here, but fortunately, we only are effected during heavy rain storms."

"When water is directed outside and away from houses, it is okay with all of the neighbouring residents involved."

"Water from different directions all come together and form a pool in my yard."

"When other interventions intrude into neighboring yards, tension is created."

Broken Tap

On the northwest side of the road, there is a communal water tap which lacks proper management and is cracked along the base. This crack results in the excessive release of both clean tap and dirty grey water along the road and leads to the pooling of water in front of the toilets and in the path of neighbouring side roads.

Potential Ponding

Due to the varying levels in the road in this area, water flows to specific spots and pools in the low-lying areas. As discussed in the "broken tap" section, water tends to build up along the side roads and it creates a risk for the people residing beside these areas. When the ground is fully saturated and unable to take in any more water, it begins to push water outwards, resulting in the water having no place to go. As the water builds up to an excessive amount, it begins to spread to nearby areas, most commonly yards and doorways of houses. This results in increased flooding and water damage within and around multiple houses.

Existing Physical Conditions

Elevated Road

Due to location of this area, the majority of houses along the road are located off of small side roads. These side roads are on a downhill slope from the main road resulting in the houses being set at a lower level than the road. With the high amount of ponding that occurs in this area, these houses are often inflicted with flooding from the runoff that spreads from the pooled water.

Existing Social Conditions

High Tension

After talking with residents in this area, it was apparent that there was a high amount of tension between neighbours. One resident explained how he **"cut a hole in his side fence to redirect the water directly into his neighbour's yard."** Attitudes such as this related to stormwater management result in both isolation and lack of trust between community members. This resident's actions lead to verbal conflict between him and his neighbour, and it was witnessed that this level of tension was widespread throughout the entire area (Level of tension: "8") . The residents understand that there are only a limited number of methods they can implement to solve stormwater problems, so they feel that by eliminating the techniques that negatively effect others, they will loose out on opportunities for themselves.

Low Awareness

The lack of care and understanding of maintaining these facilities leads to the overflow and pooling of water, which spreads into neighbouring yards. This lack of maintenance is caused by the overall low awareness of stormwater management throughout the area (Level of awareness: "2"). Residents are not educated enough and do not possess the knowledge base that allows them to understand the importance of maintaining water and its effects on household flooding. Without having an in depth background of the philosophy behind stormwater management, residents do not see the issue as a top priority and they are unsure of how to properly approach the underlying problems. With a dysfunctional tap, water can easily accumulate and increase the risk of flooding, but it the knowledge base was present in this area, a simple plan could be put into place that would help to fix the tap, or at least minimize the amount of water that leaks out of it.

Existing Social Conditions

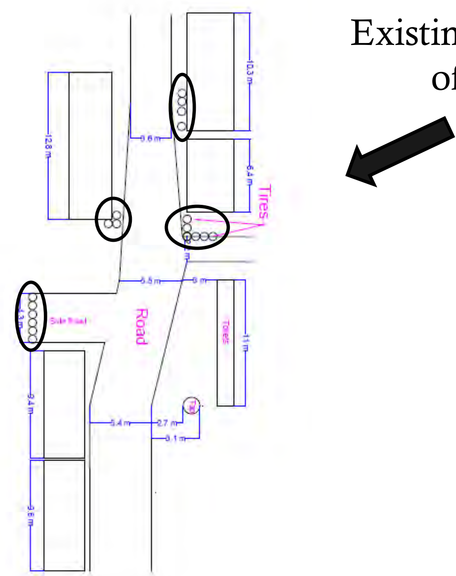
Lack of Collaboration

As a result of the high levels of tension and the low levels of awareness, it was apparent that people do not work together in this area. Many interventions are designed on an individual basis, and often times, they are created to redirect the water away from their house, without thinking about how it effects the people living around them. One resident stated, **"I have put tyres in my front yard and built a barrier on my side yard, but I still get flooding in the back of my house because my neighbour gets upset when I try to implement something in that area. She claims that it effects her house and increases the amount of flooding that she endures."** Attitudes like this are very common throughout this section of the road and it leads to the lack of trust between residents, as well as the lack of interest to implement a community wide intervention. Unfortunately, an intervention that was implemented on a more collaborative level would be benefit to residents living in this area, because it would provide the entire region with some type of preventative measure (even if it was minimal). When asked if such an intervention would be possible and accepted by the residents in this area, residents claimed that **"Every man is for himself. People do not work together here, and they have decided that working alone is more beneficial than working with other people."**

Current Interventions

Tyres

Residents often use tires in this area to prevent water from entering their yards and houses. There are numerous ways in which interventions are designed using tyres. Some residents fill them with sand to create a strong, reliable barrier around their yards that help to stabilize the sand during a rainstorm (southeast side of the road). Other residents strategically stack the tyres on top of one another to form a wall that acts as a barricade against standing water and water that has begun to pool as a result of the uneven road surface (northwest side).



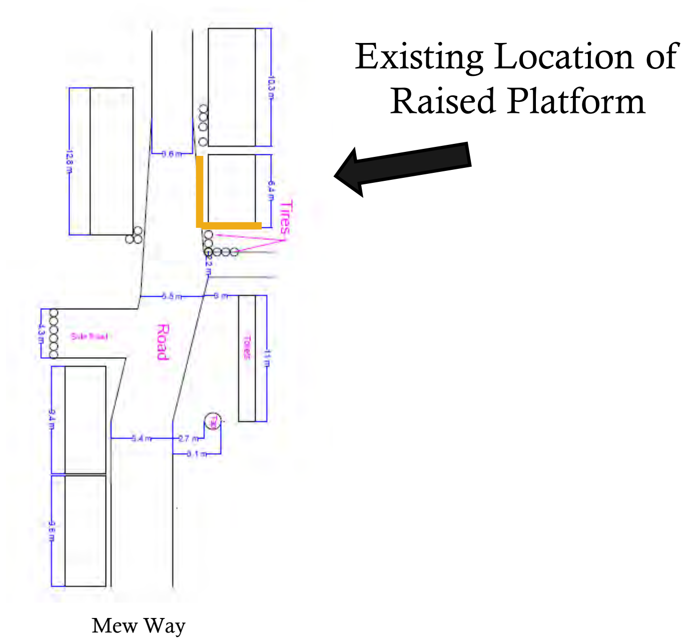
Existing Locations of Tyres

Mew Way

Current Interventions

Raised Platforms

In this area, a few houses were built on a raised platform so that the base of their house is approximately 30 centimeters above ground level. This solution works very well because it allows the water to travel underneath the house in a natural pattern and prevents the house from receiving a large amount of flooding, specifically from standing and pooled water.

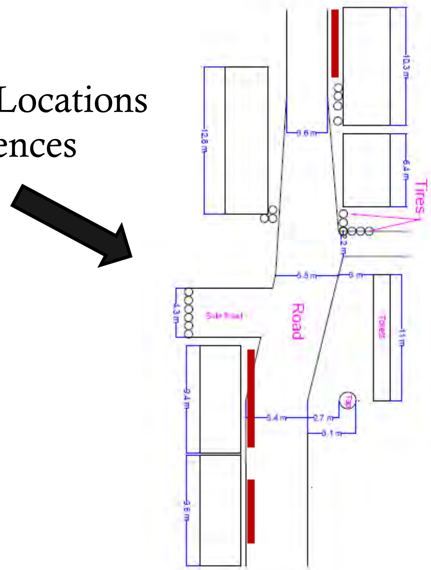


Current Interventions

Fences

There are a variety of fences found within this area of the C-section road. The materials used for each fence are very different from the other fences found within this region, but the residents all have different reasons for why they built their fence they way they did. One resident used metal siding to create a wall around the perimeter of his yard, and he cut a hole in the corner of it to help redirect the water away from his house. Another resident used tyres to create a fence, which also served to stabilize the sand surrounding his house. No matter what material or design the fence is made from, they all work to serve the same purpose, create a blockade against the rainwater runoff and to prevent household flooding.

Existing Locations of Fences



Mew Way

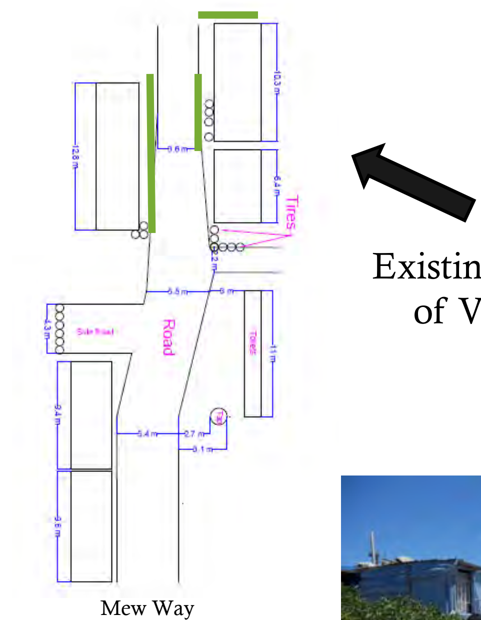
Metal Siding Fence

Stacked Tyre Fence

Current Interventions

Vegetation

As in other areas of the C-section road, small patches of grass are found throughout the road and alongside adjacent yards. In this region, vegetation is found mainly on the southeast portion of the road, and it is incorporated with a minor build up of sand, to form a small water barrier. Implemented in a continuous strip along the church yard, the grass helps to both soak up extra water and defer it towards the main road, so that it does not enter the church yard. Vegetation is also found faintly along the northwest side of the road. In collaboration with stacked tires and large rocks, these small patches of grass help to reinforce the barriers that these other interventions create.



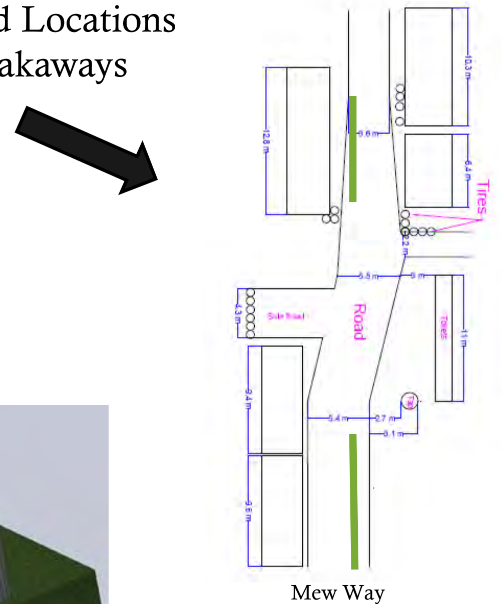
Existing Locations of Vegetation

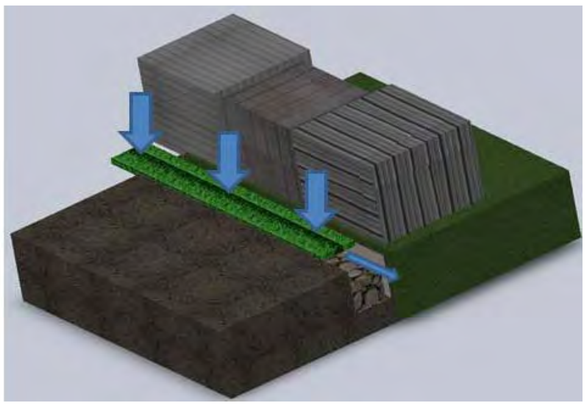
Proposed Solutions

Soakaways

Along both the northwest region and southeast region of the main road, the implementation of soakaways would be ideal. In these two locations, slightly northeast (closer to Mew Way) of the communal tap, and further down the road near the church (southeast side), are both fairly flat, and they are areas of high-flooding and water accumulation. The soakaways would work to capture the water that flows through these areas and direct it into the ground, eliminating the potential for it to spread into nearby houses.

Proposed Locations of Soakaways



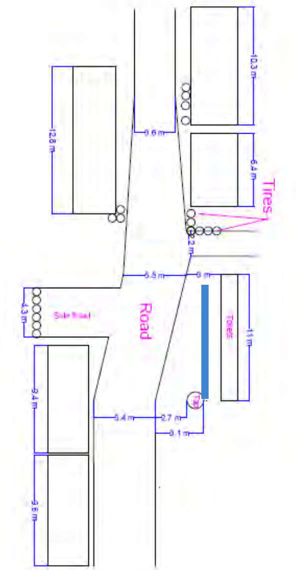


Proposed Solutions

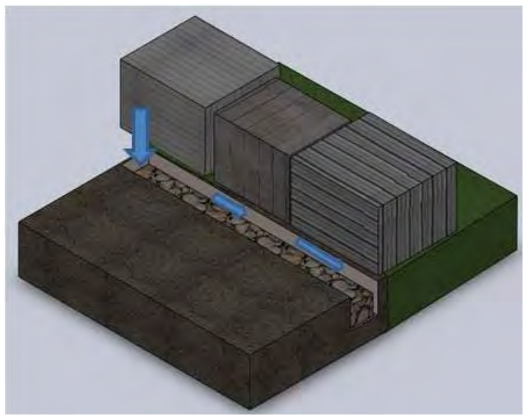
Infiltration Trenches

Due to the high amount of grey and black water around the tap and toilets, an intervention that can assist in cleansing this material would be very beneficial in this area. When the sewer drains near the toilets reach capacity, they begin to overflow and leak, resulting in the pooling of black water along the length of the toilets. This situation (standing black water) is unsanitary, and very unhealthy for people to be living near. An infiltration placed along the front perimeter of the toilets would serve to gather this water and filter it. While filtering the water, the trench would also assist in directing the water (the clean, filtered water) to a more appropriate, remote area where large amounts of water can be contained.

Proposed Location of Infiltration Trench



Mew Way

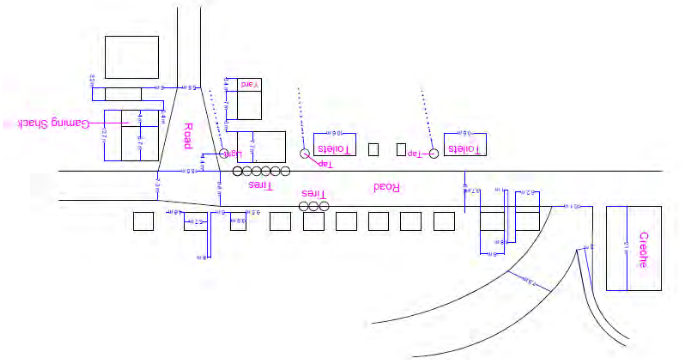



Hot Spot D

Hot Spot D

Mew Way

Mew Way



Existing Physical Conditions

- Downhill slopes
- Uneven ground
- Potential Ponding
- Highly Vegetated

Current Interventions

- Vegetation
- Culverts
- Tires
- Plastic

Existing Social Conditions

- Verbal Conflict
- Varied Tension
- Resident Involvement

Proposed Solutions

- Swales
- Soakaways
- Trenches
- Wetland

Residents' Point of View

"We like each other here, so we just do things together"

"People won't do anything to stop development."

"Water comes straight down and just stays in the road. It would be helpful to make new, smaller roads to help disperse the water."

"Most of the people living around me experience a problem with rain."

"I raised my house up and put plastic between my house and the sand, but the plastic is starting to break. I also tried to redirect the water around my house using a mat."

Existing Physical Conditions

Downhill Slopes

Perpendicular to the road, on the northwest side, the topography of this area is mildly varied. There is a steep slope, forming approximately a 30˚ angle with the ground that is aimed toward the main road. This natural landscape encourages water to flow from the hill onto the southeast side of the road, increasing the amount of flooding seen by the people who reside there. Due to the road being low-lying, gravity directs the water to this area where it spreads across the entire lower section with no barrier to control or stop it.

Uneven Surface

The composition of the road in this area is very uneven. Due to its make up of primarily sand and loose rocks, divots are very prevalent and some sections are raised up as a result of the sand moving around during rain and wind storms. When rainwater falls, it soaks into the ground and encourages the sand to shift in the direction of the water flow. Some residents have placed rocks in the road to prevent this, but this results in an even greater uneven surface, because the rocks are not distributed equally throughout the road, and some stick up while others are buried a few inches into the ground.

Potential Ponding

Due to the topography of this area, the risk for ponding in the road is very high. The natural flow of water from the hill on the northwest increases the amount of water found in the road, especially after a storm, and this excess of water does not have a place to disperse. Once the ground and the sand in the road are fully saturated, they will soak up any extra water which leads to standing water, known as ponding. The composition of the road also factors into the ponding of water, as the divots throughout the road provide space for the water to pool and collect.

Vegetation

This area of Monwabisi Park is located very closely to the Wolfgat Nature Reserve. The houses in this section therefore have more vegetation in their yards than houses in other sections of the settlement. Alongside the southeast portion of the road, there is a small amount of vegetation which acts as a border between the road and the residents' yards. This layer of vegetation can be very helpful in capturing rainwater and preventing it from accumulating and pooling in the road.

Existing Social Conditions

Verbal Conflict

After speaking with residents in this area, it was apparent that some neighbours did not get along or agree on issues caused by stormwater. Some residents would implement a local solution, but **"it would redirect the water directly into the neighbouring yard"**, increasing the amount of flooding and damage encountered by that resident. Between the lack of communication and understanding between the neighbouring residents, these issues would result in verbal conflicts (Level of tension: "3"). One resident said, **"We try to work it out, but others don't listen"**, referring to conflicts arising from stormwater issues between multiple neighbours.

Varied Tension

Through multiple interviews, it was determined that the residents in this section are broken into smaller groups. Within these groups, the level of tension varies greatly. Between the neighbours in the low-lying area behind the houses on the Southeast side of the road, they do not currently work together. One resident said, **"People will fight, but they will work together"**, when asked about the implementation of a new community-wide, solution (Level of tension: "7"). In contrast, another resident, from a different area within the hot spot, responded with, **"People like development, and they are constantly looking for it. They wouldn't do anything to stop it"** (Level of tension: "2"). Even though these residents live relatively close to one another, the group that they are part of defines how they work together, and what the overall level of tension is in that specified area.

Existing Social Conditions

Resident Involvement

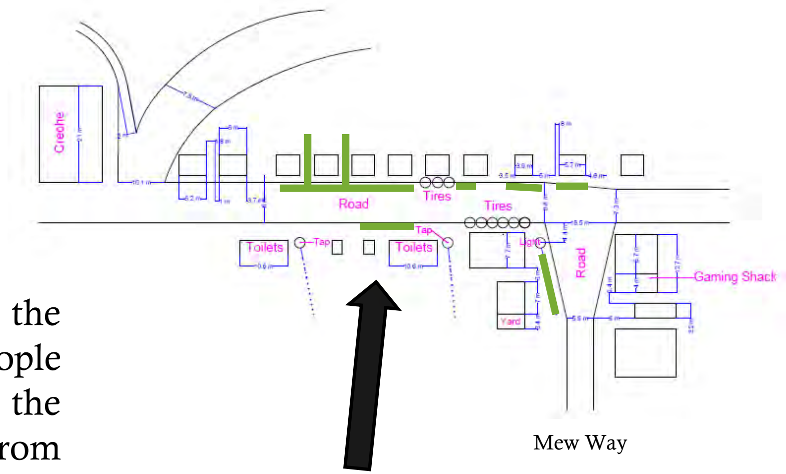
Within the small groups that the residents formed within this section, the level of involvement from residents was much higher than in other areas. Specifically in the area where there was low tension, people were currently working together to help keep their yards and neighbouring yards clean and well kept. Multiple residents said, **"the vegetated ditch found alongside the road was a result of everyone pitching in and working together."** One resident, a spaza shop owner, explained how he **"asked residents to help remove the rubbish near the toilets, and they worked together to get rid of it in a timely fashion."** This involvement will be crucial in the implementation of a community-wide stormwater solution. Residents also expressed how they liked each other; **"We like each other here, so we just do things together"**, which supported the idea that the amount of involvement in this area was high, and that the people realize that the power to change is in their hands.

Vegetated ditch along SE side of the road

Current Interventions

Vegetation

Numerous residents in this area take advantage of the vegetation that grows extensively around their houses. People have worked together to create a vegetated ditch along the southeast border of the road to help prevent water from spreading into their yards. They have also used hedges supported by fences to create barriers against the water in hopes of minimizing and eliminating the flooding that they acquire within their houses.

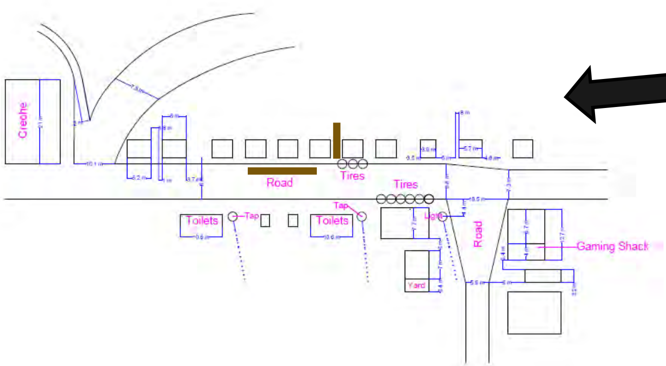


Location of Existing Vegetation

Current Interventions

Culverts/Holes

Aside from creating a community-wide ditch to help redirect the water to the end of the road, many community members in this area have dug small ditches and channels in their yards, both in front of their doors and alongside their houses, to assist the flow of water away from their residence. Specifically, the people on the southeast side of the road have dug channels in between their yards to redirect the water to the grass covered valley behind their houses.



Location of Existing Culverts

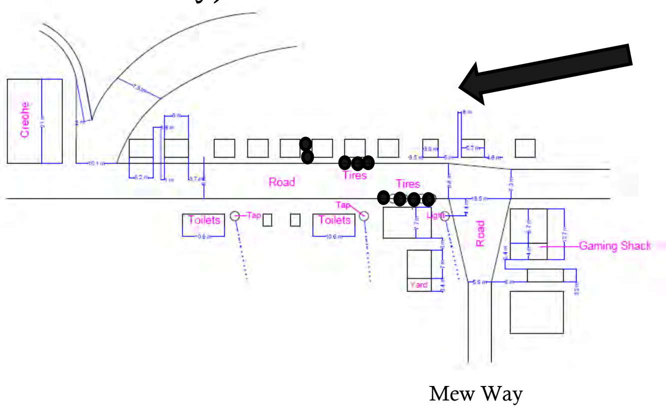
Mew Way

Current Interventions

Tyres

In this area, some residents have used tyres stacked on top of one another to form a wall-like structure. After discussing this design with the residents who built it, it was determined that it served multiple purposes; it helped to block water from entering their yard and it acted like a fence to separate their yards from their neighbours' yards.

Another resident buried tyres in the sand along the perimeter of his yard to stabilize the sand and to prevent it from creating a path leading into his house, water redirection, (this path would allow the water to flow directly into his doorway).



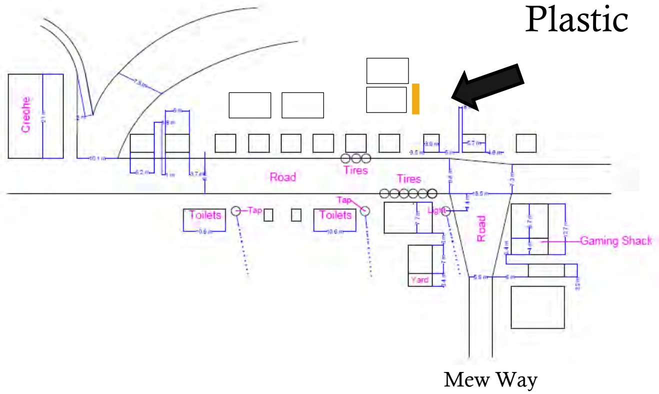
Location of
Existing Tyres

Current Interventions

Plastic

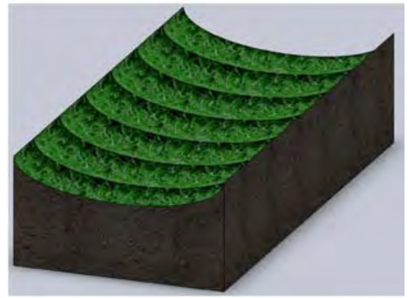
To assist in stabilizing the sand during rainstorms, one resident explained how she incorporated a piece of plastic between the foundation of her house and the sand surrounding it to help prevent the sand beneath the house from becoming saturated and moving around. When the ground underneath the houses soaks up a large amount of water, it becomes uneven, and the houses begin to slope to one side, making them unstable and unsafe to live in. Other residents have used plastic in similar ways, and after speaking with them, it was determined that the type of plastic used is crucial to the success of this preventative technique. The plastic used between the house and the sand was very thin, similar to the consistency of a plastic garbage bag, and over time, it began to break down and disintegrate.

Location of Existing Plastic

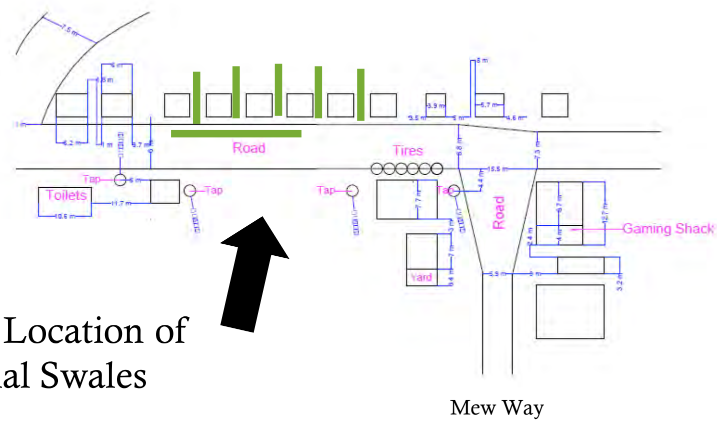


Proposed Solutions

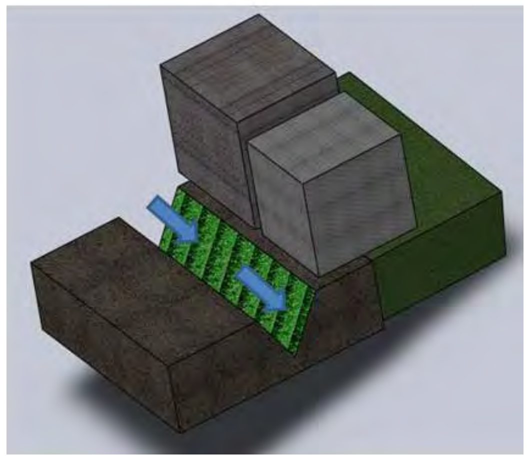
Artificial Swales



Swales can be implemented along the southeast side of the road to help direct the water behind the houses located on that side. They can be designed to help the water flow toward and/or into soakaways also located on the side of the road and in between the shacks.



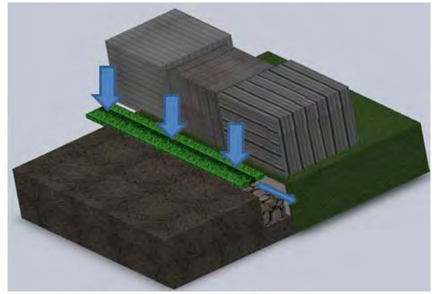
Proposed Location of Artificial Swales

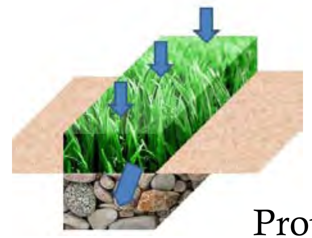


Proposed Solutions

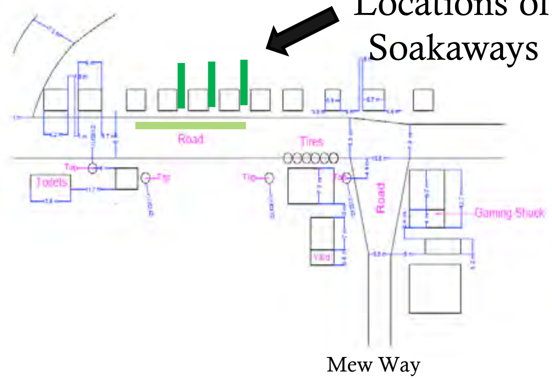
Soakaways

Soakaways can be used either alongside the southeast side of the road, or in between the shacks on that side. If they were to be located alongside the road, their main purpose would be to capture the water runoff from various sources within the settlement, including rainwater and tap water, and they would be used to filter and keep the water from spreading into yards and shacks, ultimately minimizing the amount of residential flooding. If the soakaways are located between the shacks, they would be used in conjunction with artificial swales. The flow of the water runoff produced by the swales would be directed towards the soakaways, allowing them to capture the water and disperse it into the ground. This water, the filtered water, could even be integrated into a unique soakaway design that directs it into a larger area of land, often referred to as a wetland.





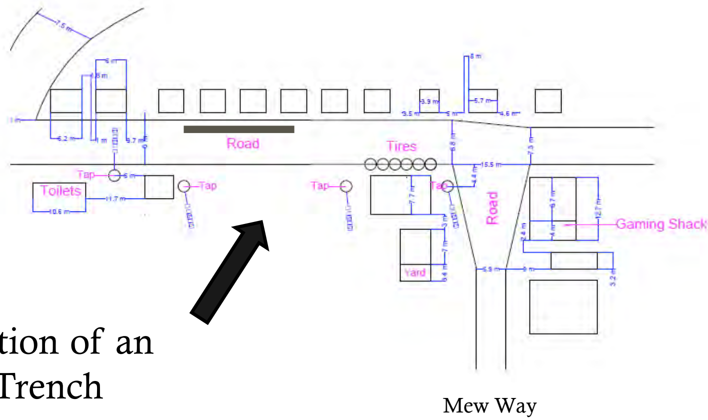
Proposed Locations of Soakaways



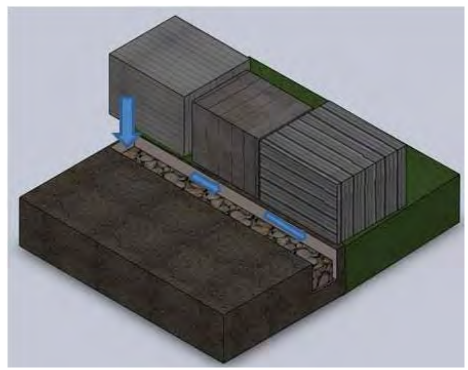
Proposed Solutions

Infiltration Trenches

Infiltration trenches can be used along the southeast side of the road. They will serve to capture runoff both from rainwater and from tap water, and they will help to cleanse the water, specifically the tap water, so that it can be emptied into a larger holding area, such as a wetland, behind the houses on the South East side of the road.



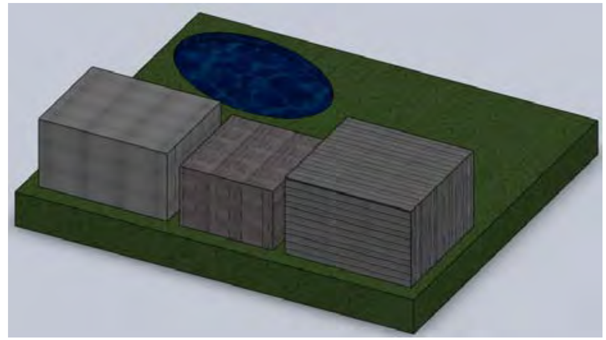
Proposed Location of an Infiltration Trench



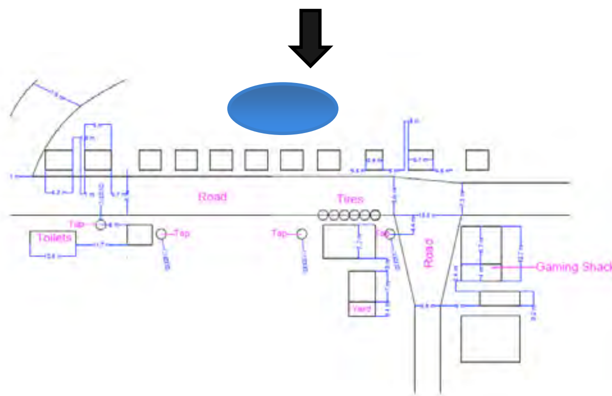
Proposed Solutions

Wetlands

A wetland would be used to collect the excess water found within the roads of Monwabisi Park. In collaboration with other proposed interventions, a wetland would take the water from either a swale, soakaway, or infiltration trench and allow it to form a small pool in a maintained environment. A wetland would be incorporated behind the shacks on the southeast side of the road in a low-lying area that is currently covered in grass and rubbish. This would encourage the growth of a biodiverse environment within the settlement and would help to diminish the amount of residential flooding.



Proposed Location of a Wetland



Mew Way

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Proposed Cost Analysis

Swales and Soakaways

Material	Cost per Unit	Number of Units	Total cost	Total Including Tax of 14% (where applicable)	Total (using exchange rate of $6.88)
Swales (10 metre length)					
Buffalo Grass Sod (per cubic metre)	R 32.00	10	R 320.00	R 364.80	$ 53.02
Soil	R 12.50	15	R 187.50	R 213.75	$ 31.07
Digging Tools	FYI: SPADES R135; PICK AXE R220				
Soakaways (10 metre length)					
Black Building Stone (per cubic metre)	R 293.86	3	R 881.58	R 2,680.00	$ 389.53
Truck Delivery of Stone	R 360.00	1	R 360.00	R 1,080.00	$ 156.98
Buffalo Grass Sod (per cubic metre)	R 32.00	10	R 320.00	R 364.80	$ 53.02
Soil	R 12.50	15	R 187.50	R 213.75	$ 31.07
Digging Tools	FYI: SPADES R135; PICK AXE R220				

Proposed Cost Analysis

Infiltration Trenches and Wetlands

Material	Cost per Unit	Number of Units	Total cost	Total Including Tax of 14% (where applicable)	Total (using exchange rate of $6.88)
Infiltration Trenches (10 metre length)					
Black Building Stone (per cubic metre)	R 293.86	3	R 881.58	R 2,680.00	$ 389.53
Truck Delivery of Stone	R 360.00	1	R 360.00	R 1,080.00	$ 156.98
Pebbles (per cubic metre)	R 65.00	2	R 130.00	R 148.20	$ 21.54
Truck Delivery of Pebbles	R 360.00	1	R 360.00	R 410.40	$ 59.65
Large Rocks (per cubic metre)	R 350.00	2	R 700.00	R 798.00	$ 115.99
Truck Delivery of Large Rocks	R 360.00	1	R 360.00	R 410.40	$ 59.65
Soil	R 12.50	15	R 187.50	R 213.75	$ 31.07
Digging Tools	FYI: SPADES R135; PICK AXE R220				
Wetland (15 metre diameter)					
Plants					
Indigenous Thatching Grass	R 32.00	10	$ 320.00	$ 364.80	$ 53.02
Lilies	R 35.00	10	$ 350.00	$ 399.00	$ 57.99
Agapanthus	R 40.00	10	$ 400.00	$ 456.00	$ 66.28
Soil	R 12.50	15	$ 187.50	$ 213.75	$ 31.07
Digging Tools (Back-ho)	R 120.00	1	$ 120.00	$ 136.80	$ 19.88