Adapting Sustainable Urban Drainage Systems to Stormwater Management in an Informal Setting

A case study in Monwabisi Park, Cape Town

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ABSTRACT

A major problem in the informal settlement of Monwabisi Park, Cape Town, is flooding caused by the low-lying topography and lack of stormwater management systems. Conducting a case study and working with local residents, we created a guidebook that analyzed the physical and social conditions underlying flooding problems, and the current interventions used by residents. In addition, the guidebook demonstrates specific Sustainable Urban Drainage System methods that we have adapted to an informal community setting.

This project report is part of an ongoing research program by students and faculty of the WPI Cape Town Project Centre to explore and develop options for sustainable community development in the informal settlements of South Africa. For more information, please go to http://wp.wpi.edu/capetown/.

The following is an executive summary that has been implemented as a website available at: http://wp.wpi.edu/capetown/homepage/projects/p2010/stormwater-management/.

PROBLEM STATEMENT

After the apartheid era in South Africa ended, many people seeking new opportunities in urban areas settled in informal settlements that grew largely unplanned and minimally serviced on the outskirts of many cities. These settlements are characterized by a lack of proper infrastructure (shacks), unsteady and unsafe housing, poor sanitation, and few job and educational opportunities (Parkinson, 2007). Without adequate public funding to improve public services, residents of informal settlements are faced with challenges to address basic needs. Monwabisi Park, an informal settlement located outside Cape Town, South Africa, has been experiencing many of the same problems as other informal settlements. However, the city has designated Monwabisi Park to be a pilot settlement for *in situ* urban upgrading, and has focused their attention on improving basic infrastructure and standards of living.

One major problem in this area is stormwater-related flooding and accumulation of stagnant water, which is created by the low-lying topography, the closeness of shacks along dirt roads, the paucity of proper infrastructure and poorly developed stormwater management systems found in this area (Butler, 2009). Water seeps into shack houses, causing property and infrastructure damages, such the degradation of floors, wall, and personal belongings, including mattresses and clothes. Standing water becomes a health hazard exacerbated by high levels of ground contaminants mixed with stormwater (Winter, 2010). To tackle this issue, residents of Monwabisi Park have already implemented several simple stormwater management solutions that help alleviate flooding damages; but problems persist. Therefore, an adequate, yet sustainable, stormwater management system that combines local initiative with government action is needed.

BACKGROUND

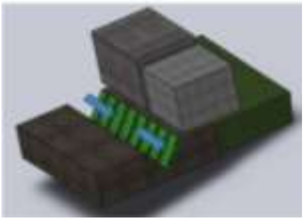
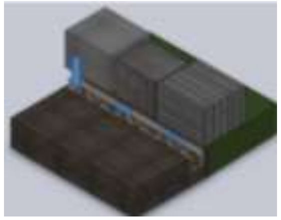
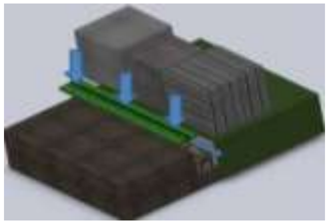
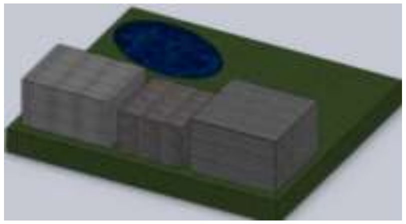
Excessive flooding in Cape Town, especially in informal settlements in the Cape Flats, has left over 32,000 people homeless during the past three years (Ziervogel, 2009). As a result, the city has established two main objectives regarding the management of stormwater runoff, which includes "reducing the impact of flooding on community livelihoods and regional economies", and "safeguarding human health, protect natural aquatic environments, and improve and maintain recreational water quality" (City of Cape Town, 2009). By clearly identifying these goals, the city is looking for simple and practical steps towards better stormwater management (City of Cape Town, 2009).

Sustainable Urban Drainage Systems (SUDS), is a philosophy used around the world to help reduce the excess flow of stormwater from spreading into unwanted areas. The major goals of the SUDS philosophy are to manage stormwater runoff, to rid the water of any pollutants and to encourage community involvement. When local community members participate in implementing and managing stormwater solutions, it increases the likelihood that community members will take care of the stormwater management systems, making said solutions more successful in the long-run (SUDS: Background, 2005).

SUDS TECHNIQUES

This project focused on integrating basic SUDS methods with the unique conditions and informal household stormwater management strategies found within an informal settlement. Using one road as a case study, this project detailed both physical and social aspects of stormwater management.

The four major SUDS interventions considered were artificial swales, soakaways, infiltration trenches, and wetlands. Artificial swales are narrow culverts dug into the ground, often into a low-lying area, with a shallow, dish-shaped depression. They are covered with vegetation and are used to redirect the flow of water away from unwanted areas, such as yards and houses. Soakaways and infiltration trenches are similar to one another in that each help to redirect and cleanse run-off water through a filtration process involving rocks that are strategically layered. Soakaways incorporate a layer of biofilters - plants used to absorb excess nutrients and minerals - on top of the rocks. In both systems, filtered water is redirected into a wetland - an open depression that is often found in low-lying areas that is rich with biological variety.

STAKEHOLDERS

Our premise is that a proper stormwater drainage system will use a combination of informal interventions and SUDS methodologies, and involve collaboration across many stakeholders. This project's specific goal was to analyze and create a plan for one area of Monwabisi Park that would produce lessons applicable throughout other sections of the settlement. Stakeholders include:

City of Cape Town: The City of Cape Town has created a new Informal Settlement Upgrading Programme (ISUP) program, with the Violence Prevention through Urban Upgrading Programme (VPUU) as lead agency. The VPUU requested this project, as they are dedicated to upgrading informal settlements through infrastructure planning, such as road development and stormwater management systems.

Dr. Kevin Winter: Dr. Winter, a professor of Environmental and Geographical Studies at the University of Cape Town, assisted both the team and the city in developing a plan that will minimize flooding in Monwabisi Park. He provided valuable insights into working with the residents of

Monwabisi Park, translating formal stormwater management systems to an informal setting, and organizing the overall presentation of the project in a way that is understandable to a variety of audiences ranging from city governments to academic scholars.

The WPI Cape Town Project Centre: IQP projects from previous years have helped gather background information on water sanitation issues and community involvement in Monwabisi Park. This helped the team understand the complexities of working in the Park and helped them prepare for these obstacles.

Residents of Monwabisi Park: Residents contributed to this project tremendously by offering their feedback and suggestions on different stormwater management systems that are already in place and those they would like to see. They are also key participants in the project's community-based approach to flooding management, as they are the ones who will build and manage many implemented systems.

Co-Researchers: The Cape Town Project Centre enlisted the help of six local Monwabisi Park residents who served not only as language translators, but also as cultural translators. They offered invaluable insights into working within the settlement, interacting effectively with the locals, collecting data, and appropriately addressing the different issues related to current and proposed solutions.

METHODOLOGY

The main goal of our project was to create a guidebook that would help the VPUU and the residents of Monwabisi Park implement simple, yet efficient, stormwater management systems. We created a poster and brochure that the VPUU could use to set up community stormwater management plans. The stormwater interventions that our team recommended employ modified SUDS methods adapted for implementation in informal settlements. The VPUU chose the main road in Monwabisi Park's C-Section as the pilot site.

Five main objectives guided our project:

- Identify and categorize flooding hot spots
- Analyze Impact of Flooding
- Measure and model the spatial conditions of the hot spots
- Generate designs for stormwater management systems for informal settlements
- Create a guidebook, brochure, and poster

To start our project, we walked along the main road to get accustomed to the people who live alongside the road, to observe the different conditions of the road, and to study and take note of the existing stormwater interventions. We were able to conduct quick and informal interviews to better understand where the residents experienced the worst flooding. Preliminary analysis determined that there are seventeen main areas that experience extensive flooding. When we walked on the road and interviewed more residents, we grouped some of the areas together into four "hot spots," which are the sections of the road most prone to flooding problems.

Two members of our team revisited the four hot spots and conducted formal interviews. The questions of the interviews focused on the physical aspects of stormwater management, such as interventions that the residents had been using, and the social aspects, which included assessing levels of cooperation and tension among neighbours related to stormwater interventions. The co-researchers introduced our team to the different homeowners and translated into English what the residents said.

The other two members of our team focused on measuring the road and creating accurate computer-generated models of the different hot spots. They showed these models to the residents so that they could point out where the trouble areas were and where they would like to see stormwater management interventions placed. Since most of the proposed interventions require gravity as a key component, they measured the different levels of the roads using a level and a tape measure. After some analysis, they concluded that this method was inefficient, and used Google Earth Pro instead to obtain the needed information.

Methods				
	Direct Observation	Mapping & Measuring	Informal Interviews	In-depth Interviews
Objective 1: Identify and Categorize Flooding Areas	x		x	
Objective 2: Analyze Impact of Flooding		x		x
Objective 3: Responses to Flooding				x
Objective 4: Generate Models	x	x		

DIRECT OBSERVATION –This method is a consideration of the current situation along the road with regards to infrastructure condition, preventative measures taken to minimize flooding, and the apparent effectiveness of existing flooding prevention systems. The information gained from this method was based on the team's knowledge and expertise on how to qualify and quantify the existing flooding conditions. It included observations and photo documentation of the visible flooding damages to homes, of problematic road topography, of types of innovations implemented by residents in an effort to prevent flooding, etc.

MAPPING AND MEASURING – The following method had two components: mapping and measuring the C-section road. The mapping method consisted of locating the exact areas of each flooding hot spot using a Global Positioning System (GPS) device so that the latitude and longitude coordinates of each location were inputted in Google Earth. However, this method did not work well because of the inaccuracy of the GPS, and the team ended up using maps from Google Earth and mapped the areas by hand. Measuring the different hot spots helped obtain a precise collection of the spatial dimensions of the different hot spots. These measurements, done by use of tape measures and levels, were then inputted into a CAD program to create floor plans of each hot spot.

INFORMAL INTERVIEWS – This method consisted of casual and quick conversations with the residents along the C-Section road to find out more about the flooding problems residents experienced. This helped the team narrow down the number of hot spots from 17 to 4. This also helped the team get an initial feeling of the community they would be working in for the 7 week project duration.

IN-DEPTH INTERVIEWS – Conducted in the four hot spots, these structured, in-depth interviews focused more on the underlying social problems caused by the existing stormwater management interventions. The team gathered information on tensions and collaborations between neighbors, input on how our proposed solutions would fit into the community and if these solutions would be accepted and preserved.

RESULTS AND ANALYSIS

To summarize our case study of SUDS applicability in informal settlements, we documented in a report, “guidebook”, and website key findings, including both the physical and social conditions that arose as a result of stormwater management issues. Below we discuss major results and findings from each of our four main objectives.

IDENTIFYING AND CATEGORIZING FLOODING AREAS

Our first objective was identifying and categorizing flooding areas along the road. We accomplished this by identifying the different types of flooding conditions and the contributory factors that perpetuate said conditions. We have categorized three main factors that contribute to current flooding conditions along the road. The three categorizations include: 1) **Taps** 2) **Toilets** and 3) **Road Topography**; and a description of and how each category contributes to the flooding conditions follows:

TAPS –Houses located near taps (abused by residents) have an increased chance of suffering from flooding. The flooding is not severe, but can lead to problems such as health hazards and distress of the residents.

TOILETS – Communal toilets leak due to a lack of proper, routine maintenance and emptying of conservancy tanks. Health hazards are created as waste water pools in roads and near houses.

ROAD TOPOGRAPHY – Conditions inherent to the natural and human influenced topography of the road can contribute to and augment flooding in areas along the road. The team has further delineated this categorization into four designations or subcategories: 1) *Gentle or Steep Slopes* 2) *Winding Roads* 3) *Divots* and 4) *Low-lying Valleys*. A description of how each of these subcategories contributes to the road topography and its affect on flooding follows:

1. *Gentle or Steep Slopes* – Depending on the gradient of the slopes in the road, the flooding can be characterized in a variety of ways. Steep gradients cause faster water runoff and create greater potential for infrastructure damage. Gentle slopes result in slower movement of water, but result in pooling of water.

2. *Winding Roads* – Bending roads frequently result in the disruption of the natural flow of water. The water won't flow along the road and will flood into the houses.

3. *Divots* – Irregularities in the road can cause problems during rainstorms, as the water flow becomes erratic due to the divots. It changes course and flows into residents' houses and accumulates and becomes stagnant.

4. *Low-lying Valleys* – The natural landscape of Monwabisi Park poses a flood risk, since water naturally flows with gravity to the lowest point possible (this area).

ANALYZING THE IMPACT OF FLOODING

Our second objective was analyzing the impact of flooding. This analysis included a consideration of the overall impact of flooding within Monwabisi Park as well as the deeper physical and social impacts associated with flooding, which are entrenched within the settlement. Results of these considerations are shared below:

OVERALL: PREVALENT, BUT NOT LONG-LASTING, VARIABLE, EPISODIC, NOT AS SEVERE AS OTHER SETTLEMENTS (CAPE FLATS)

Initially, 17 areas were identified as prime flooding spots, and through interviews, these areas were narrowed down to 4. Flooding has been described as prevalent, but not long-lasting. In Monwabisi Park, it has been identified as a problem, but it is only episodic in nature, when compared with other settlements, specifically in the Cape Flats.

PHYSICAL: SOME INFRASTRUCTURAL DAMAGE, EROSION OF THE ROAD, POOLING OF WATER.

Flooding has specific physical consequences, such as erosion of the road resulting in movement of sand from one location to another. The shifting of sand allows water to seep into homes along the road. Pooling of water also results in flooding due to sand becoming oversaturated, leading to the runoff water spreading to low-lying areas.

SOCIAL: CAN CREATE COHESION OR TENSION (MORE TENSION), HEALTH HAZARDS, DISTRESSING

Many areas have a high prevalence of tension resulting from stormwater problems, witnessed to lead to a high level of distress among residents. Pooling of water, and its mixture with grey and black water, creates significant health hazards in various areas as well.

DETERMINING CURRENT RESPONSES TO FLOODING

Our third objective was determining current responses to the flooding issues and conditions we identified and how these interventions contributed to the physical and social impacts we analyzed. A chart of the physical interventions currently employed by the residents has been included below. For organizational purposes and in order to orient the reader, we have shared a bulleted summary- illustrating the observations the team has gathered regarding current interventions- preceding the chart of physical interventions. The chart itself is followed by a specific description of each intervention and an overview of the social reactions to the use of said interventions (detailed information following objective four).

SUMMARY:

Many stormwater techniques are already in place and used by the local residents. These include fences, tyres, culverts, vegetation, accumulation of sand, wooden ledges/boards, raised platforms, and plastic. The majority of these techniques are widespread throughout the settlement, while other interventions which are more complicated to design, like raised platforms and plastics, are less commonly used by the residents.
Interventions found within Monwabisi Park serve to do three main things; create a barrier against the water, create a path of redirection for the water, and assist in the absorption of water into the ground. These three functions can all help minimize flooding in one aspect or another, but the manner in which they do this varies depending on the size, location and effectiveness of the system.

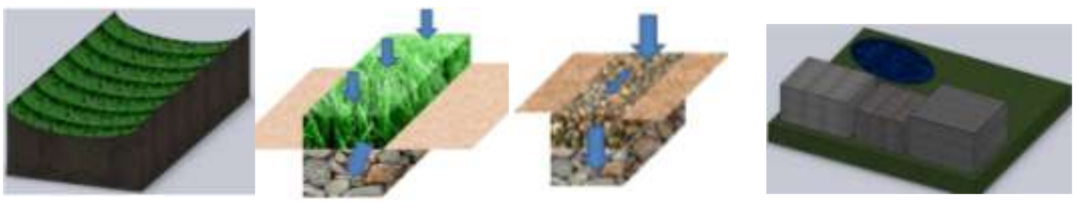
The effectiveness of informal stormwater interventions varies widely, both by intervention type and the intention of specific applications. These depend on factors such as whether the underlying strategy of the technique is intended to prevent flooding, what level of maintenance it entails (on both a long-term and short-term basis), and what extent of construction it requires. If the intervention is relatively simple to design and install, such as the stacking of tyres or the creation of ditches, then the chance of it being built correctly and effectively is higher than if it entails a greater amount of assistance to set up.

Socially, existing interventions cause numerous problems within the community. Techniques beneficial to one resident often negatively affect others, and residents expressed emotions ranging from subtle annoyance to vociferous frustration, resulting in distress and lack of trust. Our SUDS-informed recommendations to encourage cooperation among neighbours are designed to reduce these problems, and to assist in creating solutions that can benefit a large group of people all at the same time.

DETERMINING APPROPRIATE RESPONSES TO FLOODING ISSUES

Our fourth and last objective was determining appropriate responses to the flooding issues and conditions we identified and to the physical and social impacts we analyzed. We considered the interventions currently used and sought to create models for proposed solutions which incorporate SUDS and adapt it to informal settlements. A discussion of our findings follows:

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.



In Monwabisi Park, the preventative measures that the residents have implemented are only partially successful. To help increase the effectiveness of stormwater management plans in an informal setting and to work alongside these interventions, we proposed four different SUDS methods that we have adapted to work in an informal settlement. These solutions included artificial swales, soakaways, infiltration trenches, and a wetland. One main philosophy behind SUDS interventions is obtaining community involvement. By encouraging collaboration among community members, it is possible to create a plan that can benefit a larger group of people. By promoting community-wide efforts and teamwork, the management demands, which are greater than the demands of the current interventions, will become more reasonable and easier to satisfy.

CHART OF PHYSICAL INTERVENTIONS:

Physical interventions- Some of the current interventions present along the studied road included: fences; culverts and holes; accumulation of sand bordering the sides of the roads; vegetation; wooden boards and ledges; tyres. The functionality of these methods and techniques vary greatly, as summarized below.

Interventions	Prevalence	How It Works	Method of Implementation	Constructability	Level of Maintenance	Problems they Create
Fences						
Metal	Widespread	Creates barrier to redirect water	Individual	Extensive	Low: minimal care	Redirection into neighbouring yards
Cloth	Scattered	Creates barrier to diminish water flow	Individual	Simple	Low: minor care	
Wood	Widespread	Creates minor barrier, helps stabilize sand	Individual	Extensive	Low	Disruption of sand, redirection into neighbouring yards
Tyres						
Stacked	Scattered	Creates barrier, stabilizes sand	Individual	Simple	Very low	Unattractive, not accepted by neighbours
Buried	Widespread	Stabilizes sand, prevents it from shifting	Varied between individual and collective	Minor effort	Very low	Disruption of sand, creates uneven ground surface
Culverts	Scattered	Captures and redirects water	Mostly collective, sometimes individual	Simple, undemanding	Moderate: routine monitoring	Redirection of water into unwanted areas, blockages resulting in stagnant water
Vegetation						
Grasses	Widespread	Captures and filters water	Varied between individual and collective	Effortless	Very low	
Shrubs	Moderate	Creates barrier to redirect water	Mostly individual, sometimes	Minor effort	Low	Isolation between neighbours, extensive

			collective			privacy
Accumulation of Sand	Widespread	Creates barrier between house and water	Individual	Minor effort	High: constant monitoring	Uneven surface in the road, increase instability of road surface
Wooden Ledges/Boards	Scattered	Redirects water and creates minor barrier	Individual	Extensive	Moderate	Redirection of water into neighbouring yards
Raised Platforms	Rare	Promotes spread of water beneath the house	Individual	Extensive	High	Redirection of water into unwanted areas
Plastic	Rare	Creates reinforcing barrier between inner and outer house walls	Individual	Minor effort	Moderate	Instability of house walls

Fences:

Fences serve as a barrier against both rainwater and communal tap water runoff and are designed to prevent household flooding. They are built around the perimeter of individual yards and 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.

Key Features: Varied 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 use strands of wire to hold the wood together, while others use scrap pieces of metal siding to keep the poles standing. 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 nearby, neighbouring yard.

Shadecloths, large pieces of material with a dark green tint that serve to help block the sun and provide privacy to residents, are another resource used in fences. 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 slow the overall flow of water.



Tyres:

When incorporated with the sand found along the road, tyres 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.

Key Features: Incorporation with Sand
Burying the tires into the sand stabilizes the sand limiting the creation of unwanted natural paths and channels that redirects water into houses. Stacked designs allow 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 for the tyres to withstand.

CULVERTS:

Culverts (ditches) can be found bordering yards and 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.

Key Features: Varied Size

Culverts are adaptable to different conditions, and can be created in numerous, varying areas. Some culverts 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.

VEGETATION:

Grassy areas are commonly located alongside the road, and bordering the fronts of residents' yards. They serve to help catch excess water and redirect it to various places both on and off the road. Shrubs frequently resemble a small fence, but they have much greater open space throughout them, which allows water to easily flow through.

Key Features: Grass and Shrubs

The most common grass found in this area 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.

Shrubs are often placed along the border between yards and the road, and they serve to provide a barrier against water runoff as well as to provide privacy and isolation to many residents.


ACCUMULATION OF SAND:

Many residents strategically pile sand along the perimeter of their yard and at the base of their house to create a barrier against runoff. The accumulation of sand along the perimeter of yards is commonly incorporated into an existing fence to cover up any holes and to stabilize the fence. Piling sand around the base of a house also serves to reinforce the foundation, and provide 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 water damage seen by floors and furniture.

Key Features: Temporary Nature of Sand Piling

The use of sand as a preventative method against stormwater is often seen as counterproductive. The buildup 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 flow. 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 penetrate. Thus, sand barriers require continual upkeep.

WOODEN LEDGES/BOARDS:

These ledges are made from long, thin scraps of wood and are positioned either along the perimeter of yards, or directly in front of doorways. They serve not only to block water from entering the unwanted areas (yards and houses), but they also assist in redirecting water into either neighbouring yards or central areas where water accumulates and pools.

Key Features: 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. 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.

RAISED PLATFORMS:

Raised platforms are 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, enclosing an area of excess sand. The risk of flooding is highly decreased due to the entire house being raised above the ground.

Key Features: Permanency and aesthetic appeal
Similar to wooden ledges and boards, raised platforms are long lasting. They are often time consuming to initially implement, but once in place, they are very hard to remove. 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.

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:

Plastic is used to help stabilize 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. It can be located either between a layer of built up sand and the outside walls of a house, or it can be placed between the outside walls and inside walls. 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.

Key Features: Thickness
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.


SOCIAL REACTIONS

Socially, it was noted that in hot spots A and D, there was relatively low tension between the neighbours and they were willing to work together to create a community-wide stormwater management system that would have the potential to benefit many people. Specifically in hot spot D, the residents had developed a small water redirection system along the road that resembled a ditch. They created this system by working together in a large group, sharing tools and other resources, and by organizing a collaborative effort to ensure that it was properly implemented. Unfortunately, this willingness to work together was not present in either hot spot B or C. The residents in these areas experienced conflict with one another and were not as eager to work as a collaborative community to design a new stormwater management plan.

FUTURE RECOMMENDATIONS

Our team's research and work in Monwabisi Park has resulted in a detailed proposal that has left both the VPUU and other organizations with guidelines for implementing the solutions we have suggested. This process would require obtaining more community involvement in both planning and implementing the adapted SUDS methods. This would help determine if these solutions do, in fact, work in informal settings. If the social collaboration and the physical interventions work, we recommend implementing the SUDS interventions in all of Monwabisi Park so that more people can benefit from proper stormwater management. A record of the steps of the process is crucial in understanding and analyzing the solutions. From such results, a case study can be created discussing future stormwater management systems in informal settlements.

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