Guidebook Addressing the Sustainable Upgrading of Greywater and Stormwater Management Systems

Including sustainable processes and methods as practiced in the settlement of Langrug outside of Franschhoek, South Africa

This document is a detailed acount of the interactions of the Worcester Polytechnic Institute's Cape Town Project Centre with community members from Langrug. This document is intended to be a reference for any NGO or outside organisation during the initial stages of undergoing sustainable community development, as well as a database of greywater and stormwater management systems as applicable in informal settlements.

Authors
Lauren Harris
Andrea Kates
Timothy Momose
Christopher Overton

Advisors
Scott Jiusto
Steve Taylor

12/01/2012

Table of Contents

List of Figures

This Guidebook and Lessons to be Learned

Mission Statement

The purpose of this project is to partner with community members of the informal settlement of Langrug to develop and test a process for ongoing community-driven in-situ upgrading of greywater management systems, as well as generate a guidebook describing the process, our application of the process in Langrug, and a database of greywater management strategies that have been adapted to suit the conditions in informal settlements.

Objective

- Analyse and categorize greywater issues throughout the settlement
    - Document through mapping and photographing
    - Identify risks
- Develop a general process for upgrading greywater systems with maximum community participation
    - Involve the community with planning and implementation of the grey water management systems to create jobs and ownership over the projects
    - Use monetary contributions from the community to leverage necessary financial support from NGOs
    - Work with the community to implement maintenance plans for the completed upgrade
- Test the upgrading process in pilot sites and make necessary adjustments to maximize effectiveness
- Equip a team of community members to use the process to carry on upgrading throughout the upcoming year
    - Create resources to aid in analysis and planning, as well as community awareness and involvement
    - Train the team in methods for analysis, implementation, and documentation, as necessary

Organisation

This guidebook is the product of the application of the mission statement and objectives in Langrug with a team of co-researchers during the months of November and December of 2011. This document is organised in three sections. The first section is intended to provide the reader with general background and an understanding of the process used in Langrug to upgrade greywater and stormwater management systems. The second section provides examples of how the process was applied in Langrug, outlining the successes and setbacks. Thirdly, a database of greywater and stormwater management techniques is included to provide basic information on different stormwater management techniques that the WPI students have researched and adapted to greywater management in informal settlements.

NGO

This book can serve as a reference for NGO's considering partnerships with communities in informal settlements to upgrade greywater management systems. NGO representatives may use this manual as a reference and record of the work that was performed in Langrug. In this situation, multiple NGO's partnered with each other, the local municipality, and the community to work on in situ upgrading.

Community

Community members in informal settlements can use this guidebook as reference for the application of a sustainable process to upgrade greywater management systems. This process describes steps that the Greywater Management Team in Langrug has undergone to ensure the on-going participation of the community through planning, building, and maintenance. Moreover, the guidebook gives insight to social factors related to in situ upgrading and describes various options for greywater management.

This book is intended to serve as a testament to the events that occurred in Langrug from the perspective of the WPI students, and may not contain the complete perspectives and opinions of the other stakeholders with whom the WPI students collaborated.

List of Abbreviations

CORC	Community Organisation Resource Centre
CTPC	Cape Town Project Centre
CUFF	Community Upgrade Finance Facility
DIHS	Department of Integrated Human Settlements
EPWP	Extended Public Works Programme
IGSD	Interdisciplinary & Global Studies Division
IQP	Interactive Qualifying Project
NGO	Non-Government Organisation
RDP	Reconstruction and Development Programme
SDI	Shack/Slum Dwellers International
UISP	Upgrading of Informal Settlements Programme
WHO	World Health Organisation
WPI	Worcester Polytechnic Institute

Preface

Informal Settlement Upgrading

After South African apartheid ended, Nelson Mandela and the African National Congress put the Reconstruction and Development Programme (RDP) into action. This programme included many aspects that focused on economic stimulation, sustainable development, and developing social services which were lacking in most of South Africa (O'Malley, 1994). One portion of the RDP that directly affects the South African population living in informal settlements is the construction of RDP houses built by local municipalities and subsidised by the Provincial Government. Residents of informal settlements are placed on waiting lists for these houses; these lists are constantly growing, and providing houses to the people waiting will take decades. This system is not efficient enough to satisfy the lack of basic human needs that plagues informal settlements in South Africa. Thus the South African Government has been searching for alternate strategies to manage these issues. One such strategy that has arisen is the idea of in situ informal settlement upgrading.

In 2007, the Upgrading of Informal Settlements Programme (UISP) was published in the National Housing Code. This programme emphasized in situ upgrading of informal settlements, which focuses on improving the quality of life in an informal settlement. The fundamental difference between in situ upgrading and the RDP is the RDP relocated people out of their shacks and into formal housing, whereas in situ upgrading focuses on building up the entire settlement without relocating any families. The UISP pulls focus away from the central issue of housing and towards other necessities, such as water, sanitation, and hygiene. This plan provides much more flexibility in terms of providing monetary subsidies to municipalities searching for innovative solutions to providing basic services to the residents of informal settlements.

Langrug, an informal settlement on the outskirts of Stellenbosch, South Africa, is a pilot site for a unique process of in situ upgrading. The Stellenbosch Municipality has signed a contract with Non-Government Organizations (NGO's), such as Shack/Slum Dwellers Internation (SDI) and Community Organisation Resource Centre (CORC), in order to ensure cooperation while working towards urban upgrading. This contract is going to be crucial to the success of developing processes aimed at improving the quality of life throughout the informal settlements. A small group of community members has been tasked to develop and lead efforts to install localized greywater management systems in Langrug. This incremental upgrading will help bring the quality of life, overall safety, and health of the settlement to an acceptable standard, using a sustainable and efficient process.

Problem Statement

Greywater is produced by a variety of sources ranging from washing dishes and clothes to bathing. The water produced by these activities contains many contaminants such as salts, chemicals, bacteria, and food particles. When grey water pools, the germs that are present begin to multiply, releasing odours and tainting the water. According to the World Health Organisation (WHO), after 24 to 48 hours, any grey water — despite its initial level of contamination — becomes

infected and toxic (World Health Organization, 2006). In Langrug, greywater has been associated with major health risks including:

- Maggots
- Diseases
- Rashes
- Smell

In addition to these health risks, the community faces other problems due to greywater. The most severe of these problems is when heavy rains overwhelm the current greywater paths, causing flooding. Often times, and especially in the winter, people's houses are flooded by a mixture of stormwater and greywater.

The Partnership

Figure 1: The Langrug Greywater Team
From left to right: Timothy Momose (WPI), Trevor Masiy (Langrug), Sinazo Ndabambi (Langrug), Sibongile Xenxe (Langurg), Chris Overton (WPI), Kholeka Xuza (Langrug), Andrea Kates (WPI), Lauren Harris (WPI)

Four students from Worcester Polytechnic Insitute (WPI) worked on addressing a sustainable process for upgrading greywater streams in informal settlements. All of these students are third year students studying abroad to fulfil WPI's Interactive Quaifying Project (IQP) requirement. The abroad IQP programme at WPI is designed to promote interactions with different cultures, while working on a prominent social issue. The WPI students spent 7 weeks working in Langrug, an informal settlement in South Africa, along with a team of community co-researchers. This year, the team worked to establish a foundation of knowledge that future IQP groups could use to facilitate their work in Langrug, or other informal settlements.

The community co-researchers were previous enumerators in Langrug. Using skills and knowledge gained through enumeration, the co-researchers formed the Langrug Greywater team, along with support from the WPI students. This team worked within the community to create and execute a process to upgrade greywater channels throughout Langrug. Going forward, the co-researchers will continue to work throughout the year to mobilise small portions of the community to upgrade greywater channels. The team of community members will also update a blog online, making note of their experiences and issues they have had with different greywater management techniques, as well as other issues such as community motivation. This blog will serve as a record of the progress they have made as well as a database of information for other NGO's and communities that are trying to upgrade greywater channels in other informal settlements. The co-researchers have been provided with a WPI Cape Town Project Centre Co-Researcher Scholarship in order to sustain their research, observations, and community mobilisation.

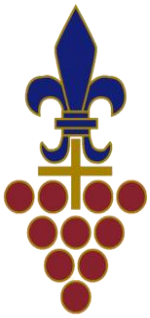


Figure 3: Stellenbosch Municipality Logo

The Stellenbosch Municipality has pioneered a forward-thinking attitude about the relationship between NGO's and the government. The City of Stellenbosch sponsored the WPI students' project, providing them with background information and resources. The DIHS, a branch of the Stellenbosch Municipality that was founded in early 2011, works directly in informal settlements. David Carolissen, the Deputy Director of the DIHS, sponsored the WPI students' project in Stellenbosch. During the preparation phases, Carolissen supported the students as their main contact in determining the allocation of the students' efforts and attention. The DIHS has also been using the Extended Public Works Programme (EPWP) to employ informal settlement residents for public works projects in their respective settlements. Many workers have been hired through EPWP to pick up rubbish and do cleaning work in Langrug at a wage of R90 per person per day.

Figure 2: SDI logo

SDI is an NGO that works throughout Africa, Asia, and Latin America. This organisation is made up of communities around these countries coming together to form a support network. This network is intended to help the communities engage the government in order to try new strategies and understand the challenges of urban development. Also, SDI works to place the communities at the centre of development.

Figure 4: CORC logo

The branch of SDI that works in South Africa is also known as CORC. CORC serves to capacitate community entrepreneurs that work with community groups, using their own resources. In order to assist these community members, CORC has a financial support vehicle, known as the Cummunity Upgrade Finance Facility (CUFF). This financial plan allows for the community to apply for financial assistance with major expenses for upgrading. To qualify for this financial support, the community must raise 10% of the funding and fill out cost tables and paperwork describing the

project and the desired impact.

In Langrug, all of these stakeholders have come together to form a partnership that would work in close collaboration with each other and the community. In November 2011, the partnership signed a contract, which reflected the strong relationship that had developed between the municipality, SDI, and the community leadership, and it established the Stellenbosch Urban Poor Fund – a pool of funds for the Stellenbosch Municipality to tap into for informal settlement upgrading. Together, the partnership will hopefully allow for much greater efficiency in providing support to mobilised communities around the Stellenbosch Municipality.

Building off Previous IQP work

Previous IQP's located at WPI's Cape Town Project Centre (CTPC) have worked with greywater/stormwater management and flooding. Major concepts for this IQP have been drawn from the following works:

CTPC 2007: Flood Risk Management

CTPC 2010: Stormwater Management

The Flood Risk Management document provided a superb background regarding the issues of solid waste management. This team worked to determine the stakeholders within the government and communities in the maintenance and caretaking of the stormwater streams. However, the team stressed that the Catchment, Stormwater, & River Management Department of the Cape Town Municipality was stretched extremely thin, as it is responsible for approximately three million people (including informal settlements) (Bouchard, Goncalo, Susienka, & Wilson, 2007). The Stormwater Management team discussed different strategies for identifying the priority areas for stormwater management systems. This team conceived a system of identifying "hot spots" which pointed out areas that were the most prone to flooding, and these "hot spots" would take priority during the decision of project sites (Button, Jeyaraj, Ma, & Muniz, 2010). We adapted this concept of "hot spots" to greywater streams by identifying the streams that carried the most risk of overflowing into homes, had the greatest affect on general community welfare, or were in the worst condition. Another factor that we attributed to the idea of a "hot spot" is the willingness of the neighbouring residents to help with construction and maintenance.

The Process

Upon reflecting back about our experiences in Langrug, we recognised the general shape of our work followed that of a spiral. Two weeks into our work, we identified what we had imagined as a circular process that would loop until greywater work in Langrug was finished. However, at the end of our work, we realised that a spiral represented our work much more effectively than a circle. A spiral is indicative of growth as well as continuity. As a team, our work started with intense physical labour in J-section and ended with four simultaneous projects led by community members. Figure 5 shows the path that our work took, each block is explained further in this document; use the labels of the spaces as references to other locations in the document (i.e. for information on step 3 of J-section work, go to the page with "J-3" at the top)

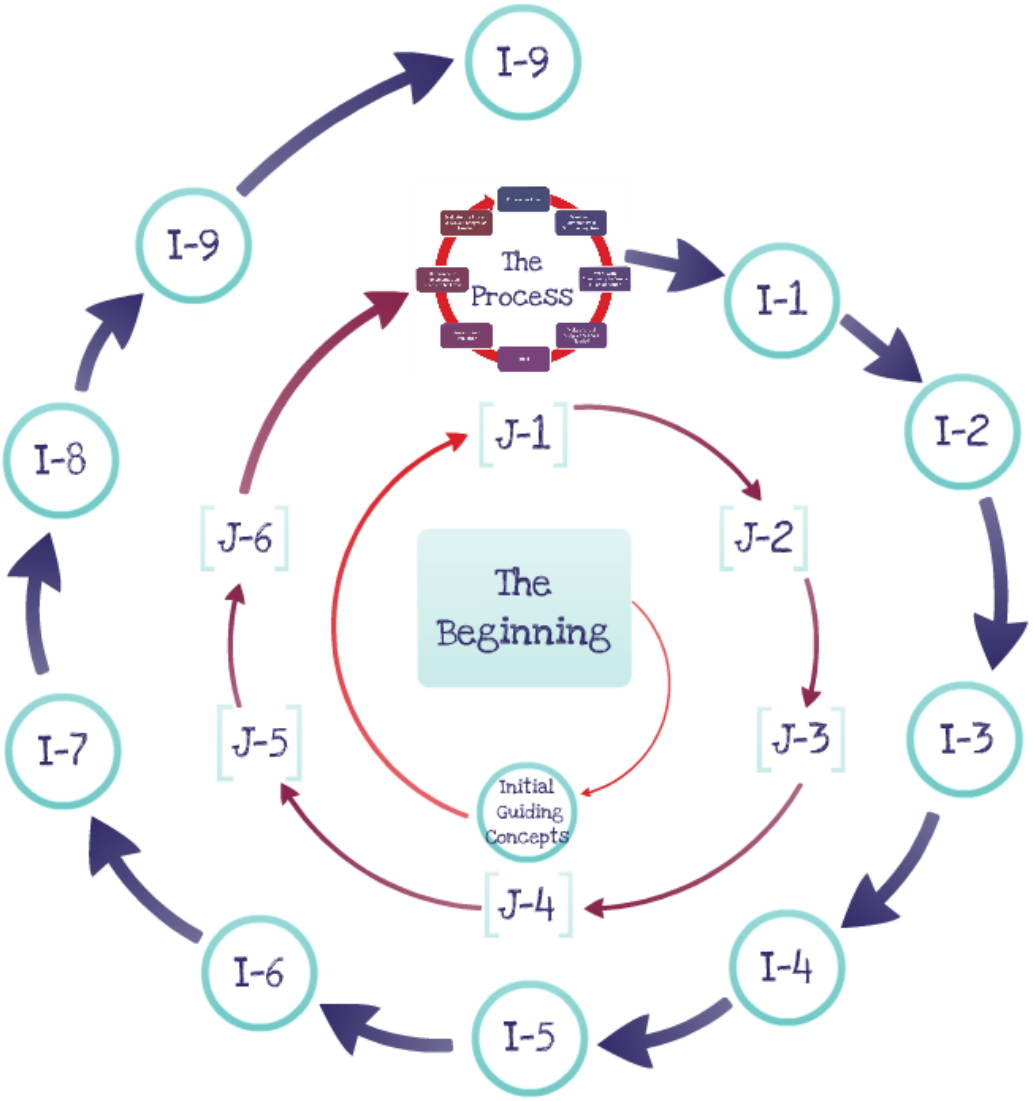


Figure 5: Spiral diagram of the process

Lessons

- Greywater was a major issue in Langrug
- Community had made attempts at greywater management strategies

Accomplishments

- Gained broad understanding of greywater situation
- Mapped greywater streams

The first step in our project was to meet Langrug community leaders who were elected by the municipality and the community in February of 2011. We also met several ladies employed by the municipality to work on the Langrug enumeration, which took place in June 2011. Upon arriving in Langrug, Mr. Carolissen – our sponsor – introduced us to Trevor, Alfred, Nyameka, Kholeka, Sibongile, Sinazo, and Siyanda – the community members whom we would be working with. They gave us a tour of the settlement, highlighting several major issues faced there.

Figure 6: Images of the many greywater streams present throughout Langrug

One of the biggest problems identified during the tour was greywater management. Community members told us greywater was hard to control, especially during the rainy season, because Langrug lacked a formal community-wide drainage system. One of the few formal greywater channels in the settlement is a cement gutter which runs along the main road. All other

greywater drainage was through informal channels either carved out of the sandy hillside by stormwater or put in place by community members using salvaged materials. Both the formal cement gutter and the informal channels had problems with clogging caused by trash and sedimentation. Clogging led to greywater pooling, especially in the informal channels.

Figure 7: Co-researchers walking down Langrug's main road next to the official cement greywater channel

When we interviewed community members about their experiences with greywater streams, they identified several problems (), including strong odours and an abundance of flies and maggots around pooled greywater. The greywater streams were often used as dump sites for food waste, which together with greywater created an ideal habitat and food source for the maggots (, right). In the warmer weather, the maggots will leave the greywater streams and enter people's houses.

We also found that many families in the settlement work hard to supply food to their children. We learned that these children sometimes play in greywater streams while their parents are focusing on searching for work in order to supply food for their families.

Figure 8: Problems due to greywater and community interventions

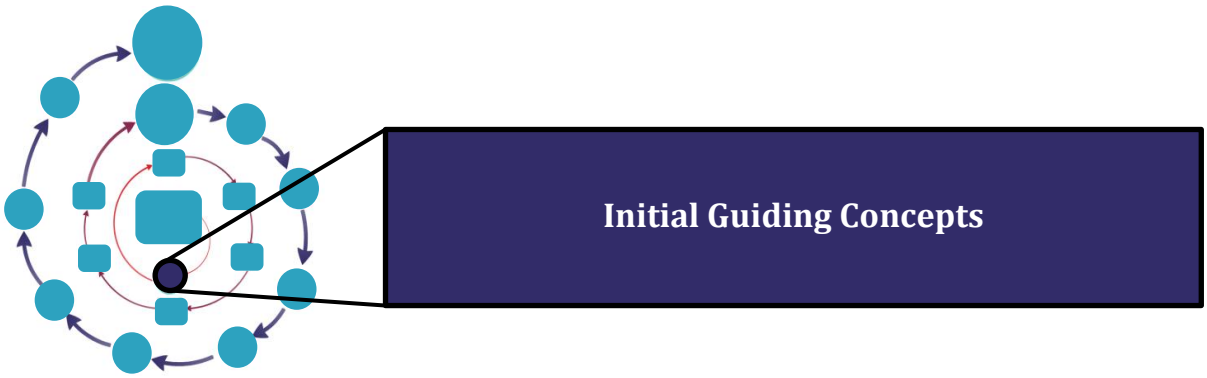
In touring the settlement, many residents of Langrug were noticeably combating greywater issues. Figure 9 shows examples of the community's efforts to control greywater. These interventions ranged from quick-fix solutions such as piling rocks against their houses, to more extensive interventions such as using half pipes as greywater channels or using metal walls which direct runoff away from houses.

Figure 9: Community attempts at greywater management

After learning about greywater issues in Langrug, we decided that a map of the greywater streams would aid in future initiatives to address these issues. Using a map created during the enumeration process, Kholeka recorded the paths of greywater streams in Langrug. While mapping, we noted the existence of several “hot spots” in the community; however, the map did not differentiate between hot spots and low risk areas.

Figure 10: The map of Langrug after adding greywater streams

Having toured the settlement together, the entire greywater team – both students and co-researchers - discussed the best way to carry out a comprehensive upgrade of Langrug's greywater systems. We initially envisioned doing this by creating a plan for the community that would suggest specific greywater management options for upgrading each greywater stream. However, creating a master plan is an extensive process which time would not permit. A more hands-on approach was necessary to gain the experience and understanding of what steps were necessary in implementing a greywater management strategy.



Lessons

- Learned importance of declaring project goals

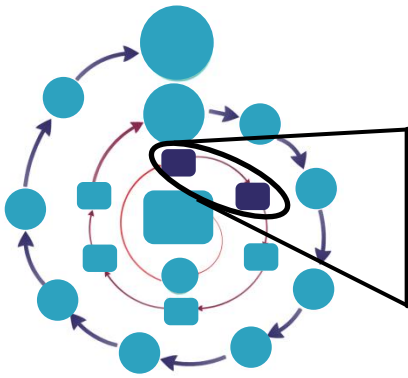
Accomplishments

- Created a plan of action for the duration of the project

The experience of implementing a greywater management system would help determine the best course of action for our project.

This plan was guided by several concepts, namely:

1. **Inspiration, by way of example:** Constructing a greywater management system would motivate other community members around the settlement to mobilise themselves around the co-researchers' expertise in order to create greywater channels near their homes.
2. **Community involvement:** Proper maintenance is crucial to the functionality of the greywater management system. If the community is closely involved in construction they will feel a sense of ownership over the project, and be more likely to take care of and clean the system.
3. **Sustainability and permanence:** Emphasising a long-lasting and effective solution is important to the community. A solution that will knowingly fail after a short period of time is not a proper solution, therefore we will emphasise creating solutions that are sustainable and long-lasting.
4. **Strengthen co-researchers as agents of community development:** The co-researchers face an immense pressure as the go-to experts of greywater upgrading. In order to produce a sustainable and effective process, the co-researchers should serve solely as experts, rather than labourers.



J-1 & J-2: Choosing J-section & Interviewing

Lessons

- Choosing an area should take into account level of likely community involvement
- Verbal acquiescence to help doesn't assure community involvement

Accomplishments

- Found a "high risk" area for first greywater management strategy upgrade
- Learned from community interviews about:
  - Problems due to greywater
  - Willingness to help with construction
  - Types of greywater management strategies the community wanted

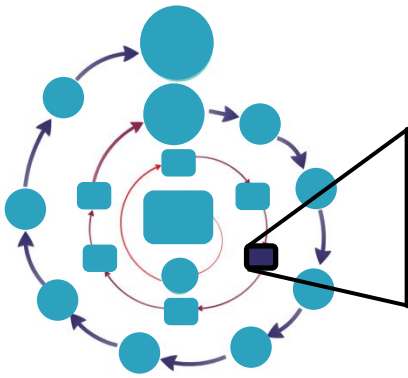
Our first step to building a greywater management system was to decide where to work. Trevor and municipal associate Johru Robbens identified an existing greywater stream in the J-section of Langrug as a good starting point. The stream consisted of a short dirt channel divided into sections by several large cement pipes that acted as walkways over the channel. Several of the pipes were blocked by sand and trash. The channel was located across the street from a crèche, headed by a woman named Gogo.

Figure 11: The J-section channel is located directly across the street from a crèche

Interviews with Gogo and several other community members living near the channel revealed how well it fit our definition of a "hot spot":

- **Flooding:** While the channel was not flooding when we found it, it was completely clogged with trash and sand, so there was a high risk of flooding in the event of heavy rain.
- **Greywater-specific Issues:** The clogging caused pooling in several sections of the channel, giving rise to maggots, smells, and health risks. Gogo was concerned that the children at the créche might play in the greywater and get rashes.
- **Community Willingness:** We interviewed several community members who lived nearby, and found them willing to help implement an improved channel.

Our decision to build a greywater channel in J-section coincided with a community wide clean-up sponsored by the DIHS in preparation for a meeting to formalise ***The Partnership*** (see page iv) with SDI. This meeting was planned for 12 November as a celebration involving the municipality, NGO's, and the community. This occasion would be an opportunity to showcase both the greywater channel and ideas for upgrading greywater management systems throughout Langrug.



J-3: Creating a Plan

Lessons

- Respecting the community's ideas/input and involving them in planning greywater management strategies creates a sense of ownership.
- "Ownership" increases community involvement during construction and maintenance phases greywater management strategies

Accomplishments

- Incorporated the community's ideas into the design plan
- Chose a design that is low-cost, easy to implement, and supported by the community members as an effective and feasible option

The next step was to create a plan of action for the intervention in J-section. When interviewing several community members, one neighbour, Kholekile emphasized that the most effective and feasible type of channel would be a stone and cement channel. This option was very practical because the greywater channel already existed, so all that needed to be done was to deepen the current greywater channel, line it with stones, put cement between the rocks, and smooth the cement. This work could all be easily done without heavy machinery. The stone and cement channel was also a popular option with the community members we interviewed.

We formulated a basic plan for building the channel:

1. gather rocks and buy materials,
2. dig out the channel,
3. unclog the pipes, and
4. lay stones and cement in channel.

Lessons

- Community involvement is essential at this stage, especially for man-power
- Critical to support community members serving in leadership roles

Accomplishments

- Initial, but limited, community involvement
- Kholekile demonstrated a strong sense of ownership for the channel

Figure 12: Steps to build the J-Section stone and cement channel

Having formulated a plan, we began building the channel. Two community members – Mayenzeke Saule and Kholekile – took part in this process. Kholekile worked several hours a day on three days, and was willing to take charge and give the team and co-researchers directions when needed. He was deeply involved in both the J-section channel and later became central as a foreman in other community greywater management efforts in different sections of Langrug. Mayenzeke helped for several hours on one day and allowed the team to store tools such as shovels and a wheelbarrow in his house overnight.

Although Kholekile and Mayenzeke's willingness to participate was encouraging, we were somewhat disappointed that more community members did not participate. Initial interviews with the community had suggested that community interest was high, but actual participation was limited.

Our first step in the building process was to collect rocks from an open area on the outskirts of the settlement. A community member volunteered to transport the rocks to the work site in his bakkie (pick-up truck). Other tools and materials were purchased with financial backing from WPI.

The second step was to widen and deepen the existing greywater channel. The soil was densely packed and filled with plastic bags and other trash, so a pickaxe was used to loosen it. There was so much trash because the location had previously been used by the community as a dumping site due to the lack of reliable trash collection in the area. While some people were expanding the channel, others used shovels, rakes, and poles to remove dirt and trash from the cement pipes. Precautions in the form of rubber gloves and surgical masks were taken in order to provide some protection from the water and the corresponding health risks.

Once the channel was dug out, stones were used to line the base and sides of the channel. Smaller stones were used for the bottom of the channel and placed to minimise the gaps between stones. The sides of the channel were lined with the larger stones for support and to prevent erosion and cave-in of the channel walls.

Figure 13: Community efforts to use grates to prevent trash from clogging a drain (top) and greywater streams (bottom)

After the stones had been laid along the length of the channel, the cement was mixed with sand and water then used to fill the gaps between the stones. Then the extra cement was used to smooth the bottom of the channel and reduce unevenness that would have caused pooling. Once the entire channel was lined with cement, Kholekile brushed water over the surface of the channel to further smooth the cement. While Kholekile was smoothing out the cement, Mayenzeke and Trevor cut up an old metal fence to create grates which was then fit over the openings to the pipes. This idea was modelled after a community intervention in a different area of Langrug (Figure 13). The purpose of these grates is to catch any trash that enters the channel before it enters the pipes and clogs them.

To finish the channel before the public event on 12 November, preparation and construction proceeded as below.

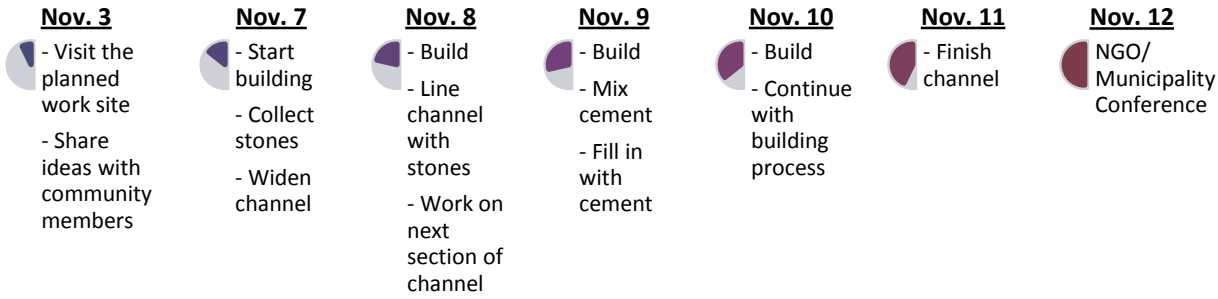
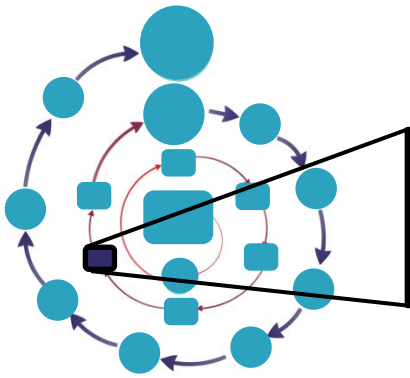


Figure 14: Timeline for the first greywater channel



J-5: Revisiting the Channel

Lessons

- Revisiting the greywater management strategies is critical to:
  - Identify problems
  - Meet with community to discuss problems and determine necessary repairs
  - Documentation of this issues with the channel for consideration next time that strategy is used
  - Trash disposal service is critical, yet challenging to secure

Accomplishments

- Conveyed importance of evaluation to co-researchers and channel neighbors
- Made sure the co-researchers understand what they need to be looking for when they evaluate
- We gave the co-researchers guidance regarding documentation (photos, notes, etc.)
- Ensured that co-researchers (and community) are able to critically evaluate greywater management strategies's effectiveness
  - Supplied co-researchers with necessary skills to aid them in addressing problems regarding erosion recognition and prevention and emphasising maintenance to the community

Our goal for the J-section channel was not merely to install a channel, but also to ensure that it remains effective. Evaluation of the channel was essential to meeting this goal. The first evaluation a couple days after construction revealed several problems. The biggest problem was that the cement had not completely dried before the channel was used; as a result the cement had sunk in some areas, leading to greywater pooling. Another observation was that the grates successfully caught trash, but they were not being cleaned out. Furthermore we found a significant amount of sedimentation, which caused small pools to occur. Further evaluation over the following three weeks involved both direct observation and meetings with the community. Other problems were identified, including:

1. food and trash had been thrown in the channel,
2. garbage had gotten into the pipes despite the grates, and

3. one section of the channel was shallow, raising concerns that it could overflow during heavy rains.

After evaluating the channel, we met as a team to review the problems with the channel and why they had occurred. We discussed possible solutions to the identified problems, and planned meetings with the community to discuss and implement solutions. Three solutions were discussed:

1. cleaning the channel (see section J-6),
2. installing trash bins, and
3. employing erosion prevention measures.

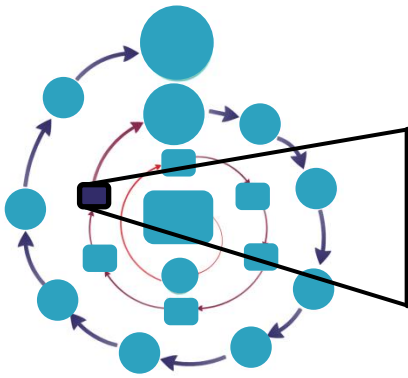
The first two solutions listed above focus on cleaning and maintenance, issues that are discussed in greater detail in section J-6 below, and in the ***Maintenance*** section (page 38).

We spoke to the community about the problems with the channel and their cooperation with maintaining and improving the channel. We introduced the idea of using plants to prevent erosion (see ***Vegetative Stabilization*** page 87). One of the most apparent problems was sediment build-up due to erosion of the channel banks. When we spoke to Kholekile about using grass to prevent erosion, he immediately agreed and suggested two types of grass which might be used to address the erosion of the channel banks: kikuyu and seed grass.

Figure 15: Grass options for erosion prevention - seed grass (left and middle) and kikuyu grass (right)

Kholekile explained the pros and cons of both grasses, and worked with us to identify parts of the channel where each type would be most applicable. Kholekile volunteered to oversee planting and maintenance of the grass.

To ensure continuing improvement and maintenance of the J-section channel, the co-researchers will continue to periodically check its condition and interact with those living around it.



J-6: Meeting about Maintenance

Lessons

- Trash and erosion are a significant problem since they block the channel
  - Erosion prevention should be incorporated into the greywater management strategies and design plans
- Lack of nearby, formal trash receptacles impedes cleaning efforts
- If community doesn't clean the solutions, initial problems will re-emerge (i.e. lack of cleaning partially/mostly negates its function)
  - Recurrence of initial problems is a strong motivator for community members to step up and maintain the channels

Accomplishments

- Helped community understand importance of cleaning
- Initiated communication between neighbours
  - This led to a more organised community-based approach to cleaning
  - The channel is now being properly maintained
- Worked with Kholekile to determine the most appropriate erosion prevention method for the channel and plan for its implementation

When clogging and food waste were identified as central problems with the J-section channel, the idea of creating a cleaning schedule for the community members arose. The co-researchers then held meetings with the people living near the J-section channel to discuss the importance of maintenance and to bring them our idea of a cleaning schedule. The community replied that a formal schedule would not be necessary since they would take the initiative to clean out the channel as needed. The community agreed to maintain the channel by removing the trash and sweeping out the sand that accumulated in the channel. Initially, each community member cleaned the section of channel adjacent to his or her own house. However, these cleaning efforts were complicated by insufficient organisation and garbage collection infrastructure, so trash and sediment continued to partially clog the channel. Eventually maggots reappeared in the channel, so the community organised itself to thoroughly clean the channel as a group on a regular basis.

The self-organised cleaning effort is very encouraging, and the co-researchers will support on-going maintenance efforts for the channel. Furthermore, maintenance has been identified as a key part of building any greywater channel, and will be carefully discussed with the community for each channel built in Langrug in the future.

Lessons

- The process must be flexible so it can evolve based on lessons learned during each iteration

Accomplishments

- Created a systematic process for informal settlement upgrading
- Applied the process to greywater management system upgrading

The work in J-section highlighted the need for a systematic process for sustainable community-based greywater system upgrading in Langrug. Although this process was designed for Langrug, it could still be adapted and applied in other informal settlements. This process was created largely based on ideas from the co-researchers regarding:

- their thoughts regarding the first implementation (J-section),
- how to improve the steps followed in J-section, and
- what key ideas should be emphasized in the new process.

Figure 16: Working on the process

As a team, we first identified the six the main steps followed for the J-section channel. These steps were revised and expanded into a new process of eight steps. The steps of the Process (Figure 17) are:

1. Choose an area to implement the intervention
2. Meet with the community living in the area
3. Develop a plan of action together with the community
4. Make a list of necessary tools and materials
5. Build the intervention
6. Analyse and evaluate the completed intervention
7. Determine if the intervention needs to be fixed, including ways to prevent similar technical problems in future interventions
8. Optimize the process in light of experiences

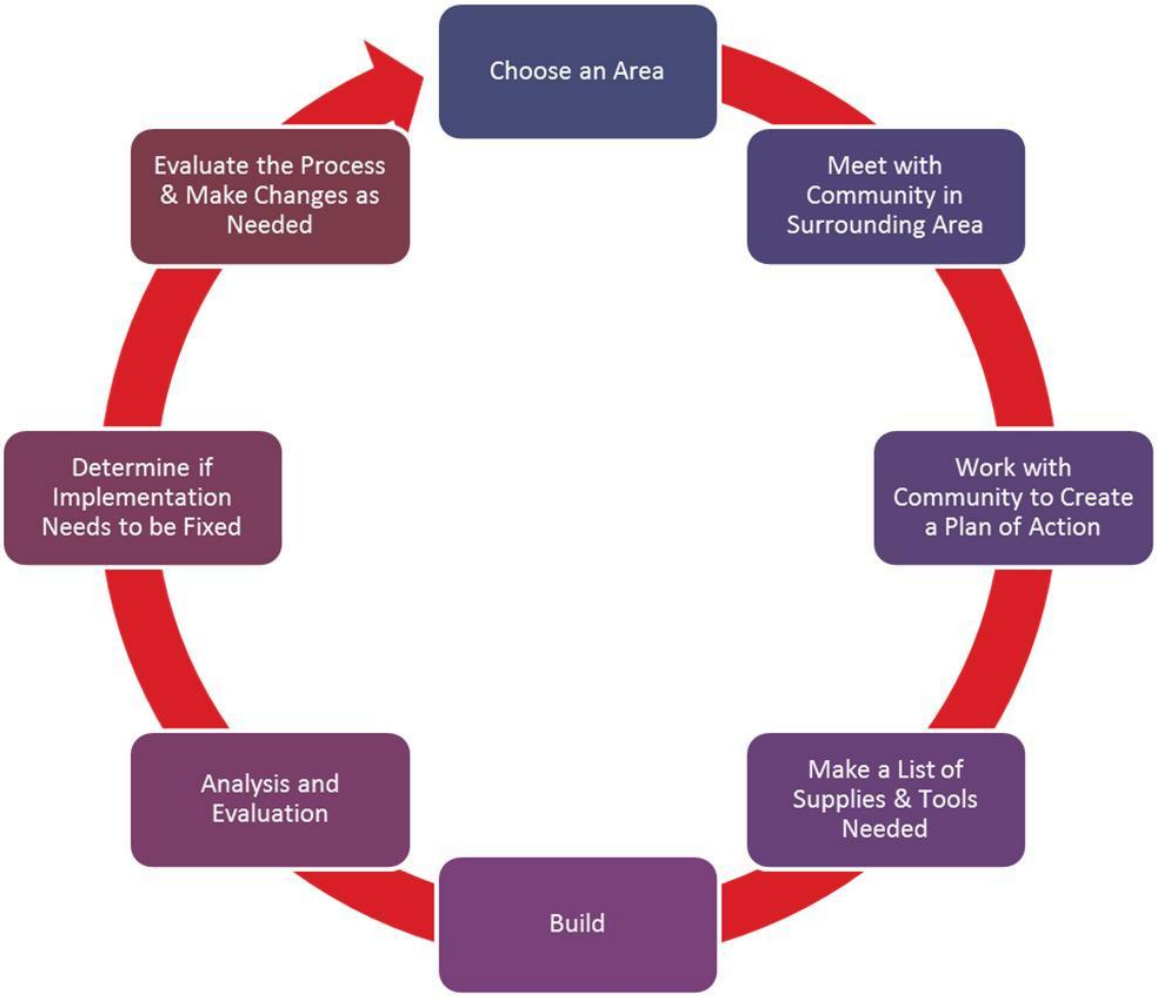


Figure 17: The Process

A detailed description of each step of the process can be found in the ***The Process*** on page 7 of this Guidebook.

Although the process was designed as a guide for upgrading greywater management systems, it can be applied to many areas of community-based informal settlement. In fact, the process was adapted and modified by another IQP team working in Langrug for upgrading communal water, sanitation, and hygiene (WaSH) systems, as well as developing a communal WaSH facility.

Lessons

- Areas where community members have made attempts at greywater management have:
  - Greater community involvement throughout the process
  - Greater sense of ownership for greywater management strategies
- The extent of problems due to greywater differs among areas
  - Several greywater-related problems (i.e. maggots, smell, rashes) are nearly universal in Langrug
- Self-help mentality is a motivating factor

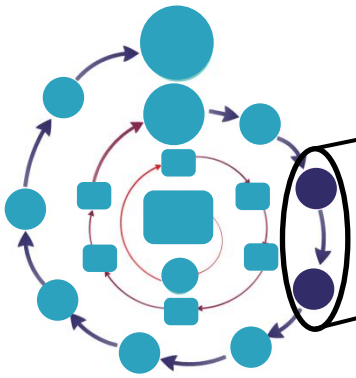
Accomplishments

- Began the second iteration of the process to test its applicability

After creating the process, we looked for a new area where the process could be applied. Around this time, Trevor found a few women in I-section who were cleaning a greywater stream that ran between their houses. The women described how:

- the smell of the greywater was unbearable in warm weather,
- their children got rashes from playing in the stream, and
- maggots would grow in the water and enter houses in the warm weather

They explained that they had been working together to alleviate these problems by cleaning the channel, and they were willing to work with their neighbours to build a greywater channel, if materials were provided to them. This I-section stream was classified as a “hot spot”, and was subsequently chosen as the site of our next project – the first implementation of the new process.



I-2 & I-3: Meeting with the Community & Developing a Plan

Lessons

- Most community attempts at greywater management are short-term in nature
- The community is more supportive of greywater management strategies used in other sections than it is of new strategies
  - Need to implement other greywater management strategies in appropriate areas of Langrug to serve as a showcase
- Strong community support for the project translates to extensive community involvement
- Expecting monetary contributions from the community didn't work in this specific setting

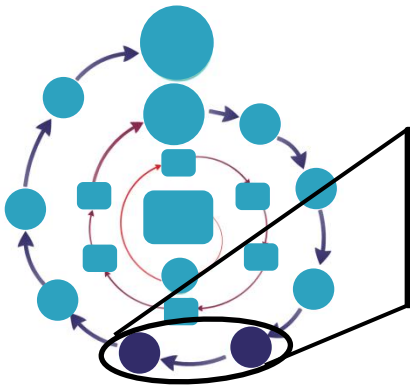
Accomplishments

- Increased meeting attendance by notifying the community in advance
- Found a strong sense of community ownership for the area
- Established a maintenance routine prior to construction
  - Attempted to avoid the problems encountered in J-section where cleaning was not frequent or organised
- Chose a design plan based on the community's needs and desires

Meeting with the I-section community began with interviewing the ladies who were cleaning the channel. The co-researchers held another meeting with the more community members the following week, involving an open discussion about the greywater problems experienced – predominantly maggots and rashes – and the community's attempts to manage the greywater. In the past, the community had simply cleaned out the paper and plastic blocking the stream without attempting any more permanent interventions. The community's willingness to work on a greywater channel was impressive, and there was overwhelming support for building a stone and cement channel like the one built in J-section. Using their experience from J-section, the co-researchers worked with the community to develop a plan for building the channel. A procedure similar to that used in J-section (Figure 12) was chosen. Finally, maintenance was discussed, and the community agreed to hold itself responsible to clean and maintain the channel once it was completed.

Once the co-researchers knew what the community wanted and how they wanted to proceed, they asked if people would be able to contribute labour or money to build the channel. The money was meant to leverage funding for materials by means of the CUFF. Although many were willing to volunteer their time, nobody offered money. Fortunately, the co-researchers were able to arrange for materials to be donated by CORC without using a finance facility.

Figure 18: Meeting with the women who were cleaning I-section



I-4 & I-5: Determining Necessary Materials & Building the Channel

Lessons

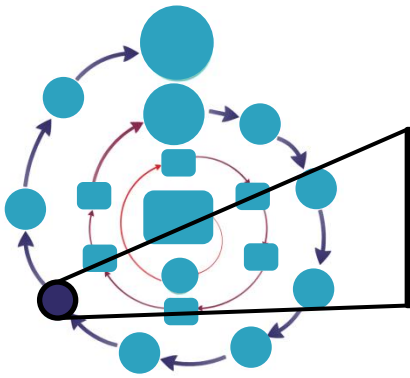
- Volunteer-based efforts may not have consistent levels of participation on a day-to-day basis
  - People have to balance volunteering with their daily lives
- Employing people to upgrade greywater management strategies undermines volunteerism

Accomplishments

- Found a new site for gathering stone
- Upgraded approximately 90 metres of the greywater channel
- Created jobs through the EPWP
  - Progress became more consistent than when dependent on volunteers

Because they had built a stone and cement channel in J-section, the co-researchers were able to quickly determine what materials would be necessary. Together with the community, they gathered stone and began digging the channel. Two days later, the co-researchers continued to work with nine community volunteers to dig out the channel, collect stones, and line the channel with stones. The following day, the co-researchers returned to I-section to continue working, but only two community members joined them. Construction continued through the following week.

During the second week, a system of payment was introduced. Through the CORC and the EPWP, the people who worked on the channel were paid R90 per day. After payment was introduced, community participation became more regular. The community was extremely grateful for the provision of employment. However, the co-researchers noticed that the introduction of payment made the community members significantly less willing to work on a volunteer basis – they expected payment. The Greywater Team flagged the issue of volunteerism and payment as a key aspect of upgrading projects. Some considerations regarding this issue are discussed in *Voulenteerism vs. Employment* on page 42.



I-6: Evaluation of the Channel

Lessons

- Progress is dependent on supplies
  - Communication between the co-researchers/community and CORC/SDI will need to be open and constant to ensure that the community has the necessary supplies to continue construction
- We were able to observe effectiveness of a stone channel to see:
  - Greywater pools between the stones until it soaks into the ground
    - Often this is temporary
    - Contamination and toxicity may be a concern with this type of channel if the greywater sits for too long before it soaks into the ground
- Pooling needs to be addressed with maintenance

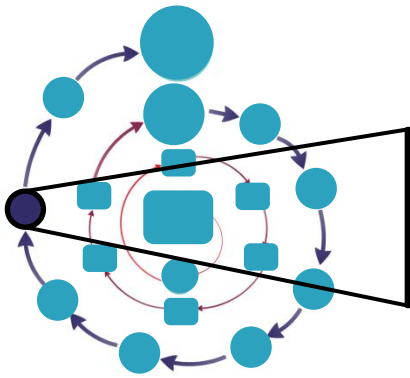
Accomplishments

- Temporary existence of a stone channel to observe its value as a greywater management strategy
- Were able to avoid several problems that were encountered after building the J-section channel
  - Partially due to the creation of and improvements made to the process , providing a data point for the process

Upon revisiting the I-section channel, it was apparent that the community had made an impressive amount of progress. The channel had been dug out and lined with stone for approximately 90 metres, 50 metres of which had already been cemented. Unfortunately, the cement ran out after 50 metres; and the workers have been waiting for CORC to supply them with more before they can continue. Although the lack of cement hinders construction, it has given the co-researchers a chance to observe a stone channel – without cement – in action. Their observations can inform future projects, as the stone channel might be a viable low-cost option that can be implemented with no outside funding.

The team observed some sedimentation and trash in the I-section channel, but the community was already cleaning the channel periodically. Some pooling was occurring in the channel, due to cement sinking when the channel was used prematurely. Overall, the channel was working successfully, but maintenance will be needed to address the pooling issues. In the future, the co-researchers plan to monitor the conditions of the I-section channel and facilitate on-going maintenance and cleaning work.

Figure 19: Evaluating the I-section channel



I-7: Determining the Need for Repair

Lessons

- Need to raise the community's awareness of problems caused by dumping water into a cement channel before it has set can damage the channel

Accomplishments

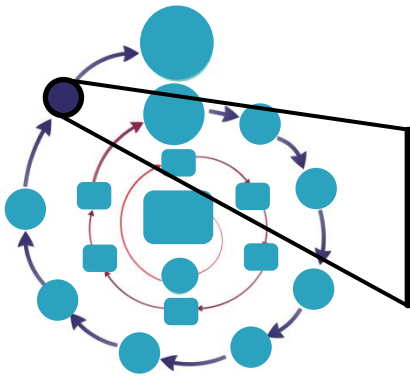
- Implemented new erosion prevention technique
  - Can evaluate its effectiveness over the coming months

Similar to the J-section construction, the channel was used before the cement was allowed to set. This caused the cement to sink and led to pooling. The sunken areas may need to be filled in with additional cement to prevent pooling. Another addition that must be made to the channel is erosion prevention. Many sections of the channel already have well-established grass that seems to be preventing erosion successfully. The community plans to lay blankets over the channel banks and plant grass in currently unprotected sections to prevent erosion there.

In addition to repairing the channel, there is a need to fix our methods for implementing cement and stone channels. In both J-section and I-section, premature use of the channels caused pooling. To prevent this problem from emerging again, the community must be made aware of the damage that occurs when the channel is used before the cement is sets. The WPI students have asked the co-researchers to investigate ways to prevent premature channel use (see Appendix D on page 124). Some ideas include:

- meeting with the community and asking them to refrain from using the channel right after cement has been applied,
- applying the cement at a time of day when channel use is at a minimum, and
- supplying the community with a temporary alternative for greywater disposal – to be used only while the cement is setting.

These ideas, or some combination of them, could be incorporated into a revised approach to building stone and cement channels in the future.



I-8: Evaluating and Adapting the Process

Lessons

- Looked at lessons from earlier steps of the process (I-1; I-2 & 3; I-4 & 5; I-6; and I-7)
- The co-researchers should act as consultants rather than active labourers in construction

Accomplishments

- Compiled lessons from previous steps so they could be used to improve the process
- Documented the contrast between volunteerism and employment

Based on the application of the process to I-section, the Greywater Team made changes to the process and flagged several topics for consideration. A key observation about the I-section channel involved community interest and flexibility. The community in I-section was so enthusiastic to implement a greywater channel that we thought they might be willing to work on building the channel even without the co-researchers' assistance. While community interest was very encouraging, the WPI students were concerned about the community's lack of flexibility regarding the type of channel to build. Community members were not very open to the idea of trying a new type of channel; they wanted a channel like they had seen working elsewhere.

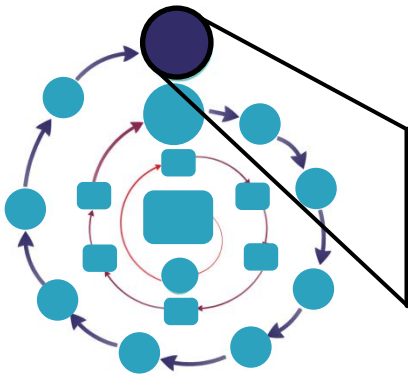
The students voiced their concern to the co-researchers, who cited a lack of awareness as the likely cause of inflexibility. We are hopeful that the co-researchers can use our ***Manual of Greywater Management Solutions*** to explain the benefits of other types of channels and emphasise how these will compare to the stone and cement channel. Once other methods are used around the settlement, the co-researchers can show these to the community and work with them to implement the most effective type of greywater management for their specific area. If examples of different greywater management options are in place, future versions of the process could include tours of existing examples to raise community awareness of alternatives and facilitate discussion on applicable methods.

Other considerations revolved around motivating the community to work on greywater solutions. In I-section, we initially planned to use a purely volunteer approach, but eventually switched to a system of compensation. The viability of these two models must be considered and

evaluated, and future interventions must use one model or the other without switching between them. This Guidebook documents further thoughts on these two approaches in the section on ***Volunteerism vs. Employment*** on page 42.

Finally, an adjustment was made to the Greywater Team's role in the process. In the I-section project, the co-researchers had been deeply involved in implementation. While this allowed them to effectively monitor construction, it was also quite burdensome. Because the co-researchers will be actively monitoring both completed greywater channels and on-going greywater management projects, their role in the projects should be consultants, not active labourers. The co-researchers will work to mobilise the community for greywater interventions in hot spots. They will focus on facilitating planning, monitoring implementation, and evaluating completed channels. Overseeing projects will be delegated to project managers appointed by the community. The co-researchers will advise and equip these managers to properly implement greywater interventions.

The co-researchers' new position as consultants will allow them to continue extensive evaluation of past channels while quickly moving forward with new projects throughout Langrug. This will contribute to the sustainability of the process in Langrug.



Moving Forward

Lessons

Accomplishments

- Several new greywater management strategy upgrades have been initiated
- Project managers have been appointed for each project in Mandela Park
- The co-researchers are supported by the Municipality, CORC/SDI, and WPI
- Created resources for greywater management strategy upgrading and documented our work

While continuing to evaluate J-section and I-section channels, the co-researchers initiated greywater projects in Mandela Park. One was located near a location proposed for a Water, Sanitation and Hygiene Multi-Purpose Centre, and another was a large-scale project on a long channel running through most of Mandela Park. This large-scale project will upgrade the channel in two sections before joining the sections.

Kholekile is overseeing the first project, and the co-researchers have worked with the community to elect another community member as the overseer for the second Mandela Park project. Using the process, the co-researchers have facilitated planning and are continuing to monitor progress.

In the coming year, the co-researchers will continue to use and optimise the process to implement greywater management solutions throughout Langrug. WPI, CORC/SDI, and the Stellenbosch Municipality will support these efforts.

The WPI students have left the co-researchers, participating NGO's, and the Municipality with a set resources for on-going greywater intervention work. These are:

1. ***Guidebook Addressing Sustainable Upgrading of Greywater and Stormwater Management Systems*****:** The Guidebook will serve as a resource for applying our work to other informal settlements, as well as a reference that the co-researchers can use to choose greywater management solutions for various parts of Langrug

2. ***Manual of Solutions for Greywater Management Strategies*:** This manual is meant to serve as a resource for explaining greywater issues and solutions to community members. It can be used to facilitate discussion and planning in the initial stages of the process, and it may help the community to better understand alternative greywater solutions.
3. ***Recommendations*** (Appendix ##): This set of recommendations offers suggestions for future projects in Langrug, research questions to consider, and considerations for cooperation between partners.
4. ***Process Evaluation Form*** (Appendix B on page 113): These forms are meant to guide the co-researchers in using and documenting the process.
5. ***Website*:** The WPI students are developing a website that documents their work during their seven weeks in Langrug. This website can be used to describe the origins of the Greywater Team and its work. The website can be found at the following URL: http://wp.wpi.edu/capetown/projects/2011-2/langrug/

   At the time of writing this Guidebook, the website is still under construction.

6. ***Blog*:** The WPI students have set up a blog which the co-researchers and partnering NGO's can use to document work in Langrug. This will help to facilitate on-going communication between the WPI students and the co-researchers, while simultaneously acting as a resource for similar projects in other settlements. The URL of the blog is http://langrug.wordpress.com/.

Maintenance

One of the biggest problems encountered in Langrug after building the greywater channels was that they quickly became blocked with trash and sediment. Sand eroded from the hillside and from the banks of the channels is deposited in the channels, while trash is either dumped in the channel or blown in by the wind. Trash and sediment quickly build up, posing a significant challenge, as can be seen in below.

Figure 20: A greywater channel that is being clogged up with trash and sand

When trash and sediment accumulate in a channel, they can block the flow of water, causing pooling. This leads to two major problems. First, the greywater flowing through the channels pools, allowing bacteria to multiply in the water and contaminate the water to a toxic level. When this happens, the health risks associated with the greywater are amplified. Second, the accumulated trash and sand can completely block the channel, making it overflow. Since many of the greywater channels run next to people's houses, greywater overflow can easily run into houses causing health risks and flooding; this is especially common during the rainy season. Both problems have serious consequences for the community's health and quality of life, but both can easily be prevented by cleaning out the channels. Accordingly, proper maintenance of greywater channels is an instrumental part of their functionality.

Cleaning

The channels implemented by the greywater team in J-section and I-section were not initially cleaned on a regular basis, and pooling was observed as a result. In order to address this issue, the greywater team brainstormed several ways to motivate the community to clean out the

channels. While we endeavoured to develop ideas for community-based cleaning solutions, the possibility of organising cleaning through the government's EPWP system was also raised.

Schedule

Our team's first idea to promote regular maintenance was to create a cleaning schedule prior to building a new greywater channel. We envisioned a set calendar which would assign one person or group of people to cleaning out the channel each day and would rotate through the people living next to and directly affected by the channel. However, when the co-researchers went to I-section, the site of the second channel, the community members in the area didn't agree with the idea of a set schedule. They said that it wouldn't be necessary since people would do the cleaning on their own as needed.

We believe that this community response may stem from a cultural resistance to rigid planning, as the community also opted for more flexible plans when planning for building the I-section channel.

Allocation of Channel Sections for Individual Cleaning Efforts

Having expressed their dissatisfaction with the idea of creating a set cleaning schedule, the community proceeded to develop a cleaning plan with the co-researchers whereby the community members living along the channel would each clean the section of channel adjacent to their own houses. Although the community followed through on this plan, the frequency of cleaning was not often enough to stop small-scale pooling, and trash and sediment remained a problem. Furthermore, although one segment of the channel was cleaned, the segments upstream were not always cleaned simultaneously. As a result, the greywater stream quickly washed sediment back into the cleaned segments, and the channel did not remain clean for long. The results of this cleaning effort led the greywater team to the conclusion that greater organization of cleaning efforts would be necessary as disconnected, small-scale cleaning efforts were not enough.

Another concern linked to this approach was that only a few of the community members who used the channel would be actively involved in maintaining it. Through interviews and meetings with the J-section community, the co-researchers found that many of the community members who regularly utilized the channel were not willing to help with cleaning it. At the beginning of creating a plan to maintain the channel, even some community members who lived directly across the road from the channel showed no willingness to help with cleaning. As a result, the burden of maintenance fell on the shoulders of only a few community members, and we were concerned that it would be difficult for them to sustain their efforts in the long term.

Trash Bins

One issue that came up when discussing maintenance of the J-section channel was the lack of trash bins in the immediate vicinity. This both contributed to the accumulation of trash and complicated the cleaning efforts.

Through interviews and meetings with the J-section community, the co-researchers found that many people from all over J-section were using it as a dump site for food waste because if was

much closer to their houses than the nearest municipality-installed rubbish skip. The community explained that food waste could not be kept in their houses because it caused smells, and it could not be left in bags outside their houses because dogs would rip through the bags to eat it. For these reasons, community members who lived too far from the channel to be directly affected by it would still dump food waste and other trash into it.

The lack of trash bins also made cleaning the channel more difficult for the community. When the community members cleaned out the channel, they were often forced to pile the trash they removed along the side of the channel because they had nowhere else to put it. This was a problem because trash left along the channel could easily be blown back in, completely negating the effort.

Figure 21: Cleaned out trash piled next to channel

When the issue of trash bins was pursued, we found that the community would be a much more willing to clean out the channel if they had somewhere to put the trash. While this was encouraging to hear, it led to a slight complication: where were the trash bins going to come from?

Municipality-Provided Trash Bins

During our first week in Stellenbosch, we had attended several meetings of the Department of Integrated Human Settlements (DIHS), and one discussion that came up was that of a settlement-wide clean-up planned to take place throughout the month of November and continue on into the future. One step in this process was to be the installation of trash bins throughout Langrug. After discussing this topic, it was decided that the Municipality would budget for three trash bins per letter section, meaning 63 trash bins total. Unfortunately, since the budget is still awaiting approval, the bins have not yet been installed.

Community-Built Trash Bins

An alternative to the municipality-provided trash bins would be for the community to build a trash bin. This would serve as a temporary solution until the budget for the municipality-provided trash bins is passed and the permanent ones are installed.

In J-section there is a wooden electricity pole right next to the beginning of the channel which we thought could be used to chain a trash bin to, if one is built. While this idea is still a work in

progress and has yet to be implemented, the group believes that creating a temporary trash bin would greatly help the community members to maintain the greywater channel. The trash bin would be made by the community, most likely from wood. A box-shaped bin would be the easiest to implement, and it should have a lid with a latch to prevent the dogs from getting to the trash. It could be made to hold a municipality-issued plastic trash bag, into which community members could dump food waste or other trash removed from the channel. We hope that arrangements could be made with the municipality to have the bin emptied regularly. A chain and lock will be purchased, ideally by the IGSD, to secure the trash bin and the lid to the wooden post so the bin and lid aren't separated and so that the bin won't be tipped over or blown over by the wind.

EPWP Cleaners

The last option that we discussed with our co-researchers was the idea that the EPWP[1] workers who are being paid to clean up Langrug as part of the municipality sponsored settlement-wide clean up could clean the greywater channels. While this idea was mentioned, it hasn't yet been thoroughly looked into. If this option was to be explored farther, the steps that would need to be taken include 1) contacting the person in charge of the EPWP cleaners to see if this is possible, and 2) potentially talking to Mr. Carolissen to see if EPWP jobs specifically for greywater channel maintenance could be created. Although this may be a viable option for keeping the channels clean, it is not ideal since it reduces community ownership of the channel by taking away the community's responsibility for keeping the channel clean.

[1] EPWP: The Extended Public Works Program (EPWP) is a South African program dedicated to reducing poverty and unemployment throughout the nation. The EPWP works to create small-scale projects focusing on informal settlement upgrading while giving the jobs created by these projects to unemployed community members. While EPWP jobs are short-term, they still create employment for people who need it.

Volunteerism vs. Employment

Encouraging volunteering in Langrug

When "The Process" was created, it focused on mobilizing the community to implement greywater management systems on a volunteer basis. We believed that once people understood that these greywater solutions would significantly improve their quality of life, they would be willing to volunteer to work on these projects. While to some extent the J-section and I-section channels showed that the opportunity for self-help could mobilize the community, unfortunately, this only held true for a short period of time.

Creating EPWP Jobs for Upgrading Greywater Management Systems

> *The unemployment rate in Langrug hovers around 50% and people live in 'grinding, sometimes humiliating poverty'*

A couple of days into constructing the I-section channel we learned that the project had been used to create approximately fifteen EPWP jobs for community members living near the channel. Hearing about this job creation was welcome news, as the unemployment rate in Langrug hovers around 50% and people live in "grinding, sometimes humiliating poverty" (Carolissen). EPWP jobs allow the Municipality "to favor communities in an empowering and meaningful way"; these jobs help people put food on the table, significantly improving their quality of life and building their self-efficacy, while simultaneously "transferring critical skills which will enable people to fend for themselves, in the long run" (Carolissen). The creation of jobs is undeniably one of the most significant results of our project, but it also brought up concerns regarding the community members' motivation.

Our initial concerns regarding paying the community to build greywater channels revolved predominantly around how sustainable this option was and how the EPWP would choose who to employ. Our concerns regarding the sustainability of this program were rooted in a long-term vision of upgrading greywater systems throughout the entire settlement. We were worried that if the government ran out of funding before a comprehensive system was installed in Langrug, the project would lose its momentum and our vision wouldn't be realized.

> *In the context of grinding, sometimes humiliating poverty, I don't think the volunteer-model is a viable option*

Once the precedent of employing people to build channels would be established, we worried that volunteering would become obsolete. We shared our concerns with the co-researchers, who strongly agreed and stressed that if the money were to run out, the next time the co-researchers go to a new channel, "these new people will expect money because they will have heard that I-section people were paid… they'll talk, [and] there will be problems if they don't get paid" (Xuza).

We contacted Mr. Carolissen and Adi Kumar about our concerns, and asked them to further explain how paying people through the EPWP would be organised. Mr. Carolissen quickly replied, explaining that the government has a program – the EPWP – dedicated to creating jobs for unemployed community members in informal settlements. Currently the DIHS has been allotted ZAR80,000 to employ people. The program is expected to run for one to two years, after which it must be re-approved. While this sizeable budget ensures that the Langrug community will be employed to upgrade their greywater system, money remains a limiting factor for employment in many informal settlements.

Favouring communities in an empowering and meaningful way

The next question that arose concerning employing people for upgrading greywater management systems was whether or not people would volunteer to maintain the channels after they were built. If the idea of volunteering disappeared with the creation of EPWP jobs and other sections experienced the same reluctance to maintain the channels as we saw in J-section, the greywater channels would soon fall into such a state of disrepair as to completely negating their purpose.

One suggestion from community members that addressed the problem of motivating people to maintain the channels was to hire community members as EPWP workers. This idea shows a mentality of using money as a motivator for maintenance, which will be revisited in ***Maintenance – EPWP Cleaners*** (page 41). When we brought this idea to Mr. Carolissen, he was able to put the situation in Langrug into perspective:

> Of course the ideal is to get communities volunteering for their own upliftment. In an ordinary community, where issues of hunger and poverty are not as pronounced as it is in Langrug, it would be fine to encourage people to volunteer, without expecting compensation. However, and as you have rightfully indicated, in the context of grinding, sometimes humiliating poverty, I don't think the volunteer-model is a viable option. In this country we have to create employment, whilst we transfer critical skills which will enable people to fend for themselves, in the long run (Carolissen)

Recommendations for further study of money as a motivator

In order to more fully understand the role of money as a motivator in Langrug, it will be necessary to talk to more community members. Because this is such a complex social dynamic, we must keep an open mind and endeavour to learn about the community's perspective in all of its depth and richness. People who would be of special interest with regards to further exploring this dynamic include: people who were selected as EPWP workers for the I-section channel and people who weren't selected for EPWP.

Greywater Management Strategies

About this Chapter

This chapter of the Guidebook is meant to describe several greywater and stormwater management strategies that could be applicable in informal settlements. Each informal settlement has its own set of greywater/stormwater issues and its own conditions in terms of topography, material availability, and funding for projects. Thus, not every intervention described below is applicable to all informal settlments. Notes on applicability specifically for Langrug are provided with each description to guide the Langrug Greywater Team in future implementation and experimentation with these methods.

A large portion of the technical information and ideas for this chapter have been adapted from the *Urban Small Sites Best Management Practice Manual* developed for the Twin Cities Metro Council by Barr Engineering Company(Barr Engineering Company, 2001), and from a stormwater management manual developed by four WPI students as part of a 2010 IQP on adapting Sustainable Urban Drainage Systems for informal settlements(Button, Jeyaraj, Ma, & Muniz, 2010).

Notes on Cost

The costs of the different materials required for building these interventions will vary based on region and availability of materials. Costs can be extremely low if materials may be acquired readily from areas near the settlement. Keeping track of costs for other interventions will give further insight into the affordability of different options.

Notes on Slope

Some of the management systems discussed in this Guidebook have specifications regarding slopes. The notation used to depict slope shows the ratio of the horizontal distance along a hillside to the vertical distance. For example, if the slope is 3:1 (horizontal:vertical), then the slope is at such a steepness that if you walked up the slope far enough that you went 3 metres horizontally, you would have moved 1 metre up. Figure 23 shows various slopes defined according to the terminology introduced here. It can be used to estimate what the slope at a given location is.

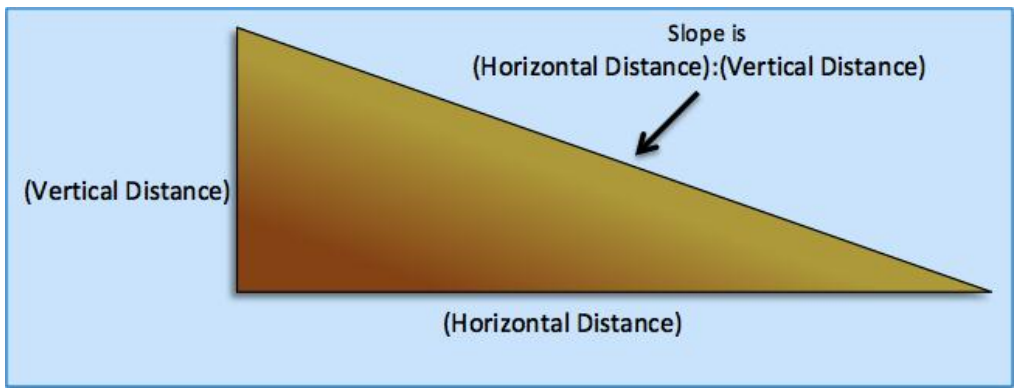


Figure 22: Determining Slope

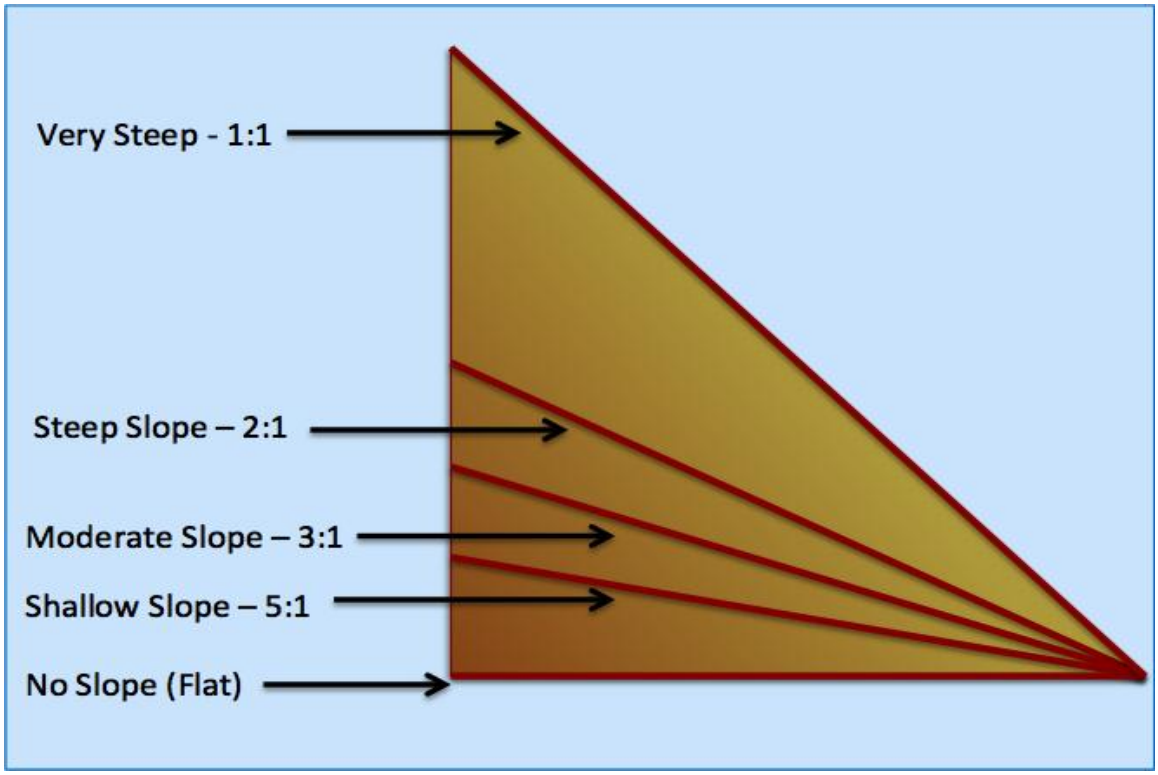


Figure 23: Comparison of different slopes

1. Basins

Basins are designed to hold a large volume of water over an extended period of time in order to remove pollutants. Most basins are designed to remove major contaminants that include the following:

1. Sediment
2. Chemicals such as phosphorus and nitrogen (from waste or soaps)
3. Disease-causing bacteria

These contaminants are removed through a combination of methods.

- Sediment is removed through settling in the calm water
- Many chemicals are removed by plants growing in the basins
- Microbes growing in the basin can reduce levels of harmful bacteria

An additional benefit of basins is that they can store large volumes of stormwater, so that the stormwater systems downstream of the basin are not overwhelmed during heavy rains.

Because of the high level of contaminants in Langrug's greywater and stormwater, basins may be difficult to successfully employ there. The processes whereby basins remove pollutants from the water may not be fast enough to remove contaminants before the standing greywater develops dangerous levels of bacteria. The basins described below were designed to deal with mildly contaminated stormwater, but not greywater, or greywater-contaminated stormwater. Basins may be unsuitable for Langrug's greywater, and their effectiveness and safety as a greywater intervention in the setting of Langrug informal settlement must be carefully evaluated and tested on a small scale before any large scale implementation is attempted.

1-1. Wet Swales

Description

Wet swales reduce runoff volume and flow by storing the water and using vegetation for infiltration. A wet swale is a shallow, vegetation-lined channel that runs across the slope so that it cuts off the water flowing down the slope.

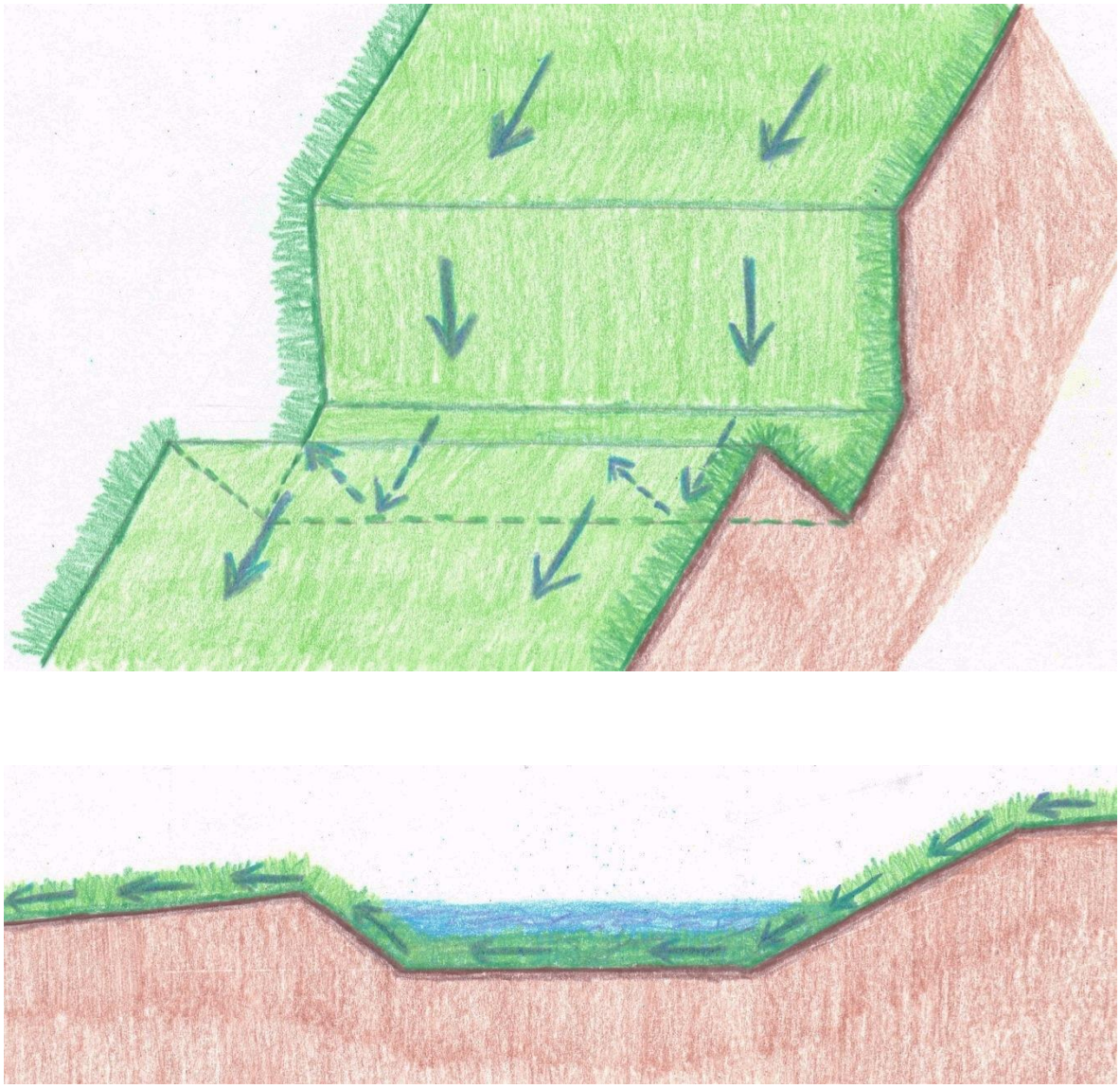


Figure 24: Wet swale, shown in three dimensions (top) and as a cross-section from the side (bottom)

Ideal Location

Wet swales need an open strip area of land that is:

1. ***Along a slope:*** The wet swale is designed to catch water that is running down a slope, so it requires an area where there is open land that cuts across the slope. The slope should be

moderate – not too steep, or the wet swale will be hard to dig and unable to hold much water.

2. ***Able to support vegetation:*** The wet swale depends on grass to help to infiltrate and partially filter the water, so the land where it is made must be able to support vegetation. Sometimes, it may be necessary to fertilize the ground or use mulch for this purpose.

Wet swales are not good for flat areas or areas with steep slopes. Also, it can be hard to encourage proper plant growth in overly gravelly or sandy soil. Infiltration will be insufficient if the ground is overly packed or high in clay content and has difficulty draining, thus causing the swale to fail.

Pros and Cons

Pros

- Reduces runoff
- Promotes infiltration
- Removes pollutants
- Inexpensive
- Creates biological habitats

Cons:

- Erosion in common when area floods
- Medium area requirement

Materials and Tools

1. Spades
2. Grass
    a. Transplanted from in the settlement
    b. Planted as seeds
    c. Placed as sod
3. Mulch (optional)

How to Implement

1. Dig the swale

Dig the swale so that the bottom width is between 0.6 and 2.4 metres, the depth is between 0.15 and 0.5 metres, and the side slopes are no greater than 3:1 (horizontal:vertical).

2. Plant vegetation

Plant grass in and around the swale (See: ***Strategies Against Soil Erosion and Sedimentation*** page 85 for more detail on choosing best vegetation species and planting / transplanting grass). The best approach for minimum erosion and best filtration is to plant grass so it will grow to completely cover the bottom of the swale and the ground leading to and from the swale.

Cost Considerations

If plants are available for transplant from within the settlement and spades can be obtained from community organizations or participating community members, this intervention can be implemented at a relatively low monetary cost. If mulch is necessary for plant growth (it may be necessary if the ground is infertile), the cost will be low to moderate.

Maintenance

- Inspect swale once or twice per week in the first few months for erosion and to ensure vegetation growth
- Remove trash and excess sediment found in the swale as necessary in order to prevent clogging
- It may also be necessary to cut the grass if it grows long enough to inhibit the flow of water

Figure 25: A wet swale filled with rainwater

(River Engineering and Urban Drainage Research Centre)

Recommendations for Langrug

Applicability for Langrug: Not applicable

Wet swales are probably not applicable for Langrug because they inherently involve poolng of water. During the summer, this pooled water will be predominantly greywater, which could lead to major health risks.

1-2. Stormwater Wetlands

Description

A wetland is a small, shallow pond surrounded by vegetation that is meant to temporarily store and remove pollutants in water before it reaches rivers and streams. There are various types of wetland, but the one most suitable for an informal settlement is the pocket wetland. A pocket wetland is a small marsh designed to hold stormwater during and after heavy rains. The wetland gradually drains after the rain, so normally, it is not flooded. The wetland is designed to support plants that will help to remove contaminants from the water.

Figure 26: Stormwater wetland

(Kuh, 2009)

Ideal Location

Wetlands are best for the following conditions:

1. ***Large area:*** Wetlands need a fairly large area so that they can hold significant amounts of water and support many different types of plants, which will remove contaminants from the water.
2. ***Adequate water flow:*** Wetlands are designed to stay mostly covered with water, or at least moist, at all times so as to support plant life such as reeds. A wetland should be made in an

area with a high enough water table[2] to keep the ground somewhat moist even in the dry season. A continuous flow of water is also good for the wetland.

3. ***Land able to support diverse plant life:*** A wetland is designed to have many different types of plants growing in it. The land where a wetland is made should therefore be able to support various plants, even during the dry season.

Pros and Cons

Pros:

- Improves water quality
- Reduces water flow
- Low maintenance frequency

Cons:

- Maintenance is extensive
- Large land requirement
- High implementation costs
- Difficult to implement

Materials and Tools

1. Spades
2. Picks
3. Plants – especially reeds and other water plants
4. Rocks
5. Mulch (optional)

How to Implement

1. Dig the basin

First, the basin for the wetland must be dug out. To keep the soil moist and allow vegetation to grow even during dry periods, the wetland should be dug down about to the natural groundwater level. The basin should cover around 4000 square metres or more – the wetland should be made with such a size that it deals with runoff from an area around 100 times its own area.

The wetland should have a deep pool (around 1-2 metres deep) at its inlet to remove excessive sediment from incoming water and prevent sedimentation in the main wetland area.

2. Lay Rocks

To prevent erosion, lay rocks at the inlet and outlet of the wetland.

[2] Water table: also known as groundwater table, the term water table describes the surface of the water that has infiltrated into the ground. A “high” water table indicates that the surface of the water table is close to ground level

2. Plant vegetation in the wetland

Once the basin has been dug out, various plants can be planted in it. Species such as arum lilies, bulrushes, and reeds are suggested for the Cape Town area,(Button, Jeyaraj, Ma, & Muniz, 2010) and might also be applicable for Langrug. Specific native species will vary depending on the location of the informal settlement, and the local native species should generally be used for constructed wetlands. Mulch can be used on the embankments to promote more plant growth.

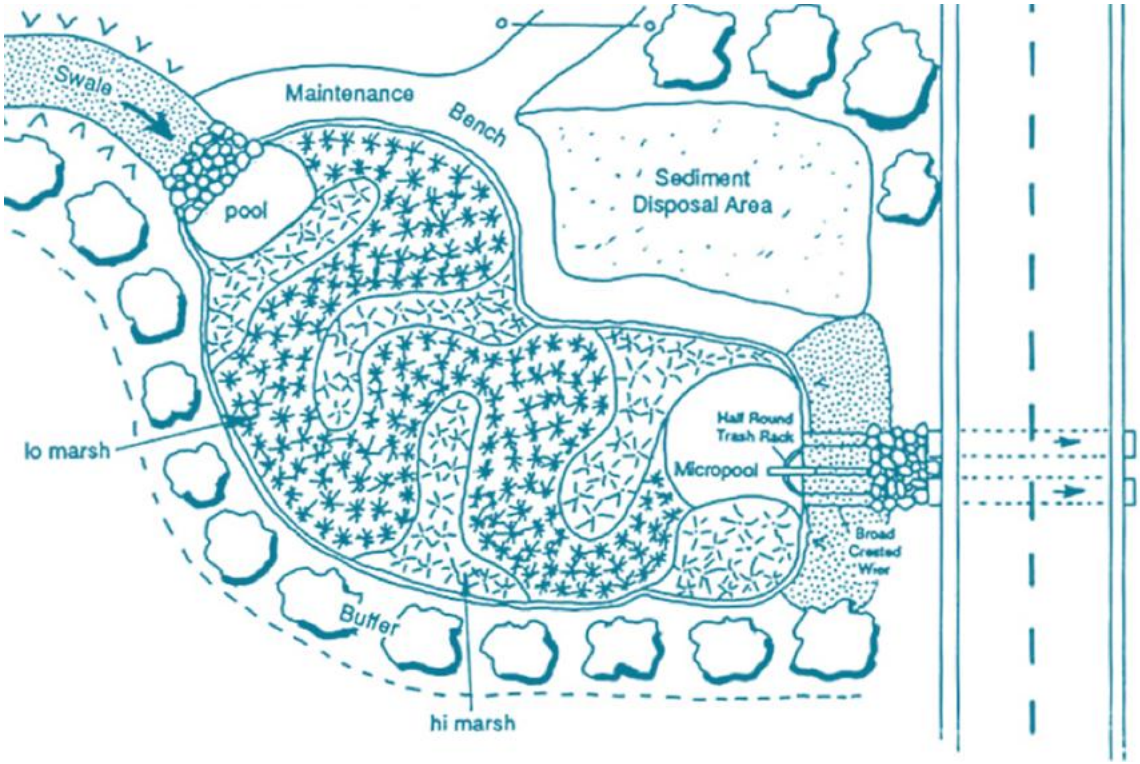


Figure 27: A top-view diagram of a pocket wetland

(Barr Engineering Company, 2001)

Cost Considerations

Tools may be obtained from community members or community organisations, and plants and rocks can often be gathered from within the settlement. Plants should mostly be water plants, which can be gathered from the ponds and rivers in and around the settlement. Since these main materials and tools may be obtained with minimal cost, building a wetland can be quite cheap. Labour, however, will generally be substantial, due to the extensive digging required and careful maintenance of plants is important in the initial stages. Mulch may add a moderate cost if used in large amounts, so building a wetland on infertile soil may be more costly.

Maintenance

Pocket wetlands, when compared to other wetlands, require maintenance regularly. The pool at the wetland inlet should be cleaned of sediment at least every two years, and the wetland itself should be monitored to ensure that the vegetation is doing well. It may be necessary to replant vegetation periodically, depending on species and wetland conditions.

Recommendations for Langrug

Applicability for Langrug: Probably Not Applicable - Experiment

Wetlands are generally not expected to be applicable for Langrug because of the high level of greywater contamination, which makes pooling undesirable. Furthermore, the lack of open space in Langrug makes large-area interventions like wetlands largely unfeasible for Langrug.

There may, however, be value in trying a small-scale wetland in Langrug, in order to test whether or not this strategy is effective. If the wetland is capable of dealing with the high level of contamination seen in Langrug's greywater, it could be very helpful for reducing greywater contamination and the resulting health issues. To test this, an experimental wetland could be constructed in an area where it would not affect the residents in the event that the wetland fails to deal with the greywater contamination.

1-3. Oversized Pipes

Description

An oversized pipe is a large pipe inserted into a smaller pipeline in order to reduce water flow by providing temporary storage of water runoff during heavy rains.

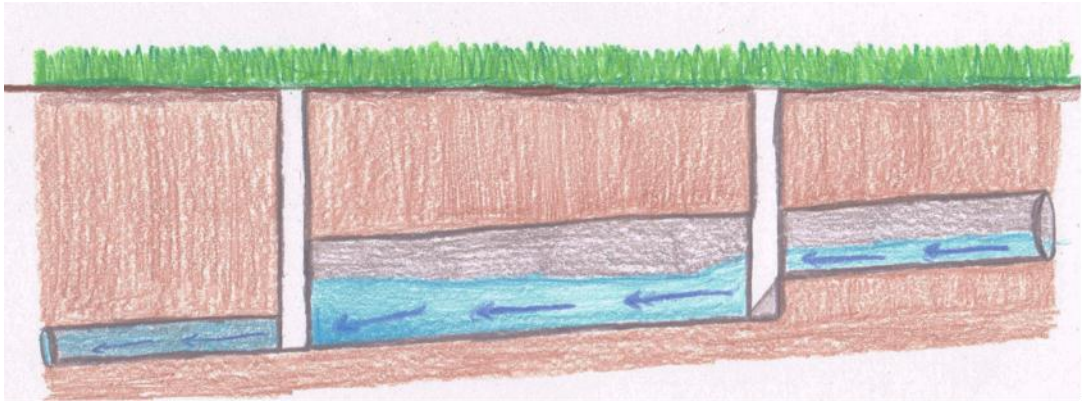


Figure 28: Oversized pipes

Ideal Location

Oversized pipes are usually used underground so as to minimize the amount of land area taken up, so ideal conditions include:

1. ***Areas with pipelines:*** Where there are already pipelines, an oversized pipe can easily be installed at one section for storage of excess rainwater.
2. ***Small slope:*** Oversized pipes are meant to temporarily store water, which can be done most effectively when the water does not flow through too quickly.
3. ***Easy to access:*** Over time, the oversized pipe can become filled with sediment, or even trash. Therefore, building this system so it is easy to access for maintenance and cleaning is helpful. Some ideas to expedite cleaning include:
    a. Bury the oversized pipe shallow.
    b. Use markers to clearly indicate the location of the oversized pipe.
    c. Bury the oversized pipe with attachments that will allow it to be lifted out easily.

Oversized pipes should not usually be installed on steep slopes or under structures that would limit access for maintenance.

Pros and Cons

Pros

- Reduces runoff flows
- Can be used in small areas

Cons:

- No water quality treatment

- High material costs
- Must be located in a place that can be easily accessed for maintenance
- Slower water flow in the large pipe means it is easy for sedimentation to occur

Materials and Tools

1. Spades
2. Picks
3. Large pipe
4. Rocks
5. Cement

How to Implement

1. Dig a trench for the pipes

Dig a trench large enough that the pipes can be placed underground. Make sure that the pipes are placed on a shallow slope to ensure that the pipes can completely drain over time.

2. Place pipes in the ground

Place the pipes such that:

a. The medium sized pipe should be at the start of the system where the water will enter
b. The oversized pipe should be placed next
c. And finally the smallest pipe, restricting the outflow of the water

Use the rocks and cement to create seals that can be placed over each and of the large pipe where it connects to the smaller pipes. The seals should prevent any sand from entering the large pipe through the gaps between it and the smaller pipes. Do not connect the cement onto the large pipe because the large pipe may need to be removed occasionally for cleaning.

3. Cover the pipes

Finally, bury the pipes, leaving some kind of marker to indicate where the largest pipe is, so it can be accessed later for maintenance.

*One variation on this method is to insert an oversized area into a channel. This area must be sloped, as the rest of the channel is sloped, so as to keep water flowing. However, it will be wider than other sections to slow water down and allow some water to be stored during heavy rains. The outlet of the wide section should be narrow to restrict flow. The further downhill the intervention is, the larger the wide section should be, since it will receive more water (See Figure 29).

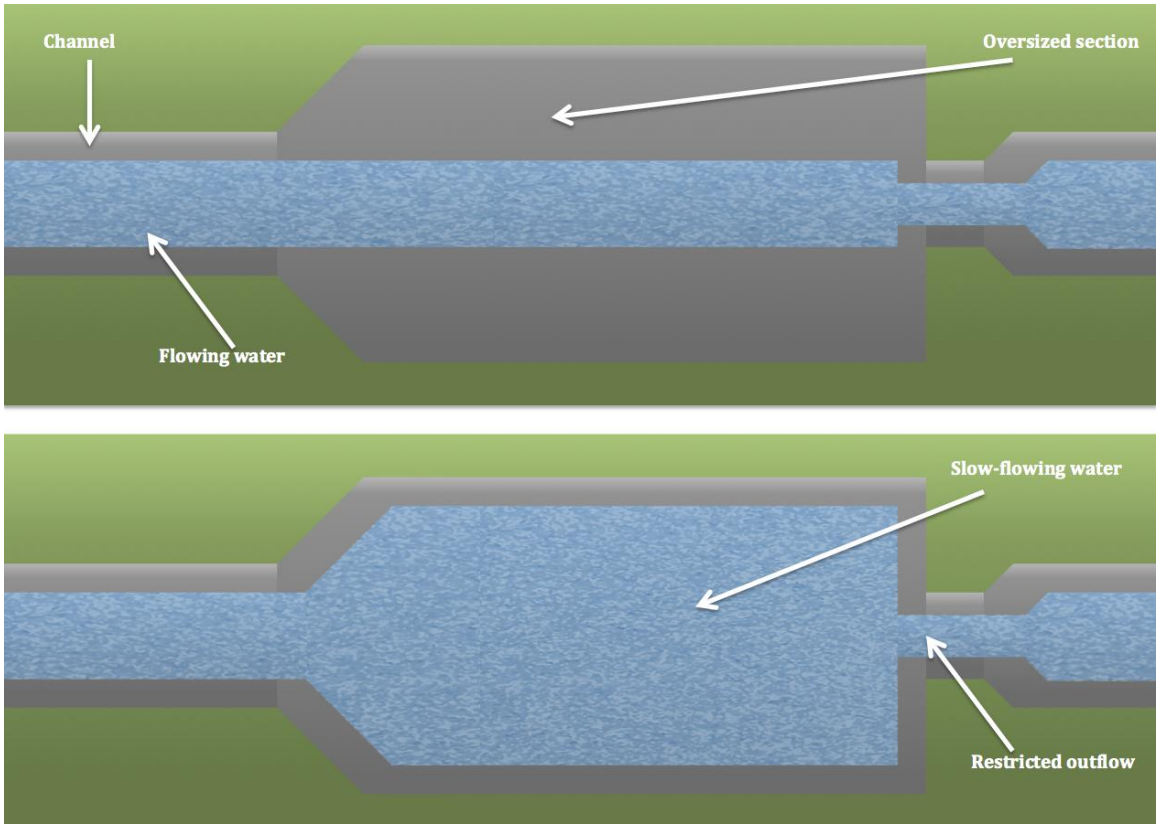


Figure 29: Oversized channel section with low waterflow (top), and high flow (bottom)

Cost Considerations

This is a high-cost implementation because the pipes and cement must be purchased. It also takes a fairly large amount of labour to install the pipes.

The oversized channel form is low-cost, since the channel simply involves the cost of material for the additional width of a short section of wide channel.

Maintenance

- Access points should be established at the ends of the oversized pipe as well as other intermediate locations (approximately every 30 metres)
- Sediment removal should be by mechanical means if possible
    - If flushing is the only option, take preventative measures so that the sediment is trapped and removed before moving further down the stream

Recommendations for Langrug

Applicability for Langrug: Applicable

The oversized channel form of this intervention could be quite useful for Langrug as a way to reduce runoff flow during heavy rains. This can help cut back on waterflow in the downstream areas of the settlement in order to reduce flooding. The intervention would take the form of wider sections of channel with shallow slope, placed at intervals along a channel. Take special care to make sure that the wide sections do have steep enough slope to insure no pooling occurs.

2. Channels

Greywater and stormwater channels are designed to direct the water flow down a slope to a point where it will be gathered for treatment or for transportation to an offsite treatment centre. The simplest channels are trenches dug into the ground, following the downward slope. However, most permanent channels should be designed with protection to prevent erosion from the channel sides, so as to maximize channel life and reduce sedimentation downstream (see ***Strategies Against Soil Eroision and Sedimentation*** page 85). The protection is usually in the form of vegetation or rocks, sometimes with cement.

To avoid flooding, channels should be built to be able to carry runoff water even from the most severe rain. Channels nearer to the bottom of the slope will need to carry more water than upstream channels, which receive runoff from a smaller area. The size of channel must take into account the amount of land area that drains into the channel. Stormwater and greywater stream mapping can provide valuable insight into the amount of runoff that a given channel will receive.

Langrug's position on a hillside makes it well suited for channel systems, as the steady slope encourages water to flow in streams down the hillside. If channels are kept smooth and are made to follow the natural slope of the mountain, water may be carried easily with minimal pooling. In Langrug, pooling should be avoided in nearly all cases because its greywater and stormwater streams are mixed.

Figure 30: Grey water flowing down an informal stream in Langrug

2-1. Vegetated Channel (Artificial Swale)

Description

A vegetated channel is a long, narrow trench lined with vegetation (usually short grass). The trench is situated so as to channel water down the hillside. A vegetated channel is typically dish shaped; around 25-50 centimetres deep and 1-2 metres wide.(Button, Jeyaraj, Ma, & Muniz, 2010)

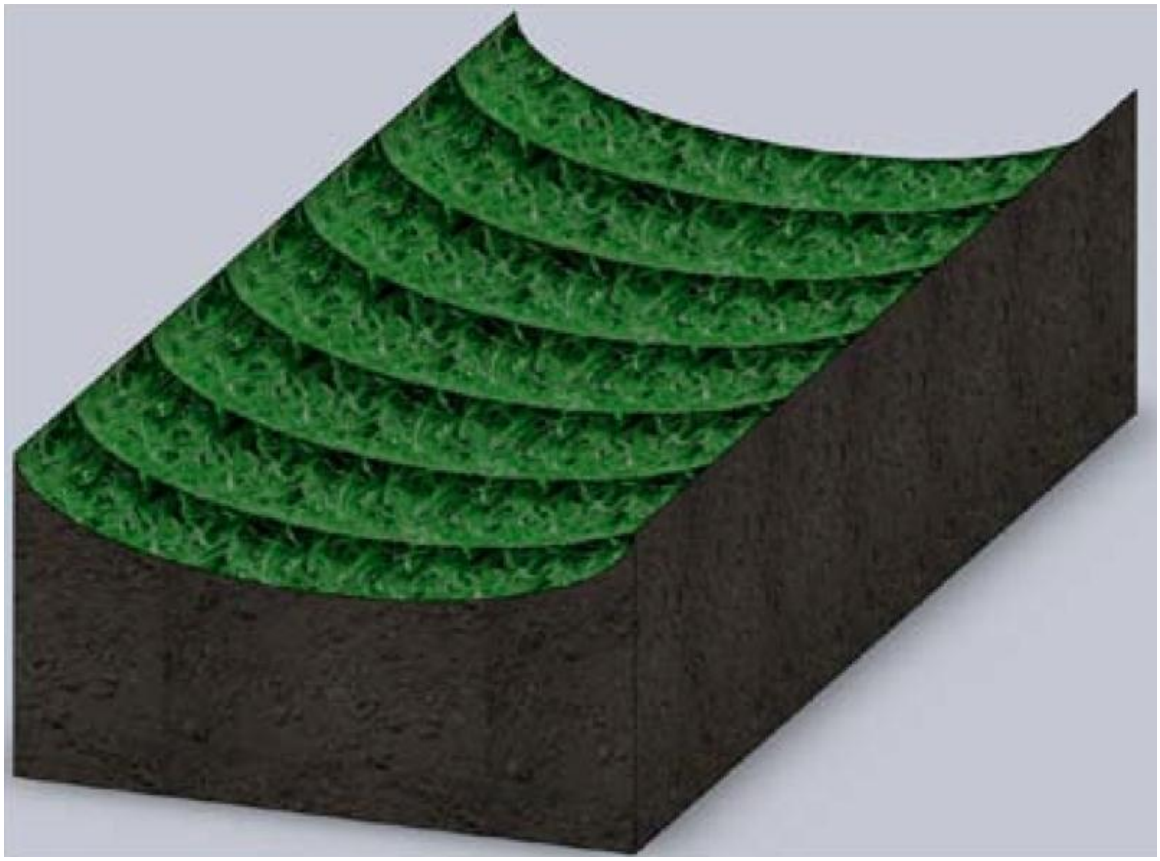


Figure 31: Computer-generated image of an artificial swale

(Button, Jeyaraj, Ma, & Muniz, 2010)

Ideal Location

Vegetated channels are best when the following conditions are present:

- ***Moderate slope:*** To ensure that water can be successfully directed down the channel without pooling, the vegetated channel must be constructed on a slope. Building the channel along a pre-existing stormwater gully ensures that the channel does indeed follow the natural slope. The slope should be steep enough that water can flow steadily through the channel, but it must not be too steep, as a steep slope will make it difficult for the swale to capture water.
- ***Fertile soil with few rocks:*** Because the vegetated channel relies on plants to hold the channel's shape and prevent erosion, the channel should be built in ground that can support

healthy plant growth. Vegetatation usually prefers fertile soil that is not excessively rocky. However, it will be possible to find grasses that can thrive in most soil conditions encountered in the settlement.

From these conditions, we determine that a vegetated channel is best suited to hillsides – especially along existing stormwater gullies

Pros and Cons

Pros

- Low cost
- Easy to obtain vegetation around the settlement
- Easy to maintain
- Self-regenerating/repairing
- Grass fosters good bacteria in its root system, helping to break down waste products in the grey water and reduce contamination and smells.

Cons

- Takes time for grass to spread and take root
- Requires regular maintenance until the grass is established
- Some types of grass may be aggressive and require regular trimming
- May be difficult to implement at certain times of the year, when grass does not grow quickly
- Not well known by community – may be difficult to gain support from the community

Materials and Tools

1. Grass or grass seeds
2. Spades
3. Picks if ground is especially hard or rocky
4. Fertilizer or mulch (if grass requires more fertile soil than the available soil)

How to Implement

1. Dig the channel

First, the channel must be dug. Use spades, loosening the ground with picks if it is packed, rocky, or full of plastic. The channel should be around 25-50 centimetres deep at its middle, and around 1-2 metres wide. The ideal shape is dish-shaped, as seen in Figure 32. The channel must run down the slope of the hillside, and it may be beneficial to follow the path of an existing stormwater gully, so as to ensure that the channel does not deviate from the mountain's natural slope.

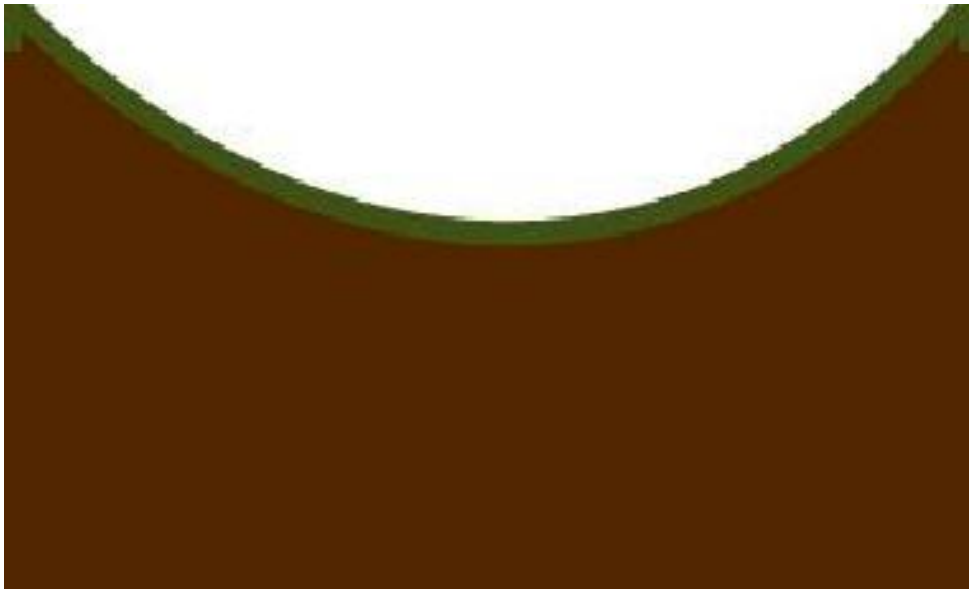


Figure 32: Cross-sectional view of dish-shaped vegetated channel

(Button, Jeyaraj, Ma, & Muniz, 2010)

2. Choose suitable grass species

Once the channel has been dug, a type of grass to plant in the channel should be chosen. The grass should meet the criteria for erosion-preventing vegetation, as discussed in ***E-1. Vegetative Stabilization*** page 87. The criteria for plant decision are:

1. Dense, deep root systems
2. Preferably native species, alrea dy growing well in the settlement
3. Preferably not an overly aggressive, invasive species (to reduce maintenance requirement and minimize possibility of property damage)

In addition to these criteria, the plant must also be able to thrive even when in contact with the contaminants contained in grey water.

3. Plant vegetation

The grass must be planted along the sides and bottom of the channel. The planting can be done either by seeding or by transplanting.

Transplanting involves moving the grass, including root systems, from one place where it was naturally growing, to the channel, where it is meant to be planted. Another kind of transplanting is sodding, which takes squares of sod (grass in a thin mat of dirt) and lays them over the ground. Sod is usually obtained from a retailer.

The second option for planting is seeding. This involves spreading grass seeds over the ground. Seeding is not usually a good option for vegetated channels because the seeds are easily washed away by water flow before they have taken root. For this reason, a newly seeded channel cannot be used for a few days or weeks after it has been seeded.

The implementation processes for transplanting and seeding are discussed in more detail in the ***E-1. Vegetative Stabilization*** on page 87.

Cost Considerations

If transplanted grass is used, these channels can be made easily at no cost, assuming sufficient grass is available in the settlement for transplanting and tools can be borrowed from community members or organisations.

Maintenance

Until the grass takes root firmly and becomes established in the soil, the transplants or seeds should be watered regularly - the ground should be kept relatively moist. Inspect the grass at least once a week to ensure that it is growing properly. Reseeding or additional transplanting may be necessary if the grass is not growing well.

After the grass has matured or established itself, it should be trimmed if it grows beyond the desired area. Most native grass species will not require regular watering beyond what is naturally received via rainfall. It may be necessary to occasionally remove trash that becomes caught in the grass.

To ensure that the channel continues to properly transport water without slowing it down too much or causing pooling, it may be necessary to trim the grass from time to time. If the grass becomes too tall, it can catch the water and cause pooling in parts of the channel that have mild slope.

Recommendations for Langrug

Applicability for Langrug: Widely Applicable

One type of grass to consider for this type of channel is kikuyu grass. This grass is very strong and holds the ground in place well. However, it has an aggressive nature that must be taken into consideration whenever it is to be used. Kikuyu grass is discussed in more detail in ***E-1. Vegetative Stabilization*** on page 87.

Vegetated channels are a promising intervention for Langrug. There is plenty of grass available for transplanting at little or no cost, making this a very cheap option that can be implemented quickly – without waiting for significant finances to be acquired. However, because nearly all channels implemented up to this point have used cement, much of the settlement sees cement channels as the ideal solution for greywater channels and many people seem hesitant to try new options that do not use cement for channeling. It may therefore be necessary to construct a small-scale vegetated channel to demonstrate the viability of this option to the community and to increase awareness and willingness regarding this method.

2-2. Stone & Cement Channel

Figure 33: A stone and cement channel implemented in J-section, Langrug

Description

The stone and cement channel is a basic channel that is lined with stones and held together by cement. The cement is meant to provide a smooth surface over which water can flow without pooling.

Ideal Location

Stone and cement channels are best for locations with:

1. ***Moderate slope:*** The slope will keep water flowing and prevent pooling, even if rocks are causing the channel to not be completely smooth.
2. ***Existing greywater / stormwater channels:*** Building along existing stormwater gully ensures that the channel does indeed follow the natural slope.

Pros and Cons

Pros

- Stone is readily available and can be gathered from around the settlement
- Can be adapted to available materials
    - Can build stone channel with no cement
    - Can use a variety of stone sizes
    - Can build pure cement channel for better smoothness
- Well known by community – readily accepted

Cons

- High cost of cement
- Hard to repair if cement cracks
- Can get pooling if built as a rock channel without cement or if rock and cement are not laid down properly

Materials and Tools

1. Spades
2. Picks
3. Stone
4. Sand

5. Cement
6. (Wheelbarrow)
7. Trowel
8. Brush

How to Implement

1. Dig channel

First, dig a channel. Use spades and picks to loosen and remove soil. The channel must be large enough to deal with the waterflow expected during the most severe rainstorms experienced in the wintertime. To minimize the risk of erosion from the channel sides, do not make the sides overly steep. Avoid having sharp drops in the banks along the channel so there will not be collapsing. Dig the channel so that it goes down the natural slope of the mountain. Be careful to dig with a constant downward slope so as to prevent pooling in the finished channel

2. Lay stones

Next, line the channel with stones. This reduces the amount of cement required for the channel while also forming a solid base for the channel. Larger stones (up to about 30cm in diameter) should be applied along the sides of the channel to firmly hold the walls in place and prevent erosion and collapse. Smaller stones (up to about 15cm in diameter) should be used along the channel bottom to ensure that the base is smooth for minimal pooling.

3. Cement

When the stones are in place, cement must be put between and over them. The process of preparing the cement is as follows:

1. *Mix sand and cement powder*
   Use spades and rakes to mix fine sand with the cement powder. The ratio of sand to cement should be in the area of 2:1 or 3:1 (horizontal:verticle). Using the greater amount of cement will tend to yield a stronger cement, but at a higher cost.
2. *Add water*
   Once the cement powder and sand have been mixed, gather the mixture into a pile and create a bowl-like indentation in the center. Add water and mix in, gradually adding the water until the consistency of the cement is like damp sand.

The mixed cement must then be put into the channel, fitting in the gaps between the stones. Smooth it using the trowel. There must not be indentations or large bumps in the channel that could lead to pooling. Once the cement has been added and smoothed, brush it down using a wet brush to further smooth the cement.

The steps used to implement a rock and cement channel in J-section in Langrug are illustrated in detail in Figure 34.

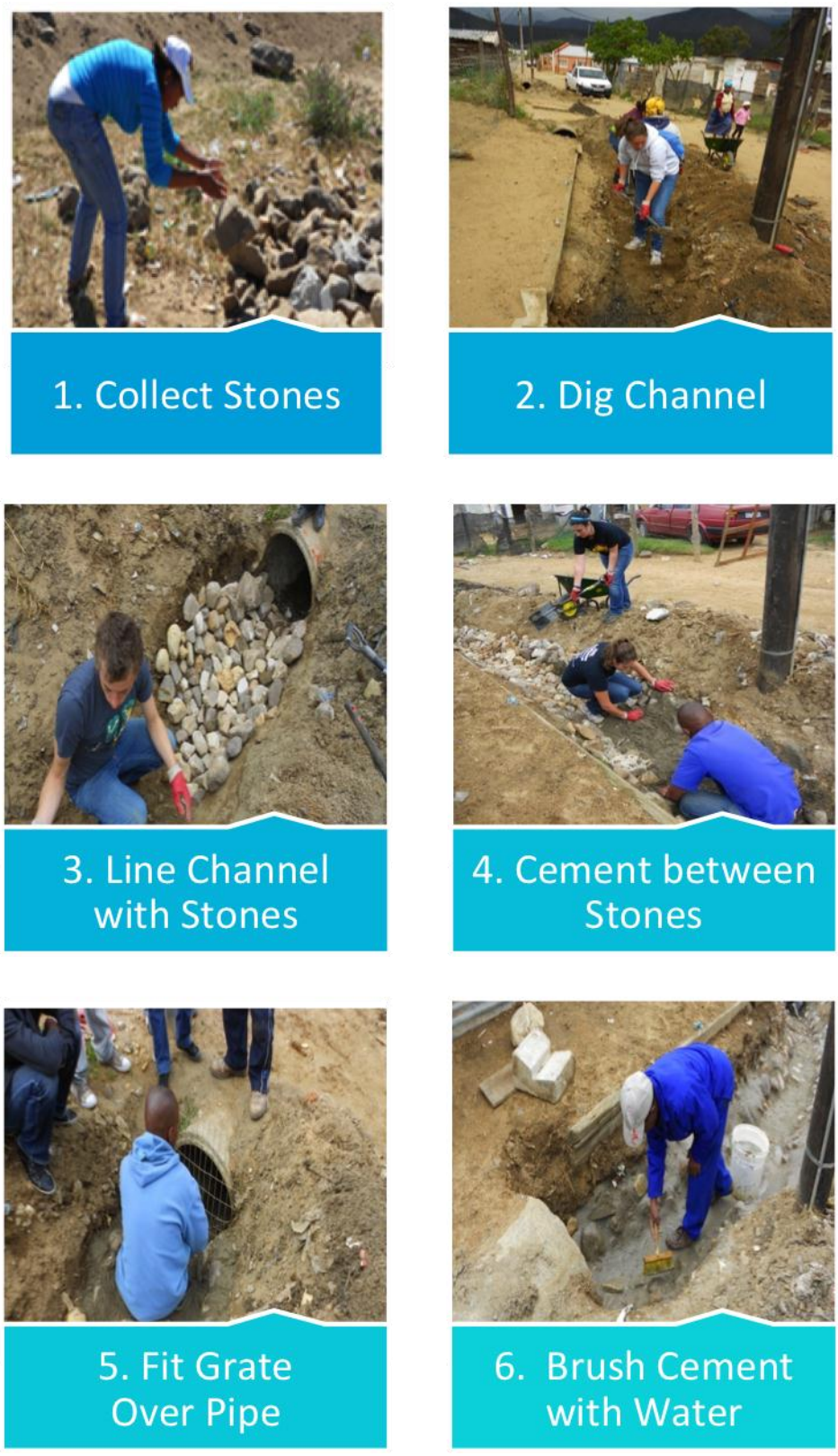


Figure 34: The building process used to implement a stone and cement channel in J-section, Langrug

Cost Considerations

Stone and cement channels are a moderate-cost intervention because of the need to buy cement and sand. Other materials and tools can usually be obtained within the settlement. If a pure stone channel is made, cement will not be needed, so cost will be significantly lower.

Maintenance

Rock and cement channel maintenance will mainly involve removal of trash and sediment. Over time, any bumps or indentations in the channel will begin to fill with sediment, and sedimentation will occur naturally over the bottom of the channel. Additionally, trash will accumulate in the open channel, whether because people throw it directly into the channel or because it is blown in by wind or carried by water. The sediment and trash must be removed periodically to prevent pooling and blockages. The community must be involved with this cleaning and maintenance, as discussed in the Maintenance section of this guidebook (page 38). If the channel involves pipes, it will be helpful to place grates over both ends of the pipes to prevent trash from being washed or blown into the pipe from either end of the pipe.

Variations on the Stone and Cement Channel

The stone and cement channel can be adapted to make various types of channels by using or not using certain components. These variations are:

- ***Stone-lined channel:*** If funding or materials are not available, the channel may be made using only the stone lining. The result is a very quick, cheap alternative approach to making a greywater channel. This method comes with the risk of pooling between the rocks. To limit pooling, small gravel can be put in the gaps.
- ***Cement channel:*** For maximum smoothness, a channel can be made only out of cement. For such a channel, the cost will be relatively high due to the larger amount of cement required. If properly smoothed out, the cement can pass water very effectively, allowing the channel to operate with minimal pooling.
- ***Concrete channel:*** Channels where cement is mixed with gravel can provide a smooth surface, while also allowing the same amount of cement powder to cover a larger area.

Recommendations for Langrug

Applicability for Langrug: Widely applicable

Stone and cement channels can be applied in most areas requiring greywater channels in Langrug. They are rather easy to implement, and can be made fairly quickly if materials are available. The stone and cement channel is the most widely known and accepted greywater intervention in Langrug. As such, most community members ask for such a channel when asked what kind of intervention they want to implement in their area. For this reason, it is easy to get community approval for a stone and cement channel intervention, but other interventions may be harder to get approval for.

3. Infiltration

Infiltration systems are used to encourage water to sink into the ground. They are often used to help store more water underground, reducing stormwater runoff to minimize the strain on drainage systems. When used solely for moving water underground, infiltration systems are most useful in areas with soils such as sand or loam that are highly permeable.

Infiltration is also applicable for various basic filtration systems. Filters are useful for improving the quality of greywater on-site. They can remove various contaminants from the greywater, reducing many of the problems caused by greywater, most significantly, smell and disease. Many modern filter options involve complicated membranes and machines, but the methods described below are simpler filters suited for implementation in informal settlements by informal settlement communities. These filters rely on natural materials including sand, rocks, and plants to remove contaminants from greywater. The filters described here are designed to encourage water to infiltrate into the ground, where layers of rocks and sand can work together with remove various contaminants.

In Langrug, we believe it may be valuable to use filters at points where greywater will be commonly dumped. These filters could be connected to channels, such that greywater dumped over the filters would emerge comparatively clean into the channel. A system such as this could reduce greywater-related issues downstream.

Infiltration systems may have only limited applicability for most areas of Langrug because of the shallow clay bed that exists under most of the settlement. The clay bed prevents deep infiltration of water, such that water that infiltrates in the upper areas of the settlement often emerges in the lower sections, sometimes causing flooding issues. However, infiltration could be used in conjunction with underground perforated pipes for stormwater management in some situations.

3-1. Infiltration Trenches

Description

An infiltration trench is a shallow rock-filled trench designed to encourage water to sink through the rocks into the ground. It sometimes uses a buried perforated pipe to channel some or all of the infiltrated water to another area. Various sizes of rocks are used in layers to filter out some of the contaminants from the water as it infiltrates.

Figure 35: Rock-filled trench that encourages water to sink into the soil
(Infiltration Trenches, 2007)

Ideal Location

If the infiltration trench is meant to merely let water sink down into the ground and stay there, it must be implemented in an area that allows for good infiltration of water. Some requirements include:

- ***Permeable soil:*** If the water is to effectively soak into the ground through the rocks, the ground must be made up of permeable soil (soil that is loose and allows water to pass through easily). This means that loose, sandy soils are ideal (as opposed to clays and compacted soils)
- ***Low water table:*** Infiltration will not occur if the ground is already saturated with water.

- ***Low amount of sediment in runoff:*** As the water infiltrates through the bed of rocks, it can deposit sediment that it is carrying. Over time, this sediment can clog the trench, so infiltration trenches should be implemented together with erosion prevention or sediment removal interventions.

If the infiltration trench will use a perforated pipe to remove the infiltrated water from the area, the requirements are the same, except that the soil no longer needs to be especially permeable, since the infiltrated water no longer needs to be stored in the ground. For the perforated pipe to effectively channel water, the trench must be implemented in ground with a slight slope.

Infiltration trenches can thus be implemented in areas such as:

- In loose soil at the bottoms of hills (to reduce runoff load)
- As part of a road, to carry runoff (using a perforated pipe)

Pros and Cons

Pros

- Doesn't "waste" space because it's part of the ground
- Reduces runoff volume by moving water flow underground – as a result, flooding is reduced
- Can remove sediment, some chemicals, and bacteria from stormwater

Cons

- Can have clogging issues if runoff contains large amounts of sediment
- Can contaminate groundwater if polluted water infiltrates
- Can be hard to get enough rocks for a long trench
- Hard to maintain/clean

Tools and Materials

- Spades
- Picks
- Rocks
    - Large rocks (up to around 20cm diameter)
    - Gravel (up to around 3cm in diameter)
    - Pebbles (less than 1cm in diameter)
- Perforated pipe (optional)

How to Implement

1. Dig the trench

Use the spades and picks to dig a trench around 1-2 metres deep and about 1 metre wide. If used for draining via a perforated pipe, the trench must be dug so as to follow a downward slope and must extend as far as an outlet from the pipe to a stormwater drain or channel. If the trench is meant to infiltrate stormwater into the groundwater, it can be placed perpendicular to the water

flow along or at the bottom of the slope. The length of the trench can vary depending on the amount of runoff expected and the amount of space available.

2. Place the pipe (optional)

Once the channel has been dug, the perforated pipe can be put in. It must be laid so as to have a constant slope to keep water flowing through it.

3. Fill the trench with the rocks

Fill the trench until the rocks are about level with the surrounding ground. The lowest layer will be made up of the large rocks. If a pipe is to be placed in the trench, the large rocks should be layered at least up to the top of the pipe. The second layer is gravel, and the third is pebbles.

The pebbles serve to remove any trash or large objects from the water. The layers of larger rocks remove other contaminants.

4. Implement sediment-reducing measures (recommended)

To prevent clogging of the channel by sediment, it is helpful to incorporate sediment removal/erosion prevention interventions around the trench. One method that could be applicable is ***Filter Strips*** on page 79.

Cost Considerations

Spades and picks have already been purchased for other projects, and many community members may be able to provide tools as well, so the cost of tools should be minimal. Rocks could be gathered around the settlement, but small rocks and pebbles such as those required for the trench may be difficult to gather in large amounts. For this reason, it may be necessary to purchase the gravel from an outside source. This could be a large cost if the trench is to be very long. The perforated pipe could be purchased or could be made by putting small holes in the upper half of a pipe, along its length.

Maintenance

Infiltration trenches are susceptible to clogging by sediment. When they become clogged, the trenches do not allow infiltration to occur as quickly as they are designed to, which can lead to an increase in runoff volume. To restore the infiltration trench's functionality, the sediment must be removed. This requires removal of the rock together with the sediment, followed by replacing the rock to the trench.

Recommendations for Langrug

Applicability to Langrug: Moderate

Because of the shallow clay bed present around Langrug, this method may not be very applicable if pure infiltration (no pipe) is desired. However, it may be useful for channeling runoff using a perforated pipe.

One possible application of the infiltration trench with a perforated pipe is to place the infiltration trench along the length of a section of road. The trench can be placed at the middle of the road, and the road can be sloped slightly toward the middle. This will drain the water that comes

to the road down into the trench rather than off the road into people's houses. When the water reaches the infiltration trench, it will drain through the rocks into the perforated pipe, which can carry the water away to the city's stormwater system or into a channel further down the hill. For this implementation, the road must be built on a slope so that the water that reaches the perforated pipe can actually flow through the pipe to a point downstream. The design is shown in Figure 36, with water flow shown by blue arrows.

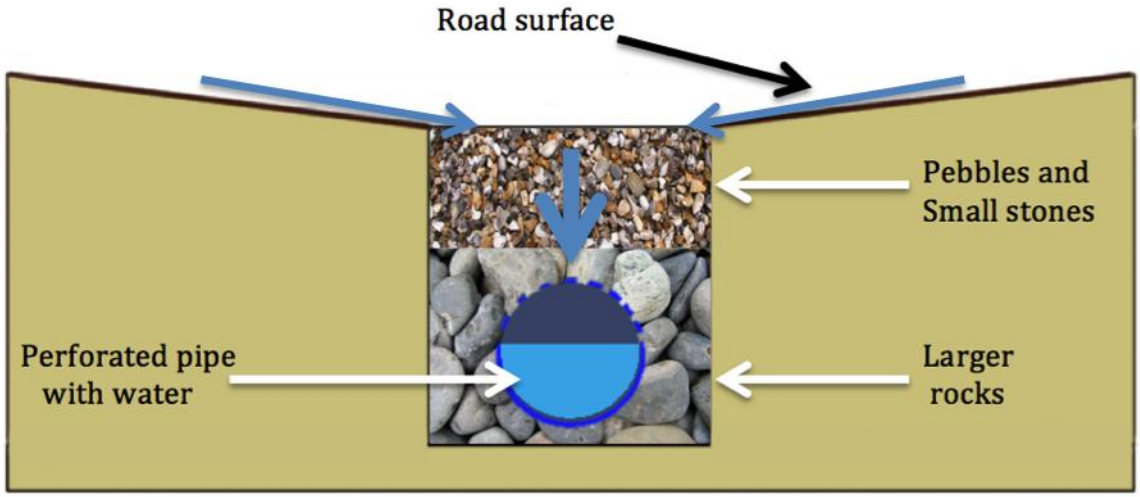
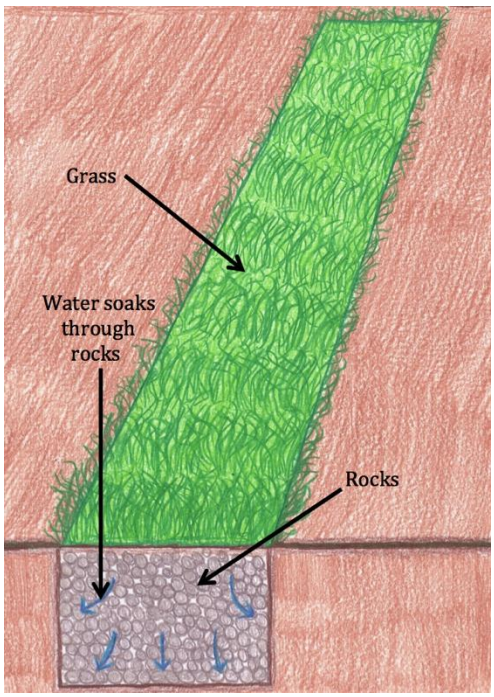


Figure 36: Infiltration trench built into a road with perforated pipe

3-2. Soakaways



Description

A soakaway is a ditch in the ground that is filled with rocks and then covered with vegetation. The purpose of a soakaway is to allow runoff water to soak into the ground, after being filtered through the rocks and vegetation, and then redirected to a larger body of water.

Ideal Location

No specific area size necessary, but the soil should be able to support vegetation.

Pros and Cons

Pros:

- Filters water
- Encourages nutrient absorption
- Generally inexpensive
- Low maintenance

Cons:

- May not be effective if flooding occurs
- Vegetation must be managed

Materials and Tools

1. Spades
2. Stones
3. Vegetation

How to Implement

1. Dig the ditch

Dig a ditch approximately 1 metre deep, 1.5 metres wide, and 4 to 6 metres long

2. Fill the ditch with stones

Fill the ditch with stones, until the stones are about level with the surrounding ground.

3. Plant vegetation

Plant grass over the ditch. See ***Strategies Against Soil Erosion and Sedimentation*** on page 85 for more detail on choosing best vegetation species and planting.

* One way that this could be implemented in many informal settlement, including Langrug, would be to use the soakaway as a filtration point at the beginning of a greywater channel. Community members could dump their greywater on the soakaway grass strip, so the water could filter through the soakaway and emerge into the channel as cleaner water. This could reduce some of the issues associated with greywater.

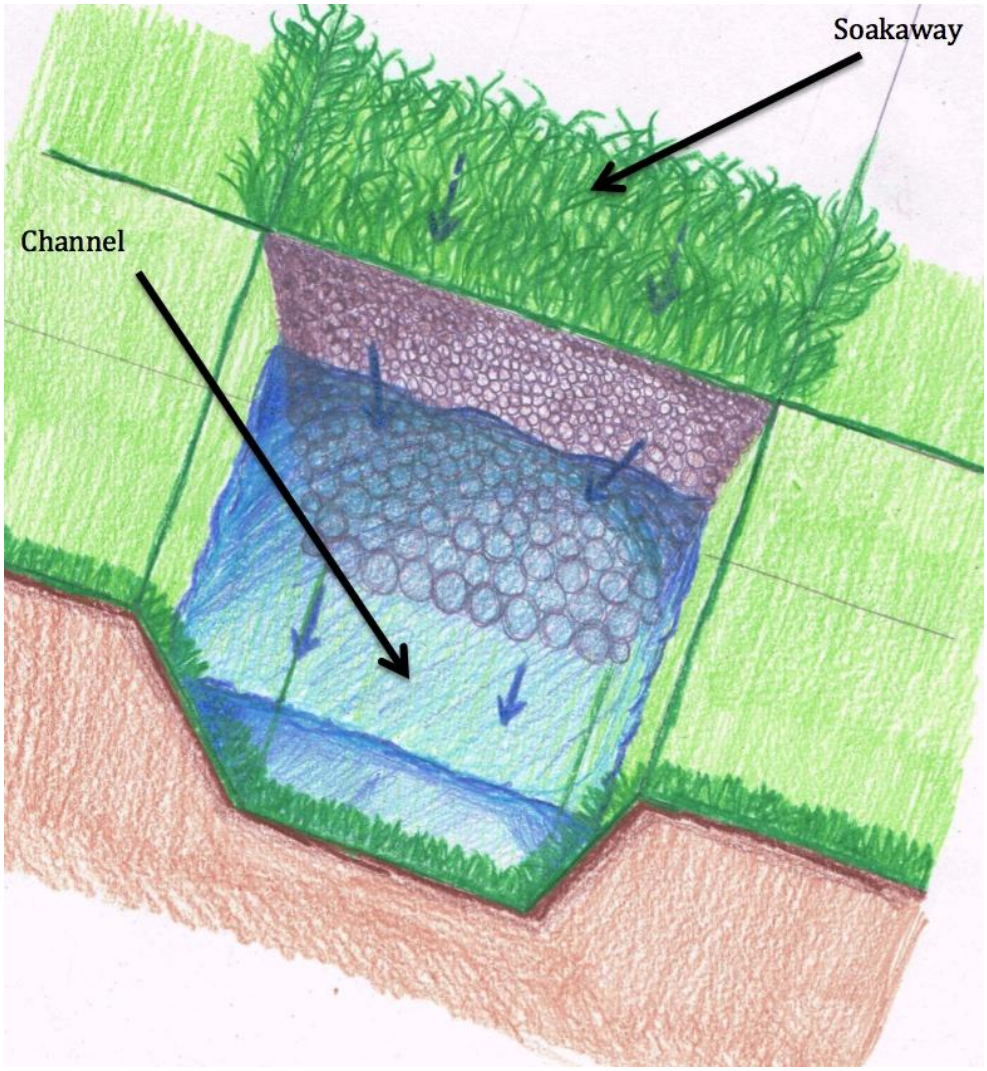


Figure 37: A soakaway used as a greywater filter at the head of a channel

Cost Considerations

If grass is transplanted from other areas of the informal settlement, this intervention can be implemented for little or no cost, since all materials and tools can come from within the settlement.

Maintenance

Soakaways require minor maintenance on a regular basis to control grass growth and prevent clogging.

- Vegetation must be controlled and cut on an as needed basis
- Removal of excess sediment or trash will be necessary to prevent blockages

Recommendations for Langrug

Applicability for Langrug: Applicable

It may be hard to use soakaways in Langrug because of the shallow clay bed which prevents the water table from holding a significant amount of water. When the water table is full, water can reemerge from the ground further down the mountain leading to minor flooding issues.

However, soakaways could be useful as filters for the start of greywater channels. If they are to be used for this purpose, some community education may be necessary to ensure that the soakaways are properly used. The community should avoid throwing any trash or food waste on the soakaway, and the soakaway must be properly maintained.

4. Combination

Some greywater and stormwater interventions use a combination of methods to move or treat water. The methods listed here use combinations of channeling, infiltration, and storage to deal with stormwater and greywater. When two or more types of intervention are required, these combined solutions can sometimes yield good results at a smaller total required area.

4-1. Dry Swales

Description

A dry swale is a vegetation-lined channel built over a filtering bed made up of layered rocks. It removes pollutants from runoff water as well as carrying excess water downstream and causing some of the water to soak into the ground. If the slope is steep, checkdams can be installed to temporarily pool the water, which provides more time for pollutants and sediment to settle and for water to infiltrate into the ground.

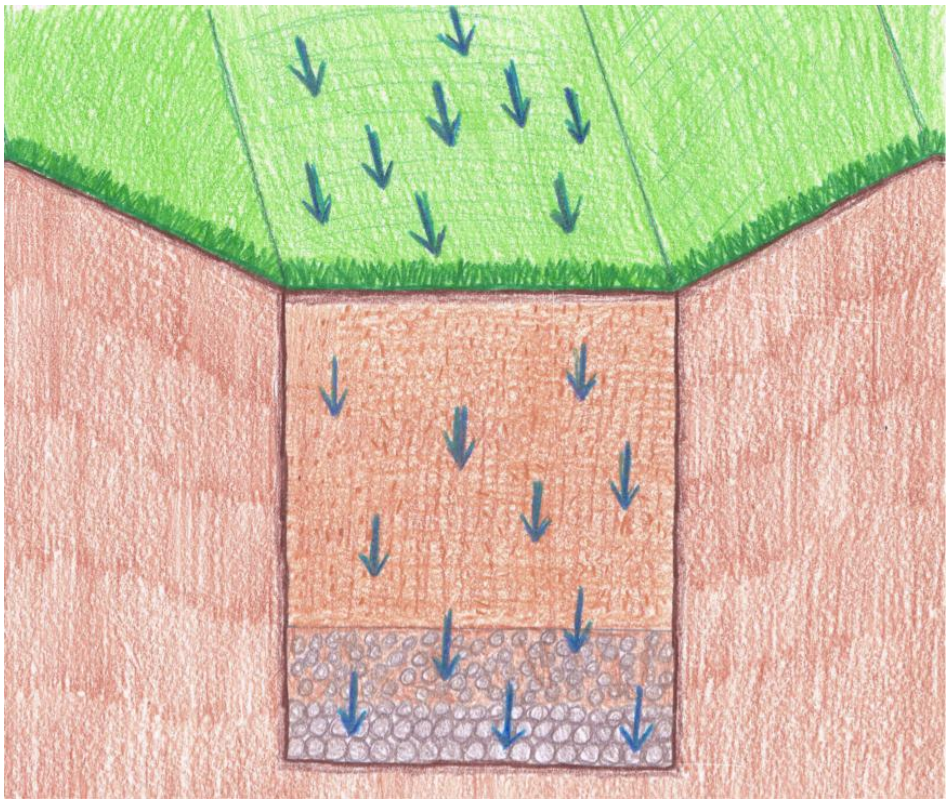


Figure 38: Dry swale with arrows showing water flow through channel and infiltration into ground

Ideal Location

Dry swales can be applied for areas that have:

1. ***Shallow slope***: In order for water to properly flow through the dry swale, it must be build running down a slope. The slope should not be overly steep because the water must move somewhat slowly if it is to soak into the ground.
2. ***Soil that can support vegetation:*** Since a dry swale depends on grass to hold the channel walls in place and to filter out pollutants, the ground where it is made must support vegetation.
3. ***Permeable soil:*** The soil around the dry swale must be able to absorb the water that seep in through the rocks. Soil full of clay or highly compacted soil is not desirable.

Pros and Cons

Pros:

- Traps and filters sediment and other pollutants
- Reduces runoff flow speed
- Prevents erosion
- Inexpensive

Cons:

- Does not reduce bacteria levels in water
- Not effective with steep slopes
- High maintenance

Materials and Tools

1. Spades
2. Stones and gravel
3. Grass or grass seeds
4. Wooden beam for checkdam (optional)

How to Implement

1. Dig the channel

Dig the channel that will be covered with grass when the dry swale is complete. Make the channel with its banks sloped at a slope of about 2:1 (horizontal:vertical). The channel should be about 30 centimetres deep at the middle, and the flat base should be about 0.5-1 metre wide.

2. Dig the trench

Dig a trench that will contain the layered rocks. It should be around 50 centimetres deep beyond the base of the channel dug in step 1.

3. Lay rocks in the trench

The trench should be filled with rocks in the following order with the bottom two layers approximately the same thickness and the top layer about half the thickness of either of the other two. For a 50 centimetre deep trench, the layers and their thickness would be:

a. Bottom layer – Gravel – 20 centimetres thick
b. Middle layer – Soil/gravel mix – 20 centimetres thick
c. Top layer – Soil/sand mix – 10 centimetres thick

4. Plant grass

Once the filtering layers are in place, plant vegetation within the swale. (See ***Strategies Against Soil Erosion and Sedimentation*** on page 85 for more detail on choosing best vegetation species and planting.)

5. Build checkdams (optional)

If substantial infiltration is desired, checkdams can be built in the dry swale. A checkdam is a small structure built across the channel so as to cause water to slow down and pool. The pooled water will soak into the ground more effectively. To build:

1. Create a pile/ layer of rocks across the swale
2. Place a wooden beam on top of the rocks to break up the channel and insert the ends of the wood into the channel walls to hold it in place.

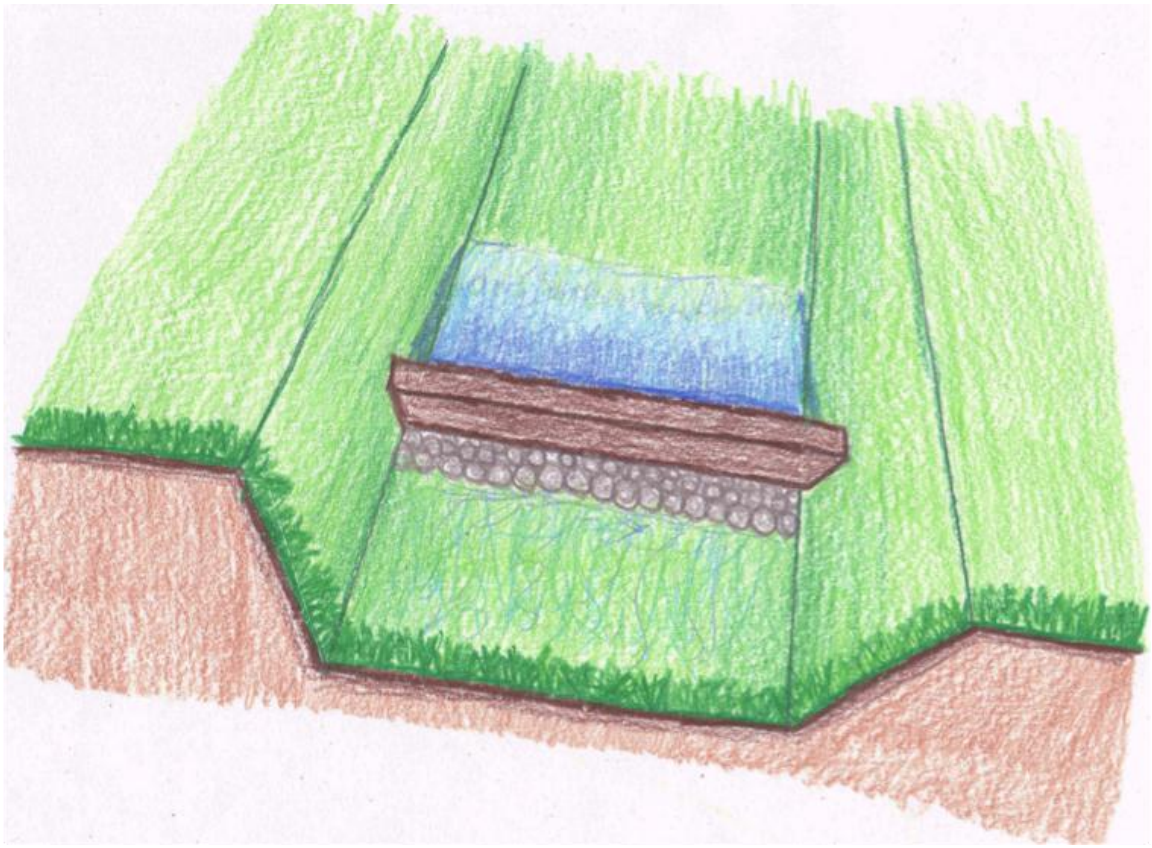


Figure 39: Stone and wood checkdam

Cost Considerations

Dry swales can be built at low cost if the necessary grass is available around the settlement for transplanting. Wood for checkdams may need to be purchased.

Maintenance

- Inspect swale once or twice per week in the first few months for erosion and to ensure vegetation growth
- Remove trash and excess sediment found in the swale as necessary in order to prevent clogging (also examine the checkdam)
- Grass must be cut to a height of 0.1 metres, especially in the first year

Recommendations for Langrug

Applicability for Langrug: Applicable

Dry swales can be used in Langrug for channeling water and providing some filtration. Because Langrug's soil structure will not allow significant infiltration, and because pooling greywater should be avoided, it may be best to build dry swales without checkdams.

4-2. Filter Strips

Description

A filter strip is a vegetated strip of shallow-sloped land that slows runoff water while also trapping sediment and other pollutants as well as providing some infiltration.

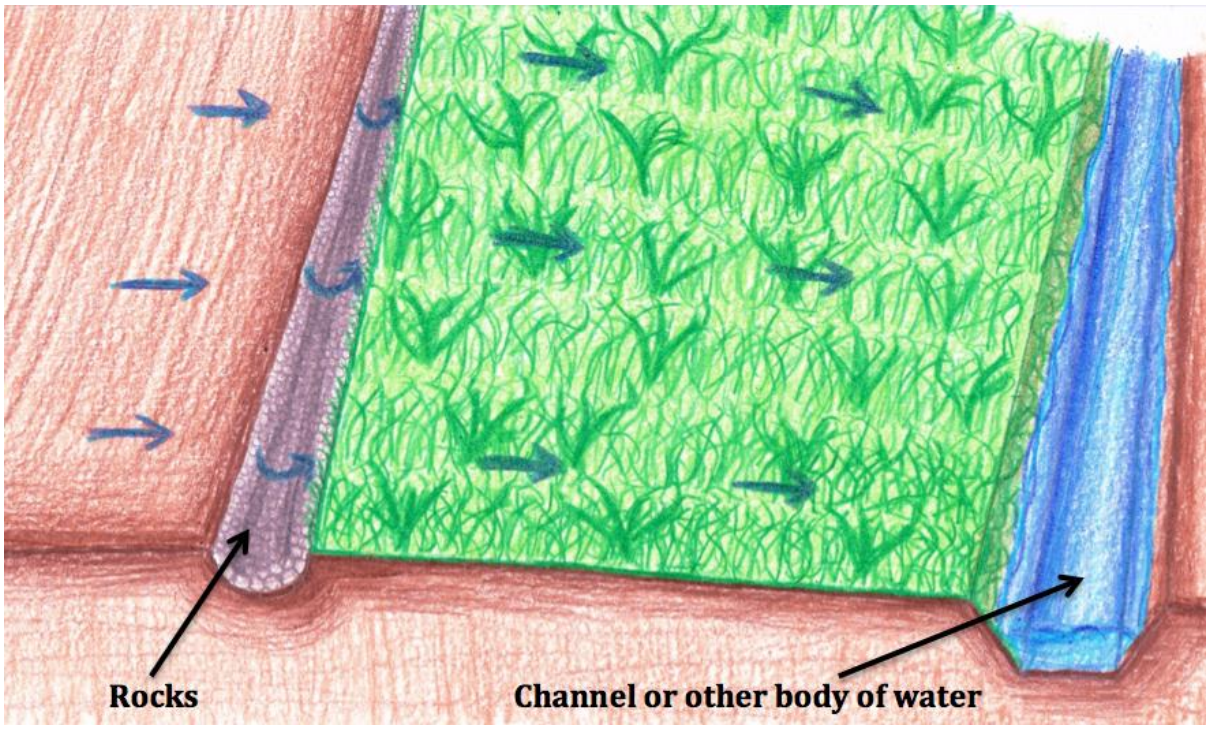


Figure 40: A grass filter strip with waterflow indicated by blue arrows

Ideal Location

Filter strips are most applicable for areas that have:

1. ***Large area:*** Filter strips use shallow water flow spread over a wide area. The slope on which the filter strip is implemented should be at least 4 metres across.
2. ***Shallow, uniform slope:*** For water to flow slowly over the filter strip without pooling, a constant but shallow slope is needed.
3. ***Soil that supports vegetation:*** Since filter strips depend on grass for filtration, choose an area with fertile soil that can support plenty of grass, or use fertilizer.

Pros and Cons

Pros:

- Help remove sediment and pollutants from runoff
- They are simple and inexpensive to install
- Low maintenance

Cons:

- Difficult to maintain sheet flow
- Need a lot of space

Materials and Tools

1. Rakes
2. Grass or grass seeds
3. Rocks
4. Mulch or fertilizer (optional)

How to Implement

1. Loosen the topsoil

Use the rakes to loosen the top layer of soil along the slope. If necessary, make the slope more uniform as well.

2. Lay rocks along the top of the slope

To slow the water flowing onto the filter strip and prevent too much sand from flowing onto it, put rocks along the top of the hill at the start of the filter strip.

3. Plant grass

Either transplant grass to the slope or spread grass seeds over it. Lay down mulch or fertilize the ground if the soil is not fertile enough to support the grass growth.

Cost Considerations

If the soil does not need to be fertilized or mulched, all materials and tools can be obtained from within the settlement at little to no cost.

Maintenance

The filter strip should be checked at least once a week to monitor vegetation growth. Transplanted grass may also need to be watered to encourage it to spread. Ideally, divert water away from the filter strip until vegetation is established. Every month or so, check the filter strip for sedimentation and trash and clean as necessary.

Recommendations for Langrug

Applicability for Langrug: Possibly Applicable

Filter strips may be used in Langrug to improve the quality of stormwater runoff. It may, however, be hard to implement them on the slopes without causing water to spread in such a way that it runs into people's houses. Filter strips might be useful for implementation together with other infiltration techniques such as infiltration trenches (3-1) and sand filters (4-3).

4-3. Sand Filters

Description

A sand filter is a stormwater and greywater management intervention that causes water to infiltrate through sand in order to filter out fine sediment particles and various chemicals, as well as some bacteria. It is made up of a pretreatment basin (***Sediment Basins***, page 98, or ***Filter Strips***, page 79) to remove large sediment particles from the incoming water, as well as a sand-filled basin that filters the water after large sediment has been removed.

Sand filters are designed to hold water in a pool after large rain events, draining over the course of no more than 24 hours.

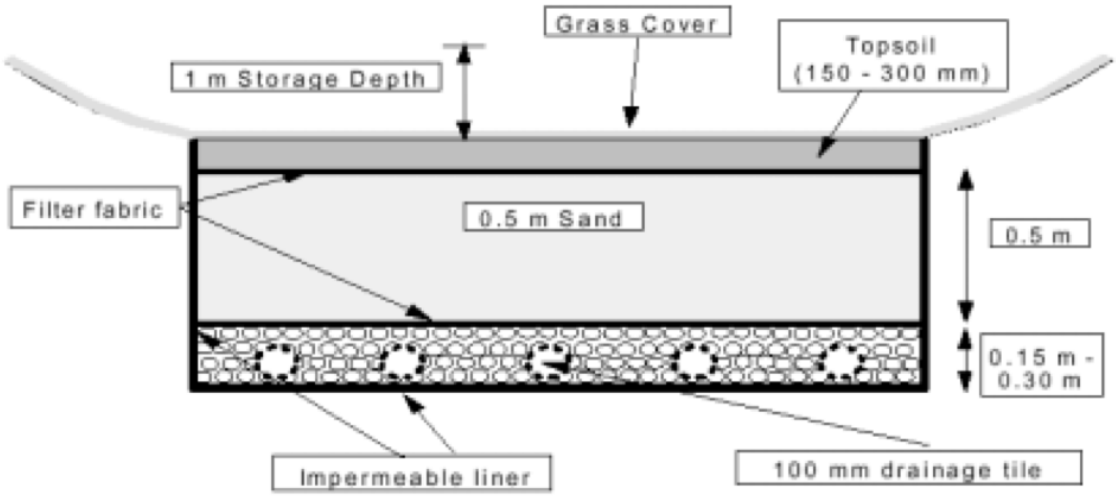


Figure 41: Cross-sectional diagram of a sand filter

(Barr Engineering Company, 2001)

Ideal Location

Sand filters have few limitations on where they can be installed, and they can even be used in areas with:

- Steep slopes
- Small area

Ideally, sand filters should not be used to service runoff from very large areas. Aim to apply one sand filter to deal with runoff from around 20,000 square metres of upstream watershed land.

With this in mind, sand filters may be most applicable partway down the slope in the settlement, where they can serve to remove some contaminants from the water before it reaches the lower parts of the settlement. This will help to reduce health risks. Building the sand filter midway on the slope rather than at the bottom will also ensure that the filter is not overwhelmed by

dealing with too much runoff, since only the part of the slope upstream from the implementation site will drain through the sand filter.

Pros and Cons

Pros

- Can be applied in a variety of situations
    - Even on steep slopes with little area available for construction
- Requires only a little space
- Very effective at removing fine sediment, with some capability for removing chemicals and bacteria as well
- Relatively simple to install

Cons

- Pretreatment basin required ahead of filter to prevent clogging
- Requires maintenance, especially when filtering a large amount of runoff
- Relatively expensive to build if higher quality sand must be purchased
- Hard to use effectively where there is a lot of sediment in the incoming water

Tools and Materials

- Spades
- Picks
- Clay or liner which will not let water pass
- Fine sand
- Stone or gravel
- Geotextile or fine shadecloth
- Perforated pipes
- Grass (optional)

Figure 42: A formal sand filter with rocks over the sand for erosion prevention

(Sand Filters, 2011)

How to Implement

1. Dig the sand filter basin and pretreatment basin.

The basin must be dug using the spades and picks. It should be about 1-1.5 metres deep. A trench must also be extended from the base of the filter for installation of drainage pipes leading out from the filter. The sand filter should be around 2 square metres in area. The banks surrounding the filter should be sloped down to the basin at a slop of up to 3:1 (horizontal:vertical) and laid so that 50 centimetres or more of water can temporarily pool over the filter.

A settling basin should also be dug ahead of the sand filter. This basin should be around 1-2 metres deep to allow proper settling of sand from the incoming water. Use implementation instructions as described in the Sedimentation Basin section of this guidebook (E-4).

2. Line the basin

The basin must be lined with a plastic lining or with a layer of clay to reduce leakage of water into the surrounding ground. The clay should be around 30 centimetres thick, and should cover the base and walls of the sand filter basin.

3. Lay pipes and gravel

Next, lay the outlet pipes and surround them with gravel to a depth of about 30 centimetres. The pipes must be perforated pipes, and should be of a material that will not crack under the pressure of the rock and sand above the pipes. Once the pipe are in place so as to drain into a downstream channel, cover the part of the pipes in the trench leading out of the filtration basin and line the wall of the relayed ground with clay, as in step 2.

4. Lay the sand

Lay the geotextile or fine-holed shade cloth over the gravel before laying the sand in the filter, up to about 20 centimetres below the upper edge of the filter basin. Do not pack the sand. It must be loose to properly pass water through.

5. Cover with rocks

Cover the sand with rocks and gravel to prevent incoming water from washing the sand away as it enters the basin.

6. Plant grass (optional)

In some cases, it may be beneficial to plant grass over the filter, or at the very least, along the banks around the basin, to improve filtration and prevent erosion. See the ***Vegetative Stabilization*** on page 87 for more information.

Cost Considerations

If fine sand can be obtained from in the settlement, this intervention can be implement for a rather low cost, with all materials except for the gravel and pipes (possibly the geotextile/shadecloth as well) being obtained from in the settlement.

Maintenance

Sand filters require regular maintenance for proper operation. They should be inspected a couple times in the first few months after installation, and at least after every major storm during that period. After the first few months, inspect at least twice a year to ensure that the filter is operating and draining properly without long-term pooling.

Trash and surface sediment must be removed from the filter surface and the pretreatment basin regularly to prevent clogging.

Recommendations for Langrug

Applicability to Langrug: Somewhat applicable

Sand filters may be applicable for Langrug if they can drain quickly so pooling of greywater does not occur. This is problematic because the pretreatment basin will have constant pooling for sedimentation removal. During rainy season, the greywater will be diluted with rainwater, so the pooling will be less of a health risk, but may still be a problem.

Test the sand filter on a small scale for effectiveness before trying on a large scale in the settlement. Check for drainage, sedimentation issues, and any greywater-related risks that occur with the filter, and evaluate whether or not it is safe and beneficial for application in Langrug for greywater filter

Strategies Against Soil Erosion and Sedimentation

A major threat to the effective operation of greywater and stormwater management systems is the buildup of sand and silt - known as sedimentation. This leads to reduced capacity for channel flow. In extreme cases, sedimentation can lead to complete blockage of a channel or pipe, causing overflow and flooding. Even mild sedimentation can lead to problems with pooling. The Figure 43 shows a greywater channel clogged with sand to the point that water can not flow through. At the time that this picture was taken, the pooled water ahead of the pipe had begun to give off a strong odour, and was probably contaminated with bacteria.

Figure 43: A clogged greywater channel in Langrug

The process by which wind or water removes sand from the ground and carries it away is known as erosion. This sand can come from all over the settlement, settling in various channels around the settlement. Rainwater erodes sand from exposed ground throughout the settlement and carries it downstream into channels. Wind can erode sand from the unpaved roads and yards near a channel and deposit it in the channel.

In addition to causing gradual sedimentation in channels, erosion can lead channel walls to suddenly collapse into the channel, quickly causing pooling or clogging. This problem usually occurs when heavy rainfall results in large amounts of runoff water flowing into the channel over its banks. As the water erodes sand from the sides of the channel, it can weaken the banks to the point that they cave in, filling the channel with sand. The figure below shows a channel whose banks have collapsed on a small scale, leading to significant sedimentation in the channel, the banks have eroded away in the circled areas, and preventative measures will be required to keep the banks from collapsing further in the future.

Figure 44: Bank erosion along a greywater channel in Langrug

One way to deal with sedimentation is to simply remove sediment from the channel whenever sand begins to build up in the channel. Cleaning can prevent the problems of pooling and clogging that sediment causes by keeping the channel smooth and sediment-free. Cleaning and maintenance processes are therefore an important part of preventing sedimentation in a channel. However, in settlements such as Langrug, where the ground is mostly unprotected sand, sedimentation can progress very quickly. As a result, an approach that relies solely on cleaning will require a significant sustained effort, and may not be a desirable option. Furthermore, cleaning does not address the problem of bank erosion and collapse. For these reasons, channel cleaning and maintenance efforts should be supplemented by strategies to prevent bank erosion and to prevent sediment from being deposited in the channel in the first place. Some of these strategies are discussed below.

E-1. Vegetative Stabilization

Description

This method prevents erosion from the banks of a channel by planting vegetation such as grasses along the sides of the channel. Grasses generally have strong root systems that can hold the sand and soil in place even during periods of heavy rain. The grass can also catch wind-blown trash and sand before it enters the channel, reducing sedimentation and trash accumulation in the channel.

Figure 45: Vegetation along a channel

(Tensar International Limited, 2010)

Ideal Location

Vegetation can be used for erosion prevention in a wide variety of locations and situations. It is most applicable to the following conditions:

- ***Exposed soil:*** The plants must have soil to grow in. For most grass varieties, this soil should not be very hard or rocky.
- ***Adequate water:*** Plants require water to grow, so vegetative erosion prevention must be applied where the plants will get water. Because this method will be used around greywater channels, water will usually be readily available for the plants.
- ***Protection:*** To ensure that the plants can thrive where they are planted, they must be protected from strong chemicals that could kill or weaken them, and from excessive trampling by people or vehicles.

With these conditions in mind, vegetative stabilization can be used in location including the following:

- On exposed banks along most greywater channels
- In exposed yards (to prevent general erosion; if the plants can get sufficent water)

- Around taps or ablution blocks

Vegetative stabilization may not be applicable to the following locations:

- Over pathways or roads
- At sites where significant amounts of toxic materials may be dumped with greywater

Pros and Cons

Pros:

- Cheap to implement
- Grass readily available around the settlement
- Grass encourages water evaporation, reducing stormwater runoff
- Easy to maintain once grass has become established
- Self-repairing

Cons:

- Takes time for grass to spread and take root
- Requires regular maintenance until the grass is established
- Some types of grass may be aggressive and require regular trimming
- May be difficult to implement at certain times of the year, when grass does not grow quickly

Necessary Tools and Materials

1. Grass or grass seeds
2. Spades
3. Picks if ground is hard or rocky
4. Fertilizer or mulch (optional)

How to Implement

1. Choosing a Species of Grass

Several factors should be considered when choosing a grass species. They include the following considerations, which should be consulted when determining the best grass species for vegetative stabilization:

- ***Depth and density of root system:*** Deep roots are desirable because they anchor the grass firmly in the ground and allow it to reach water and nutrients deep underground. Both of these advantages help the plant to thrive long-term under harsh conditions, even on steep slopes. Deep roots also help the plant to hold itself and the soil underneath it down, preventing erosion most effectively. Dense root systems are desirable because they hold the soil very firmly, making it very hard for soil to be eroded from between the roots.
- ***Native or Non-native:*** In general, it is advisable to use native plants for erosion prevention. Because native plants are generally most fully adapted to the present conditions, they tend to require the least maintenance, and they are the most likely to firmly take root and thrive. Non-native plants may require additional maintenance, including fertilizing, which can raise the cost of the vegetative stabilization process.
- ***Invasiveness:*** Planting grass for erosion prevention carries with it the responsibility of keeping the grass under control. Some species of grass grow very aggressively, and have the potential to grow into people's shacks, sometimes damaging the structures. Such grasses are useful for quick-growing

vegetative stabilization, but they must be monitored and tended to, in order to prevent runaway invasive growth.

2. Planting

Once a species has been chosen, a method for planting must be determined. There are two main options for planting: transplanting and seeding. They are each described below.

Transplanting

Transplanting takes mature plants growing in one area and replants them in another. The process for transplanting is as follows:

1. First, the grass must be dug up, roots and all, from an area where the desired type of grass is growing. Special care should be taken so as to keep as much of the root system as possible intact. Damaging the root system can compromise the ability of the plant to adapt to its new location. It is also possible to use sod, for transplanting. This option allows complete coverage to be attained very quickly, but it costs much more than transplanting wild-growing grasses, and it usually requires non-native vegetation to be used.
2. The plant must then be replanted where erosion prevention is required, e.g., along a greywater channel. Dig a hole about the size of the ball of roots on the transplanted grass. Put the roots deep into the ground, if possible, and pack the dirt lightly around the roots. Loosen the topsoil near the transplanted grass so it can spread more easily, and water the plant after replanting to cause the soil to settle around the roots. If the soil where the grass is replanted seems overly sandy, it may be helpful to mix mulch or some kind of fertilizer into it when planting the grass, so as to ensure that there are sufficient nutrients for the grass to grow. This may be especially important if the plant is not native to the settlement.
3. To encourage the grass to grow into a solid mat that will effectively hold the soil in place, water it regularly until it has spread to mostly cover the surface. Different grasses will spread at different rates. Slow-spreading grasses may require a larger amount of grass to be initially transplanted.

Pros of Transplanting

- Can be applied to steep-sloped areas
- Plants are free when transplanted from in or around the settlement
- Relatively short time until erosion protection is working

Cons of Transplanting

- Sometimes requires fertilization

Seeding

Seeding uses grass seeds rather than mature plants to start the protective vegetation growth.

1. First, loosen the soil where the seeds are to be planted. Non-native species may need fertilizer as well to encourage proper growth
2. Spread seeds over the area and pat them down into the ground and water lightly.
3. Keep the seeded ground moist for the next few weeks. Mulch can help retain moisture if it is spread over the ground surface.

Pros of Seeding

- Can give more complete coverage than transplanting
- Relatively labor un-intensive

Cons of Seeding

- May require fertilization and mulching
- Cost of seeds
- Many readily-available grass seeds may not be species suitable to informal settlement conditions
- Seeds can easily be washed away if applied on a steep slope

Cost Considerations

This is a low-cost intervention, if the grass can be obtained from around the settlement. Tools can be borrowed from residents or organisations. If sod, seeds, or fertilizers are required, this intervention can be moderately expensive.

Maintenance

Until the grass takes root firmly and becomes established in the soil, the transplants or seeds should be watered regularly - the ground should be kept relatively moist. Inspect the grass at least once or twice a week to ensure that it is growing properly. Reseeding or additional transplanting may be necessary if the grass is not growing well.

After it has matured or established itself, the grass should be trimmed if it grows beyond the desired area. Most native grass species will not require regular watering beyond what is naturally received via rainfall. It may be necessary to occasionally remove trash that becomes caught in the grass.

Recommendations for Langrug

Applicability for Langrug: Widely Applicable

To minimize costs, it is recommended that transplanted grass be used for erosion control in Langrug. One viable type of grass prevalent in Langrug is kikuyu grass (Pennisetum clandestinum). This grass has many characteristics desirable for erosion control. (Informed Farmers, 2010) Namely:

- Very persistent
- Spreads very quickly
- Survives well in dry periods
- Forms a dense mat, holding sand in place
- Has deep roots (sometimes deeper than 3 metres), allowing it to hold banks together very firmly

Kikuyu grass does, however, have some issues that must be considered if it is to be applied as a grass for erosion prevention. These are watering and invasiveness. Kikuyu grass thrives most well in areas with at least 50% more annual rainfall than Franschhoek typically receives.(Informed Farmers, 2010)(World Weather and Climate Information, 2011) Good growth can be expected during the winter months, when the grass will receive ample water. However, regular watering may be necessary during the summer, especially right after the grass has been planted.

Additionally, kikuyu grass is an aggressive species, and it has been known to grow up into shacks when left uncontrolled. For this reason, it may be necessary to trim kikuyu grass beds when they grow past the desired area. This will most likely be especially important during the winter, when rain encourages more rapid growth.

Figure 46: Kikuyu grass in Langrug

Other varieties of grass are also available in Langrug, and they should be examined according to the criteria of root system, origin, and aggressiveness, to determine suitability for use in a given area. A preliminary analysis of the advantages and disadvantages of kikuyu grass versus a species of seeded grass identified by Kholekile is illustrated below:

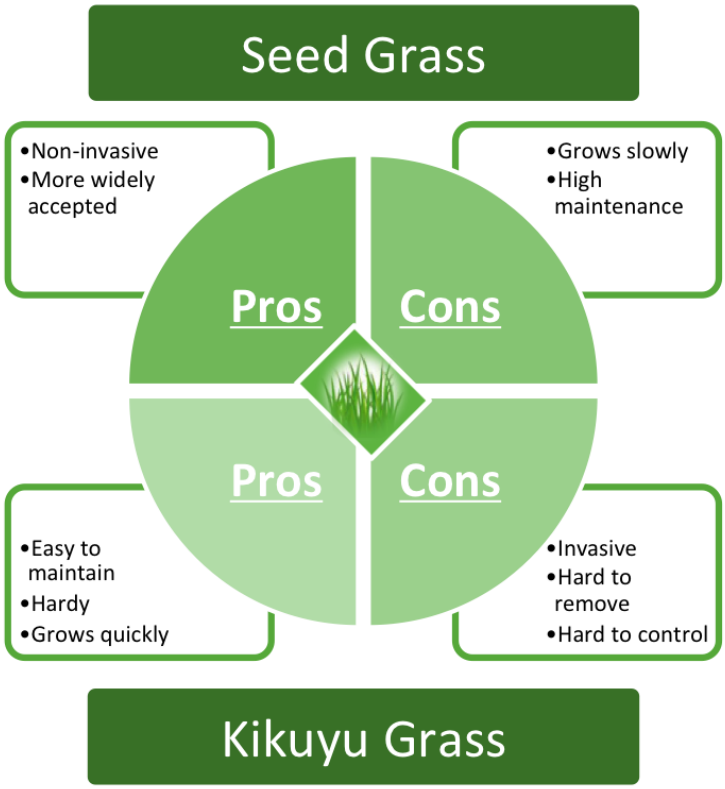


Figure 47: Comparison of kikuyu grass with a less agressive species

E-2. Mulch

Description

Mulch is small pieces of plant matter such as soft shredded wood, bark, or straw. It is laid over the ground to maintain moisture and temperature in the soil. It has also been found to be effective in erosion prevention.

Figure 48: Mulch on a hillside with some vegetation

(Main Street Materials, 2010)

Ideal Location

Mulch is most applicable for the following conditions:

- ***Shallow slope:*** Although it prevents soil erosion by rain and slow-flowing water, mulch is easily carried away by fast flowing water, so it is not effective on steep slopes or in areas where large volumes of water flow. If supplemented by vegetation, mulch can be used on slightly steeper slopes, assuming that the plant roots spread enough through the mulch to hold it in place. In general, mulching does not work well on slopes steeper than 1:3.
- ***Small water flow volume:*** Mulch is effective at encouraging infiltration and slowing water velocity to prevent the soil beneath from eroding. However, the mulch itself is prone to erode away if it is subjected to large volumes of water, and/or high-velocity flows.
- ***Vegetation:*** Mulch and vegetation complement each other well, with the mulch encouraging plant growth while the vegetation helps to keep the mulch in place in the event of high-volume or high-velocity flows

Based on these conditions, we see that locations where mulch is a viable option include the following:

- Mildly-sloping banks along a greywater channel
- Other areas with mild slopes where vegetation is desired

Pros and Cons

Pros:

- Easy to implement
- Encourages plant growth, especially in early stages of growth
- Slows water flow and protects soil from erosion by rain
- Can improve infiltration

Cons:

- Generally high cost
- Cannot be used on steep slopes
- Cannot deal with large volumes of water or high-velocity flows

Necessary Tools and Materials

- Mulch
- Spades
- Possibly Pick (if ground is especially hard)
- Seeds or plants (if using mulch together with vegetation)

How to Implement

1. Loosen the soil

To encourage the mulch to partially mix into the soil and anchor itself in the soil, loosen the soil where the mulch will be laid. Use the spades to loosen the topsoil, or use the pick if the ground is especially hard or full of rocks or plastic. This also encourages plant growth in the soil.

2. Plant vegetation (optional)

If the mulch is to be used in conjunction with plants such as grass, do planting before laying the mulch. Seeding can be done over the loosened ground before covering the ground with mulch to let the mulch insulate the seeds, encouraging growth and preventing them from being carried away by water.

3. Lay mulch

Lay down the mulch over the loosened ground. Dampen it with water and stamp it down to help it settle.

Cost Considerations

Low to moderate cost for the mulch and (optional) seeds.

Maintenance

Inspect the mulch at least once a week until the vegetation has become established. Check after heavy rains to see if mulch has been carried away. If so, replace mulch.

Recommendations for Langrug

Applicability for Langrug: Applicable in Limited Cases

We expect mulching to have only limited applicability in Langrug because it does not hold up well under high-volume, high-speed water flow, and it cannot be used on steep slopes. Because Langrug's ground is mostly steep slopes, and because the settlement experiences heavy rain in the winter, it might not be reasonable to use mulch for erosion control there. If used in conjunction with vegetation, mulching would be better suited to Langrug's conditions.

E-3. Blankets and Mats

Description

This method uses mats or blankets laid over the ground and held in place by rocks and/or soil and/or pegs. The mats hold the soil down and prevent the water from flowing directly over the ground. This reduces the erosion caused by the water. Mats and blankets also prevent wind from blowing sand away.

Figure 49: Blankets laid over the ground by a channel in Langrug

Ideal Location

Blankets do not require very special conditions, except for ground that will allow them to be firmly held down (usually by pegs). This means that blankets and mats are best for firm ground that is not very rocky. Rockless ground is easier to put pegs into, and firm ground will hold the pegs more tightly.

Pros and Cons

Pros:

- Easy to implement
- Instantly effective once implemented
- Low maintenance
- Cheap
- Can be used even on steep slopes

Cons:

- Cloth can rip, in which case the mat or blanket must be mended or replaced

Necessary Tools and Materials

- Blankets or shade cloth
- Rake
- Pegs or rocks
- Pieces of a thin, flat, weather-resistant material (wood or sheet metal)

How to Implement

1. Level the ground

For the blanket or mat to work most effectively, it should fit tightly over the ground. This will prevent the soil from shifting beneath the blanket. Therefore, the ground should not be bumpy or have indentations or holes in it. Use a rake to smooth the ground where the mat will be placed.

2. Stretch the cloth over the ground and affix it

Once the ground is smooth, the cloth can be stretched over the ground. It must be held firmly in place. If the ground is not steeply sloped, it might be enough to hold the cloth down using rocks. For steeper slopes, use pegs. The pegs should be long enough that they will not become loose. For compacted soil, use pegs 15 centimetres long or longer. Use pegs of at least 20 centimetres for soil that is somewhat hard, but crumbly. For loose and sandy soil, use pegs that are 25 centimetres long or longer. To make sure that the cloth does not easily rip through the pegs, pound the pegs into the ground no more than 30 centimetres apart, through a piece of flat material placed over the cloth, as seen in Figure 50.

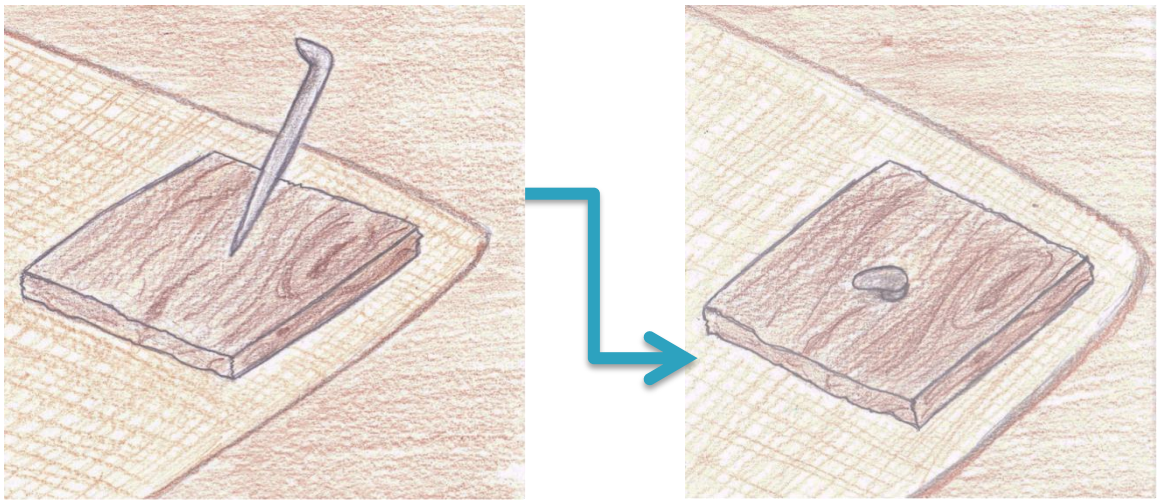


Figure 50: Using a peg and wood to affix a blanket

Pegs should also be inserted about every 1.5m through the centers of the blankets to hold the cloth firmly in place. It may also be necessary to bury the upper end of the blanket to keep it firmly in place. This method involves digging a trench (around 15 centimetres deep and 15m wide)

along the top of the slope where the mat will be placed. The mat is then fitted into the trench, and the trench is filled with soil, and optionally rocks, to hold the mat in place. Burying can reduce the number of pegs required to hold the blankets in place.

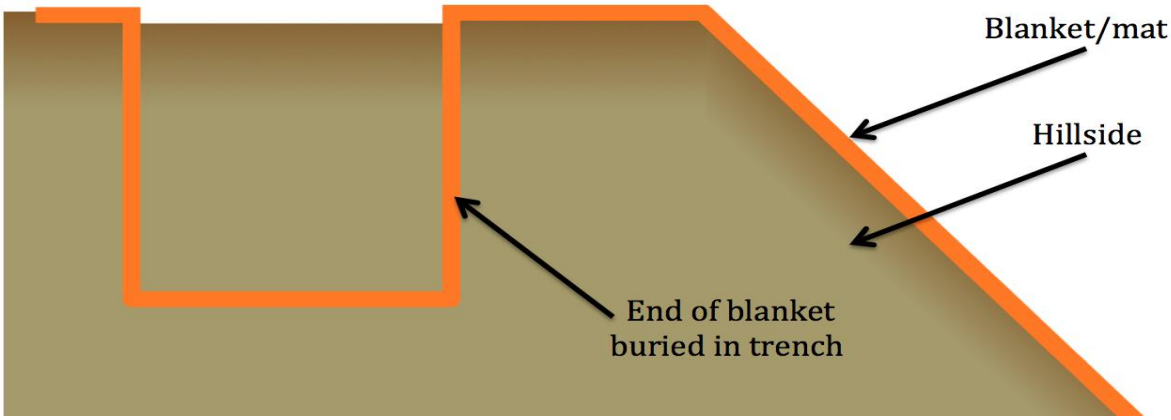


Figure 51: Burying the upper end of the blanket

In the event that multiple blankets must be used to cover the slope, the blankets should overlap by at least 15 centimetres where they join. The joint should be secured with pegs spaced no more than 1 metre apart.

Cost Considerations

If old blankets, pegs, and wood can be gathered from refuse in the settlement, this intervention can be very low cost, if not free. However, these things might not always be available, in which case materials would have to be purchased. Even if they were to be purchase, this could still be a relatively low cost intervention on a small scale.

Maintenance

Monitor the blanket or mat, checking for damage periodically. In most cases, once or twice a month should be enough. Especially check after heavy rains to ensure that the cloth is still fully in place. If the pegs become loose, it may be necessary to replace them with longer pegs. If the cloth develops rips, repair as soon as possible.

Recommendations for Langrug

Applicability for Langrug: Applicable

This method is applicable for Langrug, and can be implemented easily using old blankets or shade cloth. Pegs can be salvaged or bought, depending on availability. Some residents of Langrug have already begun using this method to prevent erosion near their homes, although the blankets used are generally not affixed with pegs. This is fine for the shallow slopes where this intervention is now most commonly seen, but pegs or stones will be required (sometimes with burying will be necessary as well) to hold cloth in place for steeper slopes, especially along new greywater and stormwater channels.

E-4. Sediment Basins

Description

Sediment traps are areas where water is forced to slow down and pool before entering a pipe or other drainage structure. By slowing the water down, sediment traps allow soil in the water to settle to the bottom of the pool. This way, much of the sand in the water is prevented from entering the drain. As a result, there is less sedimentation in the drain itself.

Most sediment traps are either in the form of basins, which cover a large area, or smaller but deep pots (gully pots). The sedimentation basin is a small pond dug out with an inlet for the sediment-laden water at one end and an outlet for the cleaned water at the other. A gully pot is a smaller, deeper pool which can be acquired as pre-made cement pots, or can be built in situ in an informal settlement context. Methods for construction are discussed further in the implementation section.

Figure 52: A typical sedimentation basin (left) and gully pot (right)

(St. Mary's Soil Conservation District, 2011);(CPM Group Ltd.)

Ideal Location

Sediment traps are best used in the following conditions:

- ***Directly before a pipe:*** Because sediment traps are designed to remove sediment from the flow, they are most useful for preventing sedimentation from occurring in places that are hard to clean, such as pipes. Putting a sediment trap right before a pipe can keep the pipe from becoming clogged with silt and sand, reducing the need for cleaning.
- ***Clean water streams:*** Because they inherently involve pooling, sediment traps are not the ideal option for dirty grey water streams, unless if there is a steady flow of relatively high volume, such that the pooled water is constantly being replaced and pushed out of the pool.

To prevent the growth of bacteria in the pooled water, the incoming water must be clean of food particles and grease before it comes to the sediment trap.

Based on these conditions, we see that locations where mulch is a viable option include the following:

- At the inlet to a stormwater drain (e.g., the drains by the relocated shacks in Langrug's J-section) *if* the stream can be controlled so as to be clean enough that pooling is safe.
- At the inlet to a drain or pipe in a seasonal stormwater stream *not* used for greywater.

Pros and Cons

Pros:

- Helps prevent sedimentation in pipes
- Easy to construct

Cons:

- Medium space requirement
- Involves pooling – cannot be used with raw greywater streams
    - Requires continuous flow it incoming water is contaminated
- Requires regular cleaning, especially after heavy rain
- Cost of cement
- Labour-intensive implementation

Necessary Tools and Materials

- Picks
- Spades
- Rocks
- Cement (for gully pot, especially)

How to Implement

1. Dig the basin

First, dig out the basin using the picks and spades. A basin will be about a metre deep and 10 metres square. Because this takes a large amount of space, it may be more feasible in informal settlements to construct a simplified gully pot type basin, as shown below.

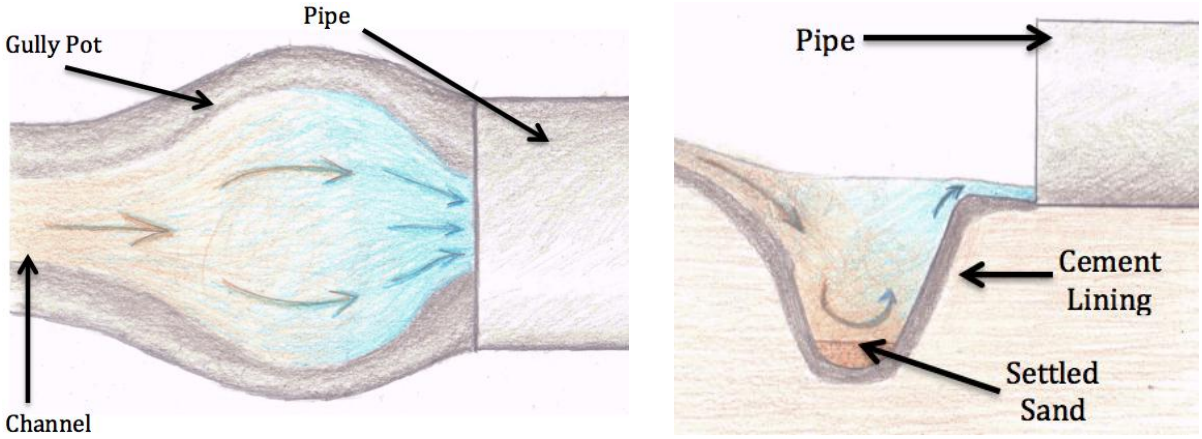


Figure 53: Simplified gully pot design from top (left) and side (cross-section) (right)

The simplified gully pot will first require that a round hole about 1-1.5 metres deep and 1 metre in diameter be dug about 30 centimetres ahead of the pipe. The sides of the hole should be sloped very steeply (around 60-90 degrees). The hole should have an outlet channel leading to the pipe and an inlet channel that starts narrow and widens up to the diameter of the hole as it enters. The inlet channel should empty into the hole at a depth of about 30 centimetres and the outlet should begin at a depth of about 20 centimetres (see Figure 53).

2. Line with rocks

If making a sediment basin (pond type), optionally line it with rocks. For a gully pot, line with rocks and cement. Try to make cement as smooth as possible so sediment can be removed from the pot easily using spades.

Cost Considerations

This is a low to moderate cost intervention, since it requires cement. Small gully pots can be implemented using a limited amount of cement.

Maintenance

Inspect at least once a month to monitor sediment deposits. Remove sediment when basin or gully pot is 1/3 or 1/2 full. Place removed sediment where it will not re-erode back into the basin.

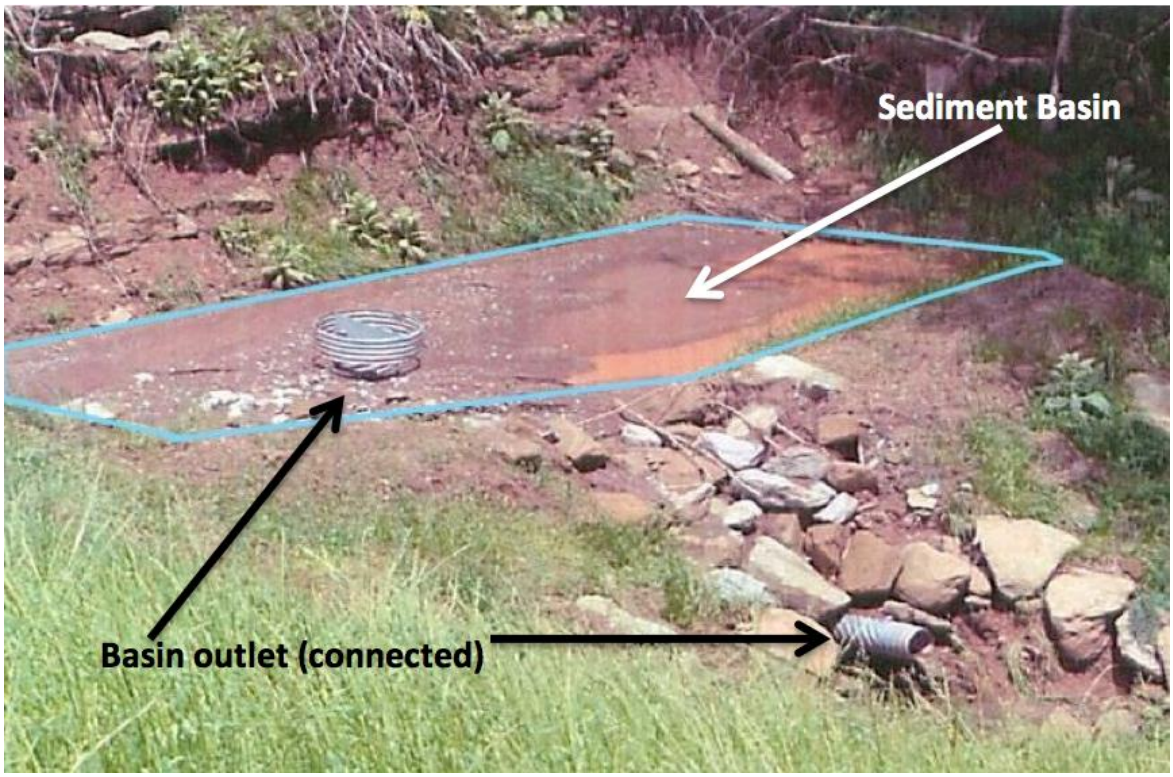


Figure 54: A sediment basin filled with sediment. Basins must be cleaned out before they reach this level of sedimentation

(The Charleston Gazette, 2010)

Recommendations for Langrug

Applicability for Langrug: Not Applicable

We do not recommend sediment basins for Langrug because most of the pooling that is involved in the operation of this intervention. The water streams in Langrug are nearly all contaminated with food waste, and sometimes contain small amounts of blackwater. As a result, pooling must be avoided. Rather than remove sediment by pooling, it will be necessary to try to keep water moving so sediment is less likely to be deposited in large amounts.

E-5. Channel Base Extension

Description

This intervention involves extending the channel base (rocks, cement, or vegetation) along the sides of the channel so as to cover the sand and prevent it from eroding into the channel. The result will be vegetative stabilization if the original channel is vegetated, or a rock/cement retaining wall lying over the channel walls, if the original channel was a rock/cement channel.

Figure 55: Cement channel base extended up the channel walls to prevent erosion

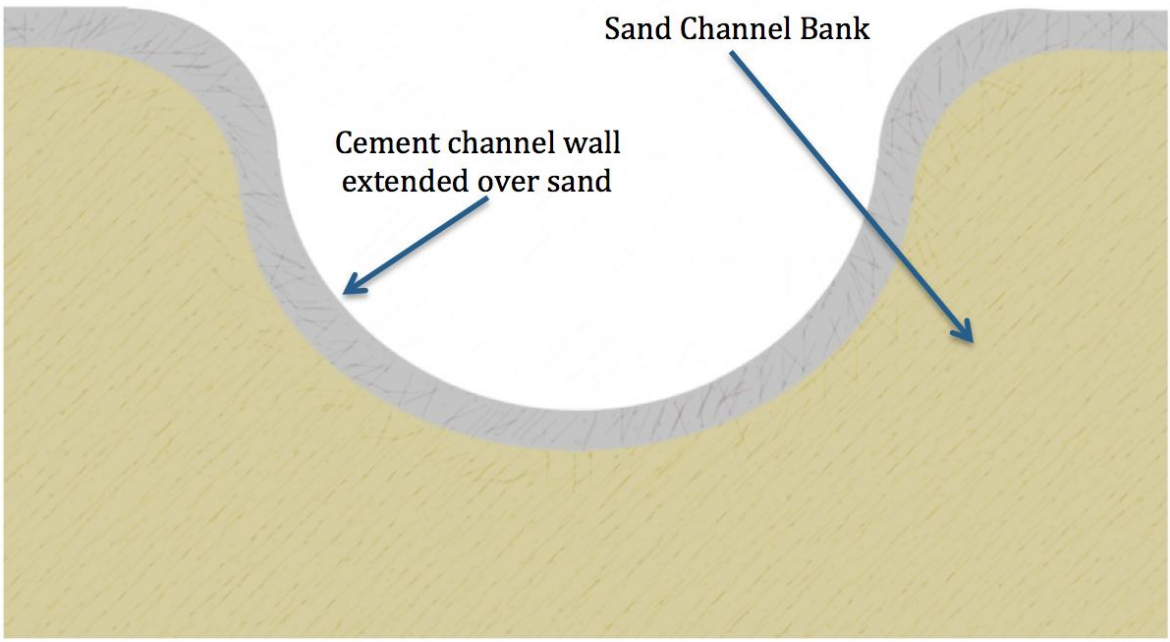


Figure 56: Cross-sectional schematic of extended channel walls

Ideal Location

Channel base extension can generally be applied wherever the corresponding channel can be applied. It is, however, necessary to consider foot traffic and vehicle traffic along the channel. The extended base must be strong enough to withstand the traffic. More specifically, vegetation used must be able to survive the trampling, or cement must be strong enough to resist cracking.

Pros and Cons

Pros:

- Can be easily implemented along with the channel
- Very effective at preventing erosion

Cons:

- Requires more materials when building channel
- Should usually be implemented together with channel – can be hard to retrofit

Necessary Tools and Materials

- Same as for corresponding channel

How to Implement

1. Extend channel walls

Using whatever materials were being use for the base of the channel, extend the base along the banks of the channel, covering the banks so as to prevent erosion.

Cost Considerations

Consult the costs for the type of channel to which this intervention will be applied.

Maintenance

Maintain as the corresponding channel is maintained.

Recommendations for Langrug

Applicability for Langrug: Widely Applicable

Channel base extensions will be applicable for most channels, assuming the banks are of reasonable size (not so large that material requirements would be prohibitive) and the method used for the channel base can be applied for the banks as well (without problems with cement cracking under traffic or vegetation invading nearby shacks).

E-6. Retaining Walls

Description

Retaining walls are walls built along a slope or at the bottom of a slope in order to hold the sand in place and prevent it from eroding away. They may be made of wood, rock, or blocks.

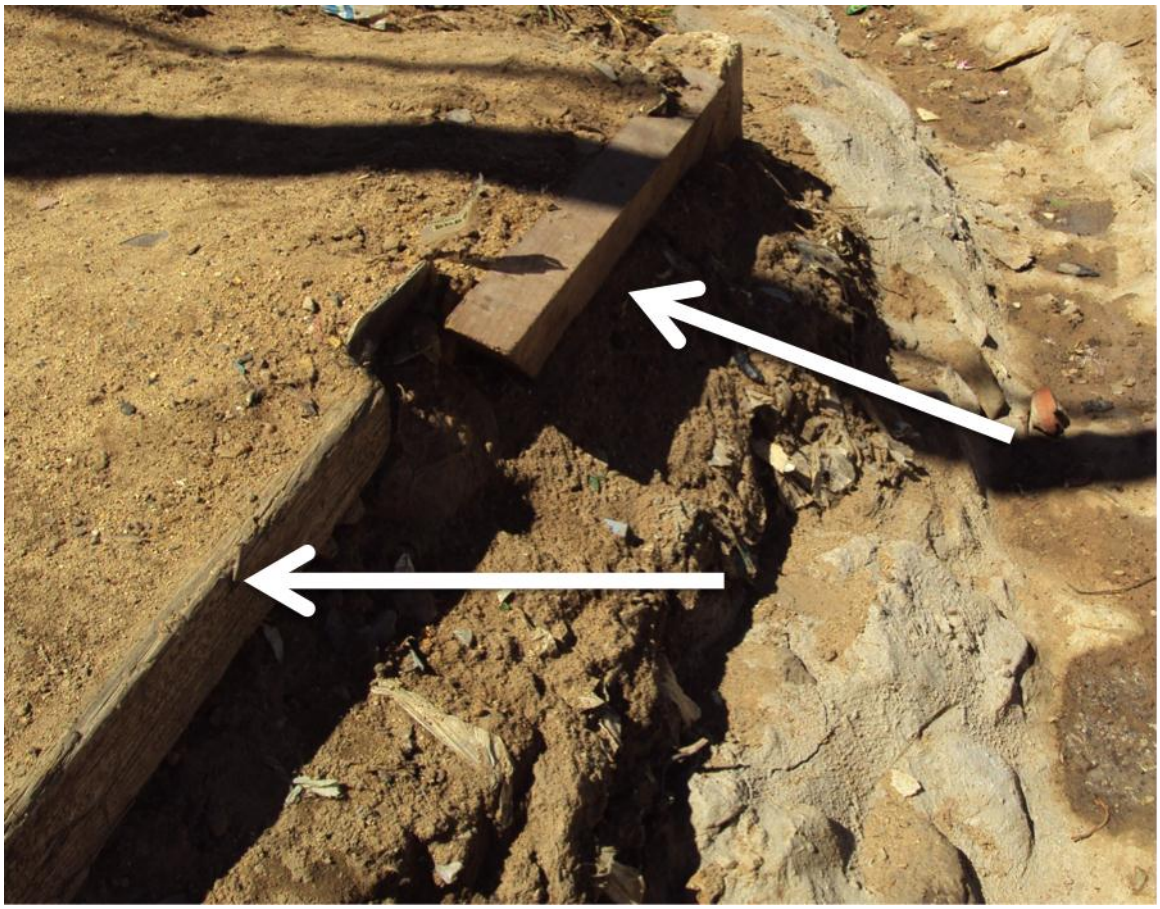


Figure 57: Wood planks used as retaining walls in Langrug

Ideal Location

Retaining walls can be built wherever there is:

- A steep slope where erosion must be prevented
- Sufficiently stable ground to support the wall
- A means of securing the wall so it will not be knocked loose or knocked over in heavy water flow (especially important for lighter wooden walls)

Pros and Cons

Pros

- Very low maintenance if wall is properly built and secured
- On a small scale, can be implemented very easily with available materials
- Very effective, even for very steep slopes

Cons

- If blocks are used, can be somewhat expensive

Necessary Tools and Materials

1. Spades
2. Wall material (choose one option)
    a. Wood and stakes
    b. Sheet metal and stakes
    c. Rocks
    d. Blocks and cement

How to Implement

1. Level the ground for the wall base

For the wall to be stable, it will be helpful to level the ground where the wall will be built. Use the spades to do so. Making an indentation where the wall will fit into the ground will increase its stability.

2. Build the wall

Build the retaining wall using the material(s) chosen, at least until it is level with the sand behind it, which it will be holding in place.

3. Secure the wall

Fill in behind the wall with sand. Secure the wall with stakes on the downhill side, especially if it is made of wooden planks.

Figure 58: A cement block retaining wall in Langrug

Cost Considerations

Retaining walls can be built using whatever materials are available, such as wood, rocks, or metal sheets. When salvaged materials such as these are used, the retaining wall can be built at little or no cost. If, however, a block wall is to be built, the blocks and mortar will need to be purchased, which can be fairly expensive.

Figure 59: Metal (left) and concrete slab (right) retaining wall in Langrug, both using stakes to hold the wall in place

Figure 60: A retaining wall in Langrug, made of salvaged rocks

Maintenance

Once built, retaining wall need no maintenance, unless if they break or are knocked over. Take care when building the wall to secure it well and make it sturdy, and there will be no need for maintenance for a long time.

Recommendations for Langrug

Applicability for Langrug: Widely Applicable

Retaining walls can be applied in many situations in Langrug. They can be implemented easily, even by individuals using low-cost (or even free) materials, and they are very low maintenance if well-constructed. They should be effective even for Langrug's steep, sandy slopes.

In fact, retaining walls of various types are already widely used throughout Langrug, and many of these walls are built by individual community members. This attests to the ease with which retaining walls can be implemented.

E-7. Tyres

(Button, Jeyaraj, Ma, & Muniz, 2010)

Description

Tyres can be used to help hold sandy ground in place and prevent it from shifting or being eroded away. The tyres are buried in the sand so that they act like a wall against sand erosion. This intervention is useful for preventing erosion in general in the settlement, and can be used for erosion prevention along channels if there is enough level ground beside the channel for the tyres to be buried.

Figure 61: Buried tyres in Monwabisi Park, Khayelitsha - used for ground stabilization

(Button, Jeyaraj, Ma, & Muniz, 2010)

Ideal Location

- ***Little slope:*** Tyres can be most easily placed in level or mildly-sloped ground. However, they can be used to form retaining walls for steep-sloped areas if they are carefully stacked on top of each other.
- ***Sandy ground:*** Tyres work well with most types of soil, but their retaining benefits are used the best in sandy ground. The tyres hold the sand in place, and when they are filled with sand, they are heavy enough to prevent the sand upstream from washing past them.

Based on this, we see that buried tyres are applicable for places such as the following

- In sand around buildings to prevent erosion from under foundations
- Along channels where a sturdy bank is required – for example when there is a lot of traffic along the channel

Pros and Cons

Pros

- Old tyres can be obtained cheaply
- Simple to implement
- Effective over long period of time

Cons

- Can lead to uneven ground surface

Necessary Tools and Materials

- Spades
- Tyres

How to Implement

1. Dig a trench

Dig a trench where the tires are to go. Make the trench just deep enough that the tyres will be nearly covered with sand when in place.

2. Place tyres in trench and fill with sand

Put the tyres into the trench. Line them up so each tyre touches the adjacent tyres, and there is no room for sand to slip between the tyres. When the tyres are in place, completely fill the inner cavity of each tyre with sand.

3. Stack tyres (optional)

If a higher wall of tyres is needed, stack another row of tyres on top of the previous one. Layer the tyres so as to create a wall that slopes back, rather than a straight vertical wall. This will reduce the chance of collapse.

Cost Table

If old, thrown-out tyres can be acquired, this intervention can be implemented at little to no cost.

Maintenance

Check the tyres once or twice a month to ensure that they are still properly in place. This is particularly important for stacked tyre walls, which could collapse if tyres in the base shift out of place.

Recommendations for Langrug

Applicability for Langrug: Widely Applicable

Tyres can be a great help for erosion reduction in Langrug. They are quite useful for stabilizing the kind of sandy soil found in Langrug. Some residents of Langrug have already used tyres in parts of the settlement, as seen below.

Figure 62: Buried tyres in Langrug

Appendix A: Works Cited

Infiltration Trenches. (2007, May 23). Retrieved December 11, 2011, from Sustainable Stormwater Management: http://sustainablestormwater.org/2007/05/23/infiltration-trenches/

Sand Filters. (2011). Retrieved December 12, 2011, from City of Sandy: http://www.ci.sandy.or.us/index.asp?Type=B_BASIC&SEC=%7BA9D3CDDE-3BA0-42DE-BE30-4E321A155AA8%7D&DE=%7B40CA8091-277E-4F97-81D4-671A67CD701F%7D

Barr Engineering Company. (2001, July). *Urban Small Sites Best Management Practice Manual.* Retrieved December 1, 2011, from Metropolitan Council - Environmental Services: http://www.metrocouncil.org/environment/water/bmp/manual.htm

Bolnick, A. (2010). *Informal Settlement Upgrading*. (MyGuru Website Designers) Retrieved November 19, 2011, from landFIRST: http://landfirst.org.za/index.php?option=com_content&view=article&id=103:informal-settlement-upgrading&catid=19:articles&Itemid=63

Bouchard, B., Goncalo, A., Susienka, M., & Wilson, K. (2007). *Improving Flood Risk Management in Informal Settlements in Cape Town.* Worcester: Worcester Polytechnic Institute.

Button, K., Jeyaraj, E., Ma, R., & Muniz, E. (2010). *Stormwater Management in Monwabisi Park: C Section.* Worcester Polytechnic Institute, Interdisciplinary and Global Studies Division. Worcester, MA: Worcester Polytechnic Institute.

CPM Group Ltd. (n.d.). *Gully Pots*. Retrieved December 10, 2011, from Bespoke Precast & Concrete Products: http://www.cpm-group.com/drainage/gully-pots.php

Informed Farmers. (2010, November 29). *Kikuyu*. Retrieved December 2, 2011, from Informed Farmers: http://informedfarmers.com/kikuyu

Kuh, D. (2009). *AILA's landscape architechture occasional papers, articles and essays*. Retrieved December 11, 2011, from Austrailian Institute of Landscape Architects (AILA): http://www.aila.org.au/lapapers/papers/syrnix-perth/default.htm

Main Street Materials. (2010). *Erosion Control*. Retrieved December 4, 2011, from Main Street Materials : http://www.mainstreetmaterials.com/products/rm/erosioncontrol.html

National Agroforestry Center. (n.d.). *3.4 Grassed Waterways*. Retrieved December 11, 2011, from USDA National Agroforestry Center: http://www.unl.edu/nac/bufferguidelines/guidelines/3_productive_soils/4.html

O'Malley, P. (1994). *O'Malley the heart of Hope*. Retrieved November 20, 2011, from The Nelson Mandela Centre of Memory: http://www.nelsonmandela.org/omalley/index.php/site/q/03lv02039/04lv02103/05lv02120/06lv02126.htm

River Engineering and Urban Drainage Research Centre. (n.d.). *The Hydraulic Resistance and Stability of Vegetation in Swale*. Retrieved December 11, 2011, from River Engineering and Urban Drainage Research Centre - USM: http://redac.eng.usm.my/html/projects/HydraResist/Index.html

St. Mary's Soil Conservation District. (2011). *Photo Gallery*. Retrieved December 10, 2011, from St. Mary's Soil Conservation District: http://stmarysscd.com/Photo.htm

Tensar International Limited. (2010). *Erosion Control of Channels*. Retrieved December 2, 2011, from Tensar UK: http://www.tensar.co.uk/Applications/Erosion-control/Erosion-Control-of-Channels

The Charleston Gazette. (2010, May 26). *Archive for May, 2010*. Retrieved December 11, 2011, from Sustained Outrage: A Gazette Watchdog blog: http://blogs.wvgazette.com/watchdog/2010/05/

Winter, K., Armitage, N., spiegel, A., Carden, K., Kruger, L., Mnggibisa, N., et al. (2008). *Let's Fix It: Managing Greywater in Shanty Settlements, South Africa.* South Africa: New Zealand Society for Sustainability Science and Engineering.

World Health Organization. (2006). Overview of greywater management Health considerations. *regional consultation on national priorities and plans of action on managment and reuse of water.* Amman: World Health Organization.

World Weather and Climate Information. (2011). *Average rainfall in Franschhoek, South Africa*. Retrieved December 2, 2011, from World Weather and Cimate Information: http://www.weather-and-climate.com/average-monthly-precipitation-Rainfall,franschhoek,South-Africa

Appdendix B: Process Evaluation Form

Location:

Greywater Management Techniques Implemented:

Date of Completion:

General Questions:

---

1. Did community members participate in most, if not all, steps of the process?

   No ☐ **Yes** ☐ If yes, how many participated? _____

   If no, what reasons were given for not participating?

   -
   -
   -
   -
   -

2. Did the process of building the greywater management system go smoothly?

   No ☐ **Yes** ☐ If no, what was the problem?

3. (a) Was the community willing to try a greywater management system other than a stone and cement channel?

   No ☐ **Yes** ☐

   (b) If yes, what was it?

   Alternative technique: _____

   (c) Was it successful?

   No ☐ **Yes** ☐

(d) Was the community pleased with the outcome?

No ☐ **Yes** ☐

4. Did the community successfully implement the greywater management technique?

   No ☐ **Yes** ☐

1. (a) Should other factors be taken into consideration when choosing an area for upgrading?

No ☐ **Yes** ☐ If yes, what factors?

-
-
-

(b)Alternatively, should any of the existing factors be removed?

No ☐ **Yes** ☐ if yes, which?

-
-
-

Comments:

Step 2: Meeting with Community Members

1. (a) Are there any other important points that should be added in order to *influence community involvement*?

No ☐ **Yes** ☐ If yes, what points?

-
-
-

(b) Should any points be removed?

No ☐ **Yes** ☐ If yes, which?

-
-
-

2. Did the team refer back to and take into consideration the documented/catalogued attempts made by the community in other areas of the settlement when proposing possible systems for implementation?

No ☐ **Yes** ☐

If yes, was it helpful?

No ☐ **Yes** ☐

Comments:

1. Was it helpful to discuss all the considerations stated in the guidebook regarding the choosing of a design?

No ☐ **Yes** ☐

If no, why?

Which considerations should be removed, if any?

-
-
-

2. Would it be helpful to add any more criteria for choosing a design?

No ☐ **Yes** ☐ If yes, what should be added?

-
-
-

3. Would it be helpful to make a timeline and schedule to ensure that the system will be implemented and maintained?

No ☐ **Yes** ☐ If yes, how could it be made/designed so that community involvement will be guaranteed and the documents will be followed?

Comments:

1. Were any supplies or tools missing from the provided list in the ***Greywater Management Strategies*** (page 44) of the ***Guidebook Addresssing the Sustainable Upgrading of Grewater and Stormwater Management Systems*** detailing the necessary supplies for the system that was implemented?

No ☐ **Yes** ☐

If no, were there any supplies or tools listed that were not used/needed?

No ☐ **Yes** ☐

If yes, what was the technique being implemented?

_____

Supply or Tool	Amount

What tools were not necessary?

If yes, what was the technique being implemented?

_____

Supply or Tool	Amount

What tools were missing?

2. Did listing necessary supplies help you to prepare for gathering supplies and building?

No ☐ **Yes** ☐

If no, should it be removed from the process? Why or why not?

No ☐ **Yes** ☐

Comments:

1. Were the steps described in the "How to implement" section of the ***Greywater Management Strategies*** (page 44) of the ***Guidebook Addresssing the Sustainable Upgrading of Grewater and Stormwater Management Systems*** easy to follow and understand for the systems construction?

   No ☐ **Yes** ☐

   If no, which step was confusing and why?

   Step: Reasoning:

2. Were any problems experienced during the implementation of the design?

   No ☐ **Yes** ☐

   If yes, what were they and how could they be prevented?

   Problem: Prevention Method:

Comments:

Step 6: Analyse and Evaluate

1. How was the system analysed (check all that apply)?

   ☐ Written documentation?

   ☐ Photographic documentation?

   ☐ Other? (explain)

2. Were these methods effective in the evaluation of the system?

Method	**No**	**Yes**
Written	☐	☐
Photographic	☐	☐
Other: _____	☐	☐
Other: _____	☐	☐

   a. How could these methods be adjusted or improved?

Method	**Suggestions for Improvement**
Written	
Photographic	
Other: _____	
Other: _____	

b. Are there any other methods that you think could be helpful or more effective for evaluation the system?

No ☐ **Yes** ☐ If yes, what?

-
-
-

Comments:

Step 7: Determine if Implementation Needs to be Fixed

1. Was there a need to fix the system?

   No ☐ **Yes** ☐

   If yes, why did this occur? And, how was this problem resolved?

2. Could making a change in the way of implementing the system have prevented the problem from happening?

   No ☐ **Yes** ☐

   If yes, what should be changed and how would that change help prevent future incidents?

Comments:

NOTE: If anything in this document was not helpful or needs to be changes, feel free to do so.

Things to change:

Date:

Location:

Technique Implemented:

Appendix C: Greywater Intervention Evaluation Form

For the Greywater Team – Based on Observation and Interviews:

1. What were their findings?
   a. Was the system functional?

   No ☐ **Yes** ☐

   b. Were there any blockages?

   No ☐ **Yes** ☐

   If yes, what was blocking the system?

   ☐ **Sediment** ☐ **Trash** ☐ **Other:** _____

   Have community members tried fixing this?

   No ☐ **Yes** ☐

   If yes, how?

   c. Was erosion a problem?

   No ☐ **Yes** ☐

   If yes, does the community want the problem to be fixed?

   No ☐ **Yes** ☐

   If yes, what are their ideas?

☐ **Walls** ☐ **Vegetation**

☐ ☐

Blankets **Other:**

_____

d. Was food waste found in the system?

No ☐ **Yes** ☐

e. Was the system overflowing?

No ☐ **Yes** ☐

If yes, what was the cause?

☐ **Heavy Rains** ☐ **Blockages** ☐ **Other :** _____

2. Based on these results, does the community plan on improving the implemented system?

No ☐ **Yes** ☐

If yes, how?

Appendix D: Recommendations

Recommendations for the Co-Researchers:

- Continue work on implementing greywater management systems throughout Langrug
- Continue to revisit completed greywater management solutions to determine effectiveness and address any problems
- Try new greywater management techniques
    - Identify areas in Langrug that are appropriate for different techniques

      Using the techniques section of the guidebook and the manual, identify areas of Langrug where new greywater management solutions that haven't been attempted yet can be implemented as a test case. Some initial suggestions (with reference numbers from the manual) include:

      1. Vegetated channel
      2. Stone-only channel
      3. Oversized channel sections
      4. Soakaways
      5. Stormwater wetlands (initially test on a small scale for suitability)
      6. Dry swales

- Build a length of channel for testing and demonstration purposes
  Build a channel which will test and compare different channel types in one area

Try: vegetated, stone-only, stone and cement, and cement; implement a soaskaway at the channel head.

    - Analyze, evaluate, and document these experiments
        - Contribute findings to a reference database, such as the blog set up by the WPI students

          Use the blog to record experiences, both personal and technical. While capturing the technical what happened, problems encountered, what worked well, etc. is important, the personal/social aspects of informal settlement upgrading process are just as important – i.e. collaboration between neighbors.

    - Fill out the process documentation and evaluation form (supplied by the students) for each iteration of the process

      To ensure that the process is constantly improving and to adapt it to the conditions in Langrug, the documentation form supplied by the students should be filled out. Problems and their solutions should be carefully documented for future reference (so we don't make the same mistake twice) and any changes to the process, along with the reason why those changes were made, should be noted.

- Work with community members in sections of completed and ongoing upgrades to implement erosion control methods before the winter (rainy season)

In the winter/rainy season it's likely/possible that the implemented greywater management systems will be overwhelmed. If this happens and the channels flood, sand and soil will erode into the channel, clogging it, and increasing the chances that greywater and stormwater will overflow and potentially flood peoples' houses

- Work closely with the Langrug greywater co-researcher team, CORC/SDI, the municipality, and the WPI students (if needed)
- Document greywater in Langrug during the winter (rainy season) via:
    - Notes
        - Observations and interviews with community members
    - Mapping
    - Photographs
    - Pictures and drawings
- Translate the greywater techniques manual to isiXhosa

Recommendations for the Stellenbosch Municipality and its Department of Integrated Human Settlements:

- Plan trash/rubbish bin installation to coincide with greywater management implementation throughout Langrug
- Incorporate grey- and storm-water management into settlement upgrading plans
- Road sloping towards a central channel – see Manual, Infiltration trenches
    - Running sewage pipes by taps without drains and connecting a drain to the sewage system
- Assist with and teach co-researchers about technical aspects of greywater management
    - ex. allow co-researchers to work with engineers and learn from them about topics such as predicting runoff and calculating how tweak designs to compensate for the rainy winter season
- Be open to requests from co-researchers and assist them when needed
- Build strong relationships with the co-researchers
    - What is the role of senior field worker related to the role of the co-researchers

Recommendations for CORC/SDI and The Partnership:

- Support co-researchers in their work
    - Supply with necessary materials in a timely manner
    - Share with co-researchers pertinent technical and experiential information from other informal settlements around the world

      While this shared information will most likely relate to greywater and greywater management techniques, other information such as experience with related factors – such as erosion, maintenance, encouraging volunteering, collaboration, and ownership – would also be helpful.

- Provide co-researchers with technical support for blogging

  Look into whether or not co-researchers have internet access; if they don't and it proves necessary, work with them to find a solution.

- Assist co-researchers with preparing and submitting their routine reports to WPI/Scott
- Explore the social dynamic surrounding volunteering vs. employed EPWP workers

  Interview people as suggested in the ***Volunteerism vs. Employment*** section of the Guidebook