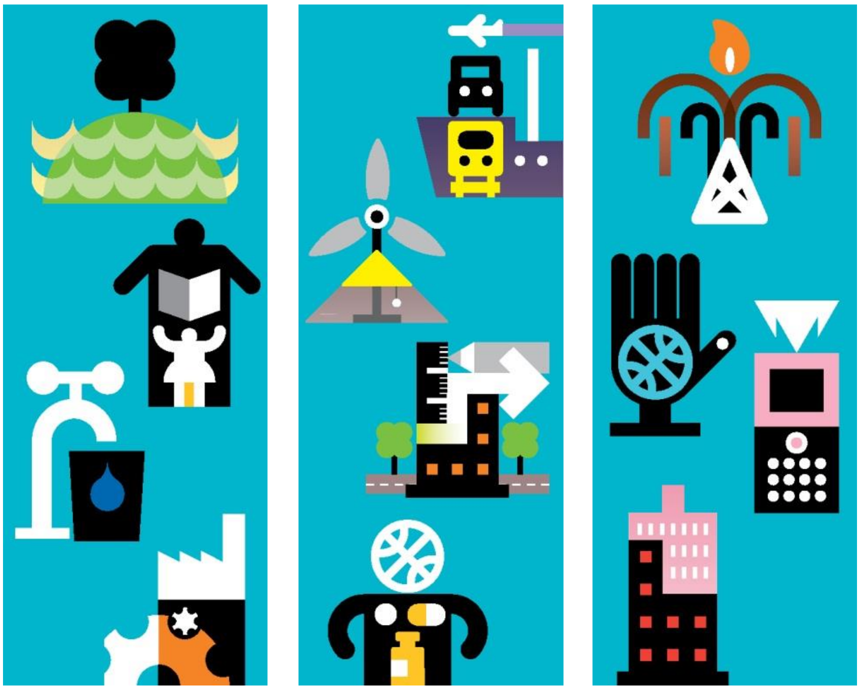

MISABID007 Stormwater Master Plan Draft Report

Prince Albert Local Municipality

December 2014

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Contents

1 Introduction

Prince Albert Local Municipality (PALM) currently does not possess a Stormwater Master Plan (SWMP). This report represents the first generation Stormwater Master Plan for the municipality. The plan will examine the current stormwater systems, planned stormwater related projects, future stormwater systems and propose a list of projects for each of the main settlements within PALM.

2 Terms of Reference& Scope of Works

2.1 Terms of Reference

Mott MacDonald PDNA was appointed by Prince Albert Local Municipality in terms of Contract MISABID007 to provide technical support and services in the development of stormwater master plan for PALM. The SWMP is to be developed for all towns in the municipality.

2.2 Scope of Works

No scope of works has been given and so it has been assumed that the following will issues will be addressed in the stormwater master plan:

- Consideration of environmental conservation,
- Current stormwater systems,
- Determination of the recurrence interval of the major flood event,
- Determination of the recurrence interval for the minor flood events,
- Run-off detention requirements,
- Pollution-abatements,
- Land use within flood plains and multi-use of stormwater facilities,
- Safety and maintenance,
- Planned stormwater projects,
- Future stormwater systems,
- List of projects and funding

The settlements or towns that will be discussed in this report are Prince Albert, Leeu Gamka and Klaarstroom.

2.3 Deliverables

The following deliverables will be given to the municipality:

- A stormwater master plan report document.
- Updated Asset Register
- Google Earth layouts

3 Background

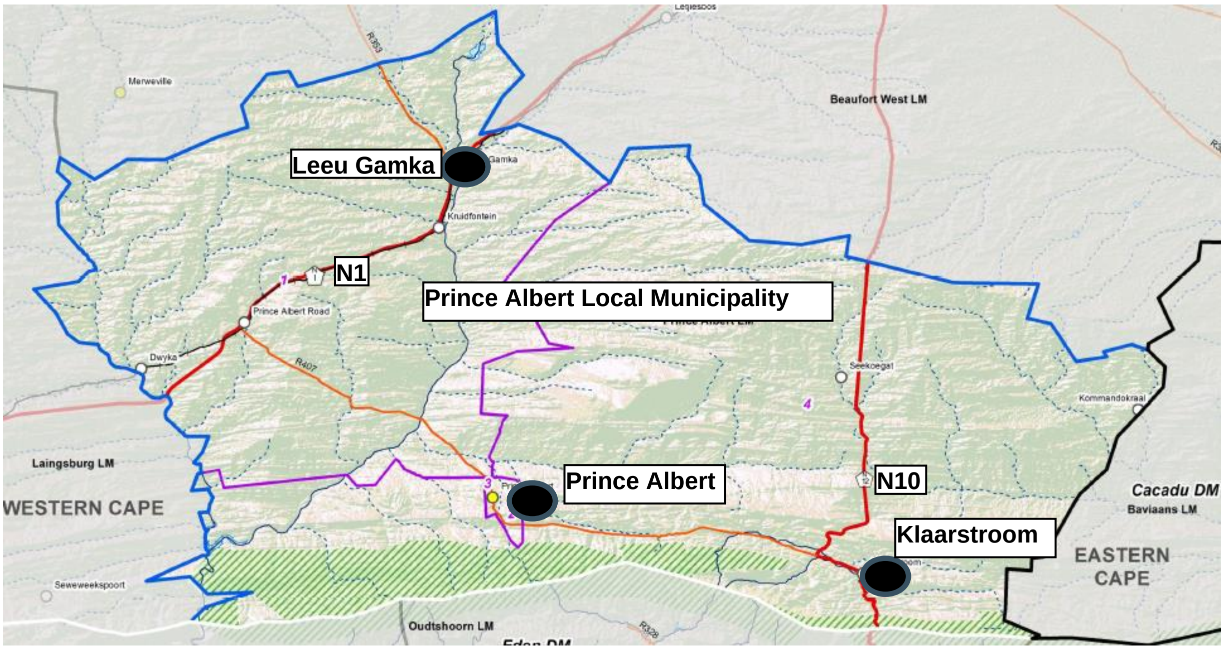
3.1 Prince Albert Local Municipality

3.1.1 Geography and Demographics

Prince Albert Local Municipality is part of the Central Karoo District in the Western Cape.The Swartberg mountain range inthe south of PALM spans approximately 230 km form Laingsburg in the west to Willowmore and Uniondale in the east (Aurecon, 2014).

PALM had an estimated population of 60482 in 2011 according to 2011 census data. It forms18.1% of the population in the Central Karoo District Municipality it accounts for 30.9% of the gross domestic product of the district. The major economic activities in PALM are agriculture and tourism. Main agricultural activities include olives, wine grapes and apricots and livestock.The main towns in PALM arePrince Albert, Leeu Gamka, Klaarstroom, Prince Albert Road and smaller rural settlements.

Map 3.1: Prince Albert Local Municipality (Aurecon, 2014)



Source: Aurecon, 2014

3.1.2 Geology and groundwater

There are four main geological formations that run from north to south in PALM (Aurecon, 2014):

- Mudstone,
- Arenite,
- Shale and
- Tillite

PALM soil has a low nutrient supply and retention ability. The soil also has a clay contentof less than 35% and therefore geotechnical investigations are seldom required (Aurecon, 2014).

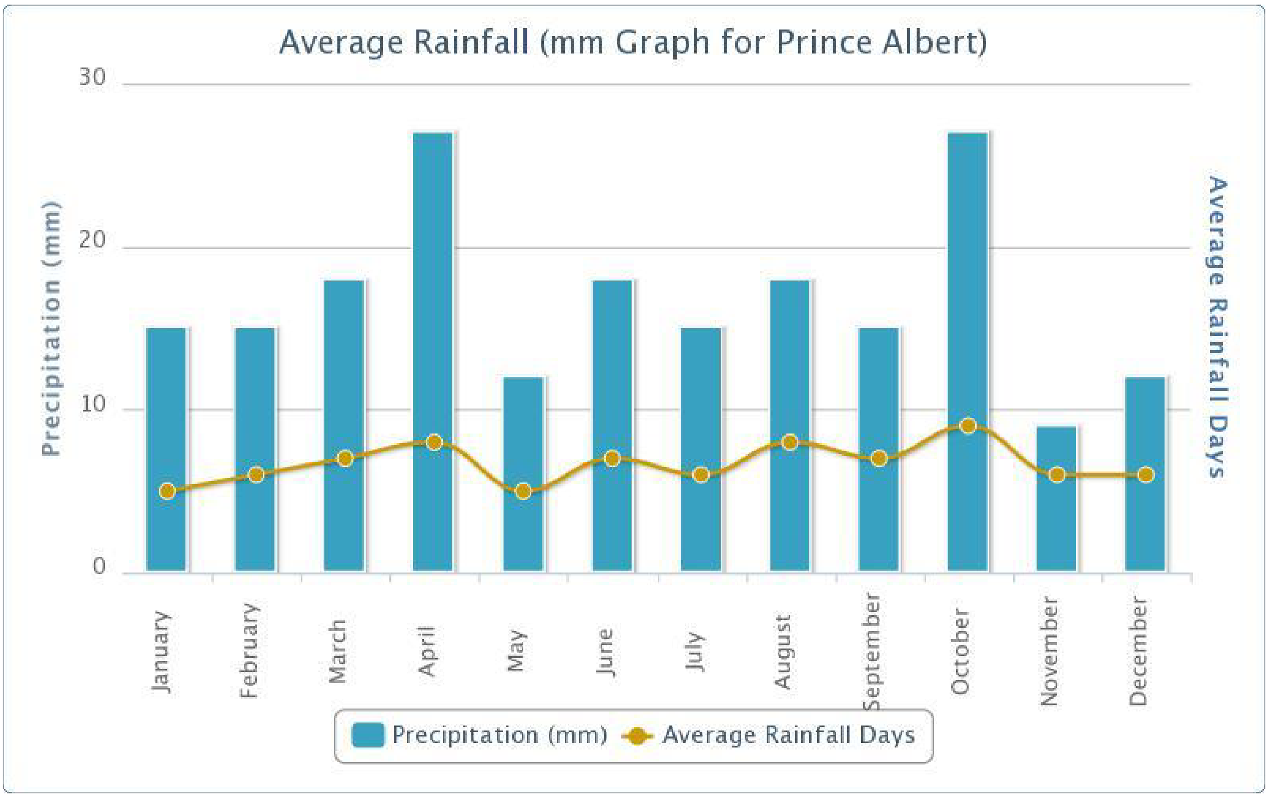
PALM is a water scarce area and so groundwater is an important source of water in PALM as it helps to meet the demand of potable water and is also used as irrigation water.

3.1.3 Temperature and Climate

PALM has large variances in temperatures between summer and winter months. Temperatures can be as high as 32°C in January and as sub-zero in the months of June and July. The hottest temperatures are experienced between December and February and the coldest temperatures between June and August.

PALM lies in a semi-arid area and on average receives between 20 to 473mm per annum. However, rainfall varies greatly with the Groot Swartberg mountain range in the south experiencing between 474mm and 926mm. The rainy season is between April and October and the driest month occurs in November.

Figure 3.1: Prince Albert average rainfall per month



Source: Aurecon, 2014

The mean annual precipitation and rainfall depths for various storm recurrence intervals (RIs) of the towns are as follows:

Table 3.1: Rainfall characteristics of towns in PALM

Town	MAP (mm)	10 year RI	50year RI	100year RI
Klaarstroom	371	23	45	54
Leeu Gamka	146	16	29	36
Prince Albert	204	20	30	40

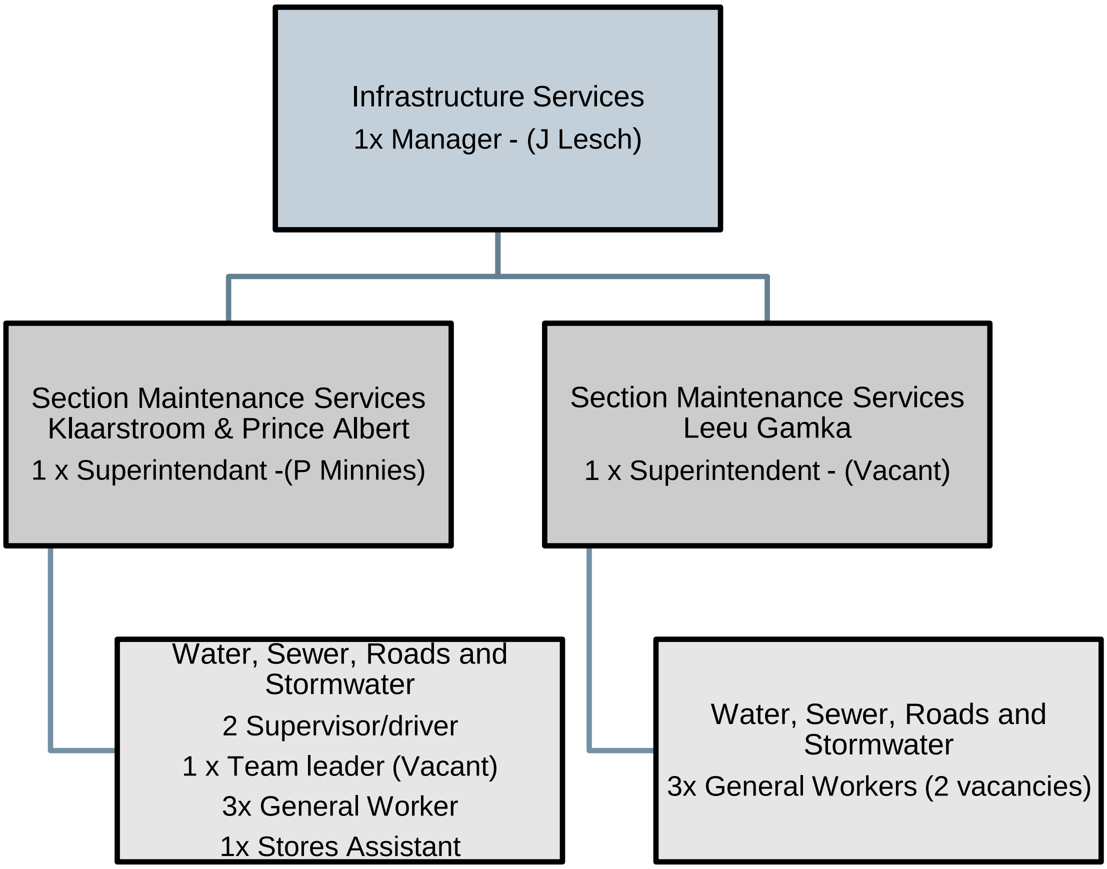
Source: South African Weather Bureau andSANRAL Drainage Manual

3.2 Stormwater Management in Prince Albert Local Municipality

There is no official department for stormwater in PALM. Instead stormwater is considered to be part of roads and lies within the responsibility of the Technical Services. The Technical Servicesdivision is led by Mr N Klink.

3.2.1 Staff

Currently there is no official stormwater division. However, it is envisaged that stormwater will become the responsibility of Infrastructure Services. Infrastructure Services is responsible for the maintenance of stormwater and the technical co-ordination of all projects. The division will be managed by Justin Lesch.



The division is in charge of two subdivsions which cater to stormwater in addition to roads, water and sanitation services. The subdivisions are “Section Maintenance Services Klaarstroom & Prince Albert” and “Section Maintenance Services Leeu Gamka”. These subdivisions main role for stormwater will be the maintenance of stormwater services in these areas. There is 1 vacancy for a team leader in the Maintenance Services subdivision for Klaarstroom and Prince Albert whilst there are 3 vacancies for Maintenance Services in Leeu Gamka (1 superintendant and 2 general worker positions).

The department in general lacks institutional capacity due to a lack of skilled technical staff and a lack of funding.

3.2.2 Operations and maintenance

The main institutional challenges in PALM according to 2013 PALM IDP are as follows:

- Asset register is needed,
- Proper management of funding of projects,

3.2.3 Challenges

Maintenance of stormwater infrastructure remains an issue due to lack of staff and technical capacity

Another issue is allocation of funding for stormwater structures is not known because of outdated asset registers and a lack of comprehensive information on existing stormwater infrastructure.

3.3 Prince AlbertStormwater By-laws, Plans and Policies

3.3.1 Constitution Schedule 4

In terms of Schedule 4 of the Constitution all local municipalities are required to perform the following functions which are relevant to stormwater systems:

- “Municipal planning,
- Storm water management systems in built-up areas.”

3.3.2 PALM Stormwater Bylaw

PALM has a stormwater bylaw that aims at regulate and manage stormwater related activities in built-up areas. The bylaw prohibits any activities by members of the public that may impair operations, maintenance of stormwater infrastructure and stormwater quality or cause flooding. Only PALM and citizens with permission and from the municipality and having undergone the necessary environmental investigations can build, remove, operate and maintain stormwater infrastructure. PALM also has the ability Any persons who contravene the regulations as set out in the by-laws is deemed to have committed an offence and is liable for paying to remediate the problem else is subject to paying a fine or imprisonment.

3.3.3 Study on the Growth Potential of Towns in the Western Cape (2010)

The Growth Potential of Towns in the Western Cape (2010) classified the potential for growth in major towns in the Western Cape region.

The major driver for growth in Prince Albert was found to be agriculture and tourism whilst the growth in Leeu Gamka is driven by an increasing demand for residential areas.Both towns were classified as having low growth potential.However, Prince Albert and Leeu Gamka were identified as having high and very high needs respectively.

3.3.4 Central Karoo District: Bulk Infrastructure Master Plan (2011)

The Prince Albert Water Treatment Works(WTW) was identified as being a flood prone area as it located near the Dorps River. A recommendation was made in the report for the investigation of the 1:50 year flood line and relocation of the WTW.

3.3.5 PALM SDF (2014)

The PALM SDF recommended that a 100 year floodline be used as a means of protecting properties and habitats from flood damage.

Buffers should be should be determined where possible and for small drainage systems where a floodline cannot be determined a 32m buffer from the top of the bank of the drainage line is prescribed.

The SDF also forewarns that any development within the floodplain will require a report from a registered professional engineer that the development can adequately accommodate the floodwater and prevent any unnecessary damage and to the habitat or building to be included with the building plans. Those that do not have must include new stormwater management plans.

Any proposed development or redevelopment within the floodplain must be supported by a report by a registered professional engineer to ensure that any new or existing structure can withstand the forces and effects of floodwaters. If building plans are submitted in respect of proposed buildings within the floodplain and such a report has not previously been submitted, it must be included with the building plans.

4 PALM Stormwater Management and Planning Status Quo

4.1 Existing Stormwater Systems

Prince Albert was visited on the 21August 2014 and Klaarstroom and Leeu Gamka on 22 August 2014. Observations were made and photographs taken of the stormwater services within the town and problem areas.

4.1.1 Prince Albert South

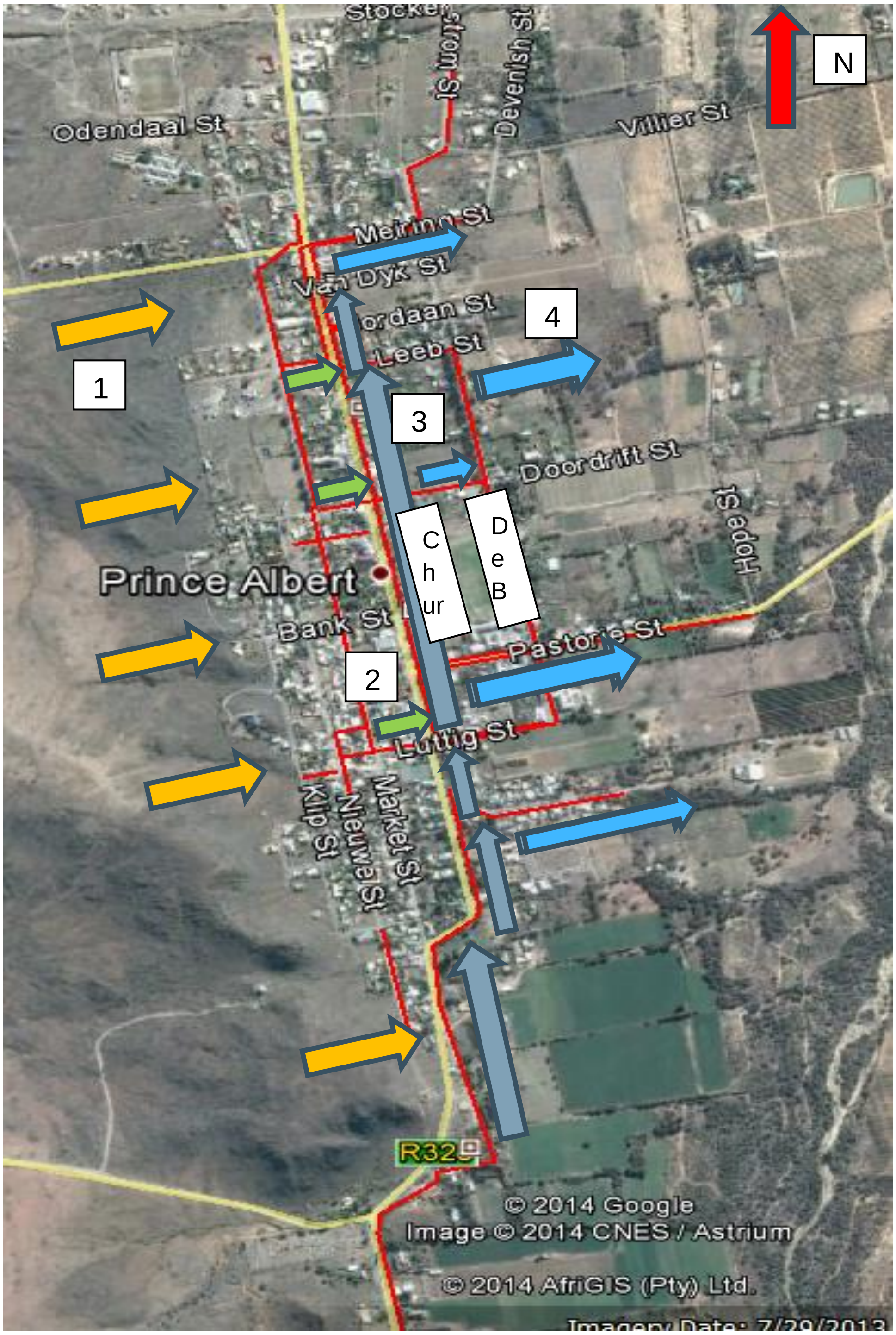
Prince Albert is nestled in theDorps River valley. The settlement is built at the foot of the hills and is divided into two areas – Prince Albert North (PAN) and Prince Albert South (PAS). PAS is the main town and consists of the central business district and businesses and residences whilst PAN is a residential area developed in recent years to accommodate the growing population.

PAS has an extensive system of furrows used for the primary purpose of irrigation. The water is sourced from the nearby DorpsRiver... These furrows act as stormwater channels during storm events. In addition to the furrows PAS has open stormwater channels. The existing stormwater system is shown as red lines inMap 4.1. The furrow system is operated using a system of sluice gateswhich are opened during major flood events

Stormwater in PAS drainage paths during a storm event are indicated via arrows onMap 4.1:

1. Stormwater flows east-west down the hills to towards PAS and the streets of Klip, Bank and Nieuwe (light orange)
2. Stormwater then flows down the side streets from Klip, Bank and Nieuwe east-west into Church Street (light green).
3. The stormwater from these upper streets are collected via stormwater channels and furrows in Church Street (dark blue).
4. The stormwater from Church Street passes from the main channel into channels on De Beer, Pastorie and Meiring and Stockenstrom Street.

Map 4.1: Prince Albert South Existing Stormwater System and Drainage



PAS lies on the foot of a hilly region to the east of the town. The town uses overland flow and open channels to convey the stormwater. However, when there are high intensity storms the town experiences flash flooding. During the site visit the following issues attributing the stormwater problem were identified:

- Poor conditions, slopes and gradients of channels
- No clear stormwater system routing for minor and major flood events
- Poor drainage in open spaces between households
- Poor maintenance of existing stormwater infrastructure which cause blockages of inlets and outlets.

These problems shall be discussed in detail after the stormwater system analysis.

4.1.2 Prince Albert North

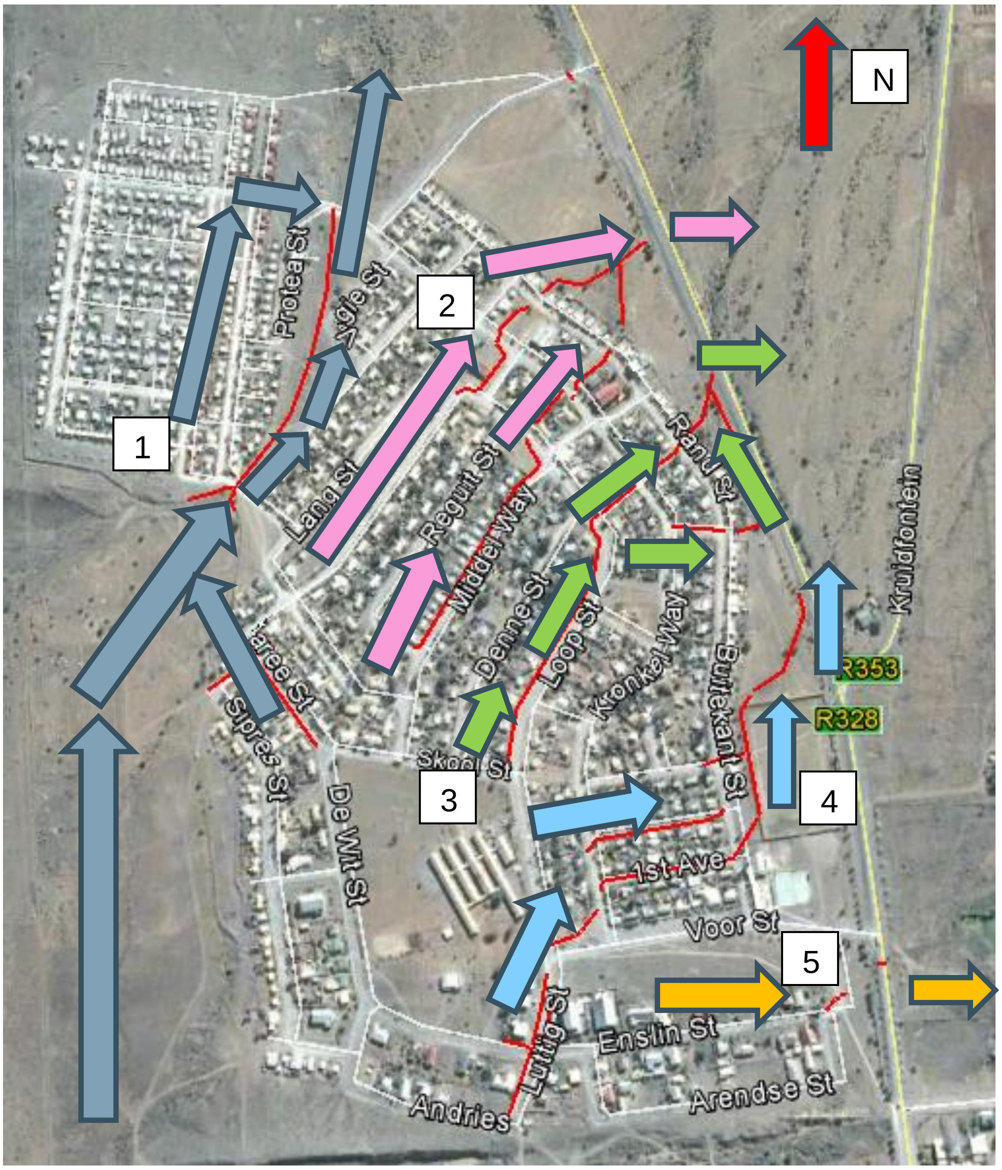
Prince Albert North lies upon the face of a hill with a natural stream running through the northern half. The stream catchment starts from the hills near MargarietPrinsloo in PAS and extends through the settlement to the R328. The stream has been accommodated by the use of an attenuation structure made of gabion walls. This attenuation structure has a double barrel culvert outlet which flows into an unlined channel and over a low level road crossing.

The main settlement has a series of channels, culverts, road crossings which drain from the south-west towards culverts in the R328 to the north-east.

The existing stormwater system is shown as red lines in Map 4.2. Stormwater in PAN drains during a storm event via five main drainage paths which are indicated via arrows on Map 4.2:

1. The natural stream that flows through the northern settlement flows from MargarietPrinsloo through the gabion attenuation and gabion channel towards the R328 (dark blue). Stormwater from Rondomskrik and Karee and Spires Street also form part of this flow.
2. Stormwater from Lang, Middelweg and Reguit exits via a culvert in the R328 (pink).
3. Stormwater from Denne and Loop exit via a culvert in the R328 (green)
4. Stormwater drains from Luttig via 1st avenue to Buitenkant Street, then through an open field to a culvert in the R328 (light blue). Stormwater from 2nd avenue and 3rd avenue also drain towards Buitenkant Street.
5. Stormwater from Enslin and Arendse drain across an open field to a culvert in the R328.

Map 4.2: Prince Albert North Existing Stormwater System and Drainage



During the site visit the following issues attributing the stormwater problem were identified:

- Poor conditions, slopes and gradients of channels
- Poor drainage in open spaces between households
- Poor maintenance of existing stormwater infrastructure which cause blockages of inlets and outlets.

These problems shall be discussed in detail after the stormwater system analysis.

4.1.3 Leeu Gamka

Leeu Gamka is a small settlement located off the R353 and is nestled in a natural valley through which the Gamka tributary flows. This tributary flows north-west to south-east through the settlement towards the Gamka River. The town consists of residential settlements, a few light businesses and public facilities such as a school and library.

This tributary is accommodated via a gabion channel and low level road crossings that flow into an open field before exiting through an open channel.

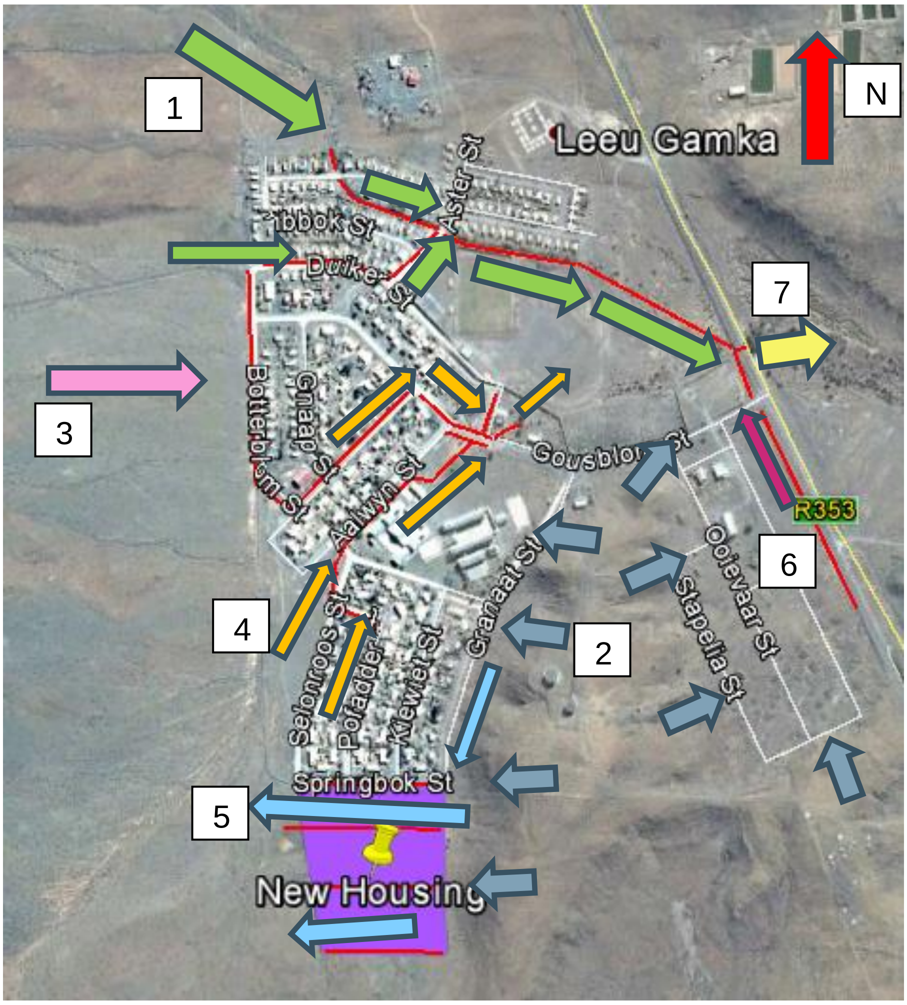
The remainder of the settlement has a network of open channels that either drain into the gabion channel or into the open field.

Leeu Gamka is currently building new houses built after the most recent Google Earth imageryand aerial photography.

The existing stormwater system is shown as red lines in Map 4.3. Stormwater in Leeu Gamka drains during a storm event via five main drainage paths which are indicated via arrows on Map 4.3:

1. The tributary flows through the gabion channel towards the R353 (green). Stormwater from Duiker and Aster Street also form part of this flow. The catchment of this tributary extends approximately 2km into the mountain range to the northwest of the settlement.
2. Stormwater from the hills flows into Granaat, Gousblom and Stapelia Street (dark blue).
3. Stormwater from hills to the east drain into Gousblom Street (pink).
4. Stormwater from Selonroos, Pofadder drains through channels alongside Aalwyn and then through a low road crossing in Gousblom. This stormwater exits from a stone pitched channel into an open field (light orange).
5. The new housing has a series of v channels which drain towards the east. It is not apparent if this will join with the stormwater from Selonroos (light blue).
6. Stormwater from the open field adjacent to the R328 flows into the culvert under the R353 (maroon).
7. Stormwater from 1, 4 and 7 drains through the culvert under the R328 towards the Gamkariver.

Map 4.3: Leeu Gamka Existing Stormwater System and Drainage Paths



During the site visit the following issues attributing the stormwater problem were identified:

- Poor conditions, slopes and gradients of channels
- Poor drainage in open spaces between households
- Poor maintenance of existing stormwater infrastructure which cause blockages of inlets and outlets.

These problems shall be discussed in detail after the stormwater system analysis.

4.1.4 Klaarstroom

Klaarstroom is a small settlement located off the N12. The settlement comprises of a school, library and residential housing. The settlement itself lies partially atop of a hill and in the path of a natural tributary to the Klaarstroom River.

The existing stormwater system is shown as red lines in Map 4.4. Stormwater in Klaarstroom drains during a storm event via five main drainage paths which are indicated via arrows on Map 4.3:

1. Stormwater from hills across the N12 (light blue) drains south through a culvert and then into a stormwater channel in Klaarstroom (dark blue).
2. Stormwater from hills in Klaarstroom flows towards the R407 to the North (pink) and stormwater from the southern side of the hill drains towards a natural channel to the south (orange).
3. Stormwater from Klaarstroom (orange) flows into a series of channels and low level road crossing which joins the natural stormwater channel (dark blue).
4. Stormwater from the R407 drains towards a low level bridge crossing (yellow) which drains towards the river.

Map 4.4: Klaarstroom Existing Stormwater System and Drainage Paths

During the site visit the following issues attributing the stormwater problem were identified:

- Poor conditions, slopes and gradients of channels
- Poor drainage in open spaces between households
- Poor maintenance of existing stormwater infrastructure which cause blockages of inlets and outlets.

These problems shall be discussed in detail after the stormwater system analysis.

5 Future Planned Developments& Projects

In 2010 the Department of Environmental Affairs conducted a study on all towns in the Western Cape. All the towns in PALM were identified as having a low development potential. However, the PALM2013 Spatial Development Framework (SDF) discusses proposed development. In addition the PALM has proposed new stormwater projects in the PALM Integrated Development Plan (IDP).

5.1.1 Spatial Development Framework

The PALM identified urban development for towns over the next 20 years in the 2013 Spatial Development Framework (SDF). Only the following towns were discussed:

- Prince Albert,
- Leeu Gamka,and
- Klaarstroom.

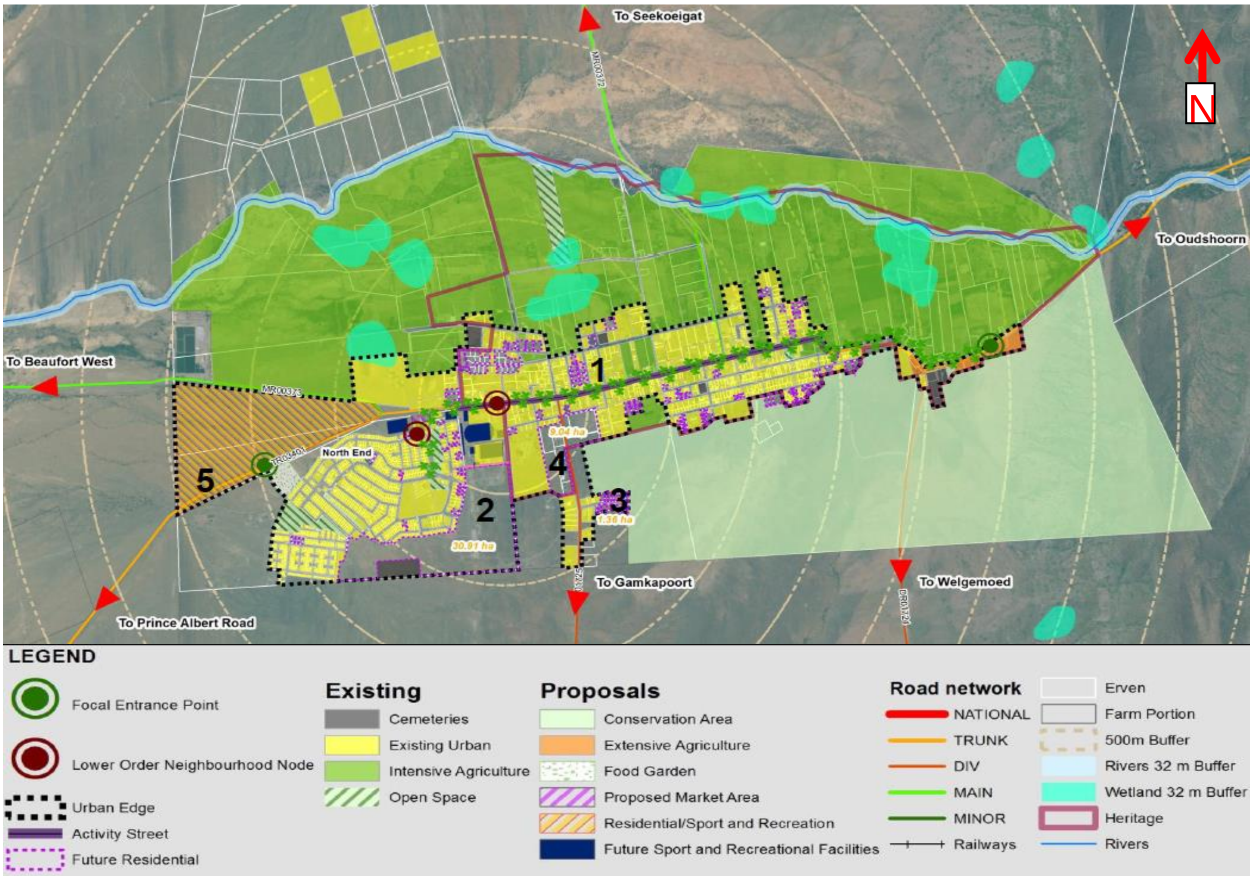
5.1.1.1 Prince Albert

The following developments were recommended in the SDF for Prince Albert (Aurecon, 2014):

- Future residential development
- Development of sport and recreational facilities,
- Extension of Mecuur street, and
- Agricultural areas

The existing and proposed layouts are shown in Map 5.1.

Map 5.1:Prince Albert Future Development Plan Map

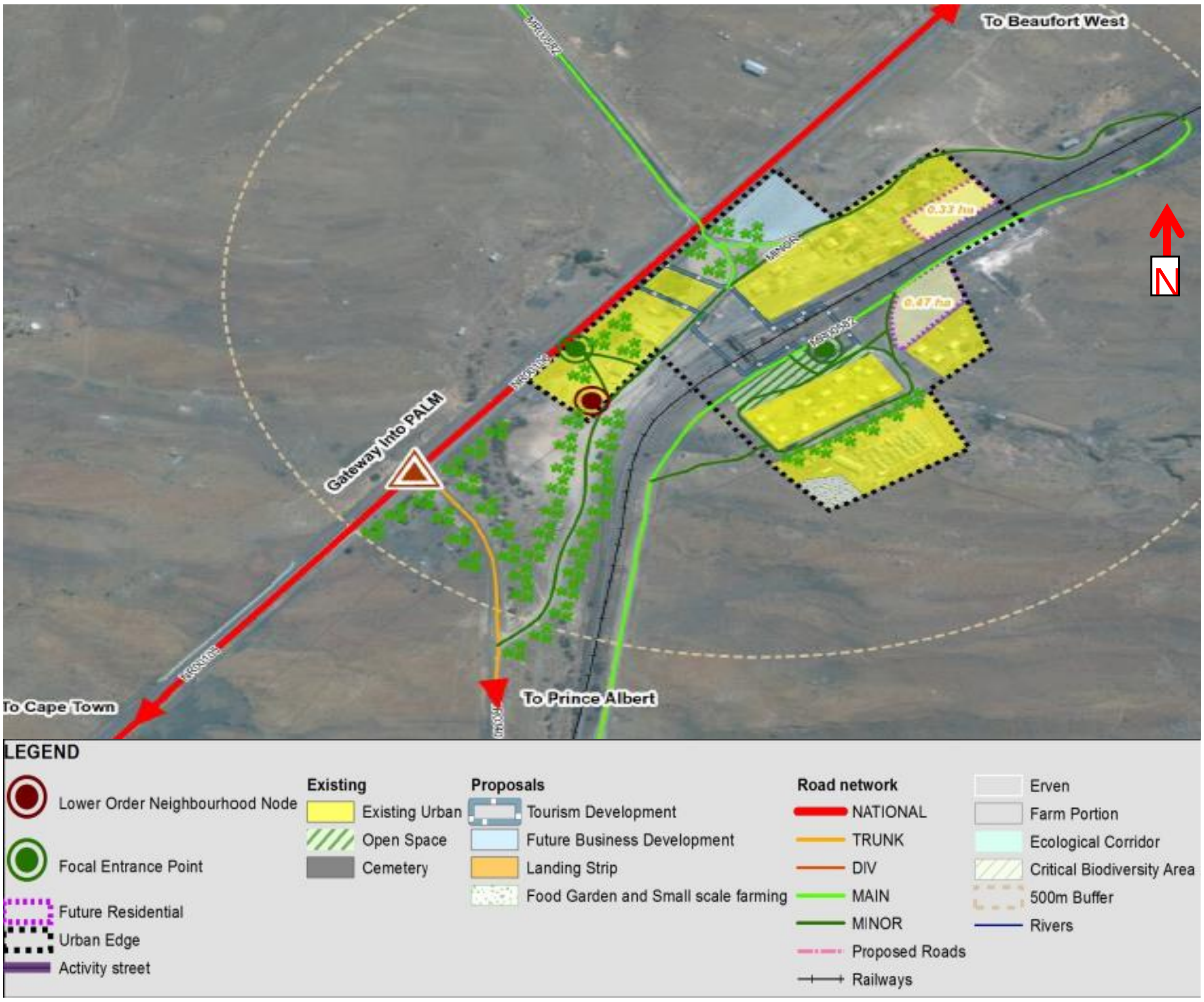


Source: Aurecon, 2014

5.1.1.2 Prince Albert Road

Most of Prince Albert Road consists of residential areas (dark yellow.) The urban development areas, identified for Prince Albert Road, have been allocated to the areas as shown in light yellow in Map 5.2. The areas add up to a total area of 0.8ha. An area dedicated for future transport and commercial services was allocated to the north of the town (light grey). The existing and proposed layouts are shown in Map 5.2.

Map 5.2:Prince Albert Road Bay Future DevelopmentPlan Map



Source: Aurecon, 2014

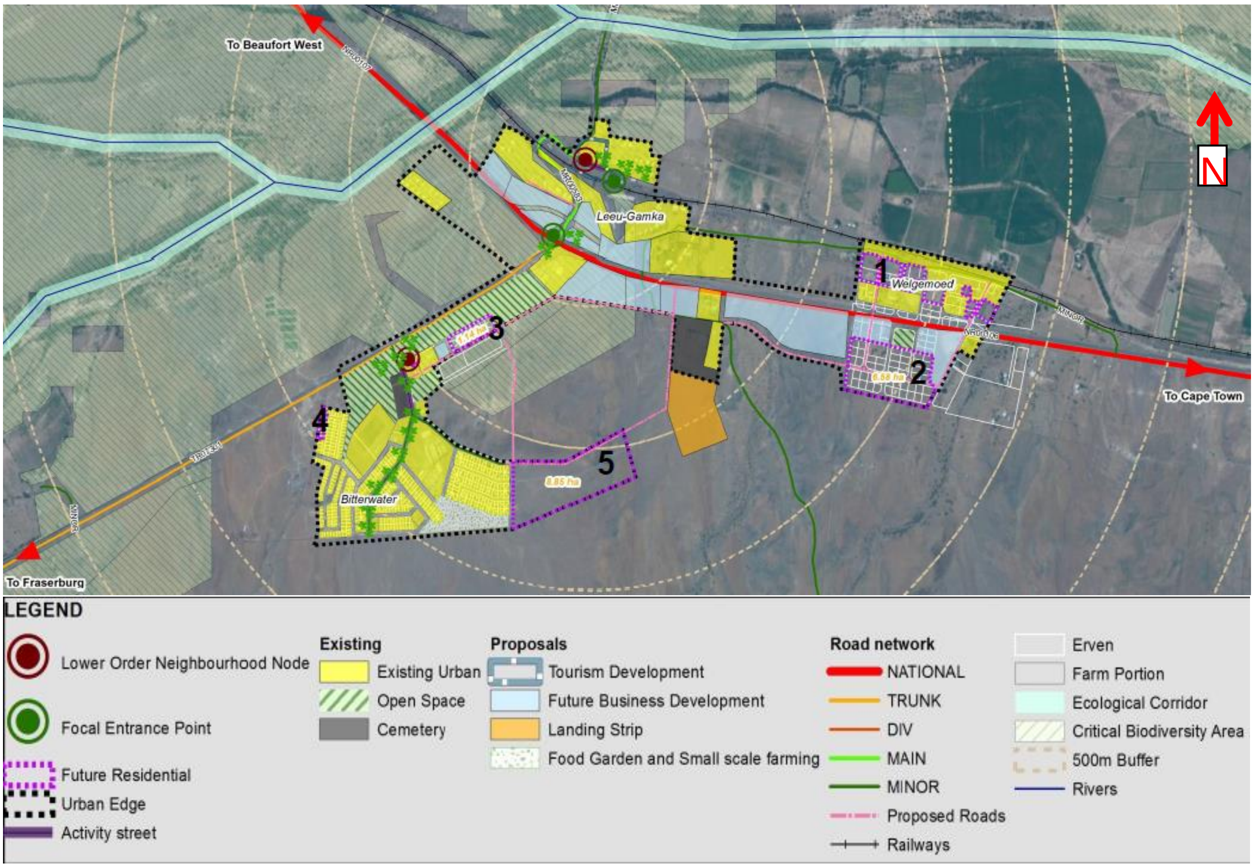
5.1.1.3 Leeu Gamka

The main developments planned for Leeu Gamka are residential and commercial developments to bridge the divide between Bitterwater, Welgemoed and Leeu Gamka. Approximately 16ha has been set aside for the following:

- "Breaking New Ground" Housing
- Gap Housing
- Business Development.

The existing and proposed layouts are shown in Map 5.3.

Map 5.3:Leeu Gamka Future DevelopmentPlan Map



Source: Aurecon, 2014

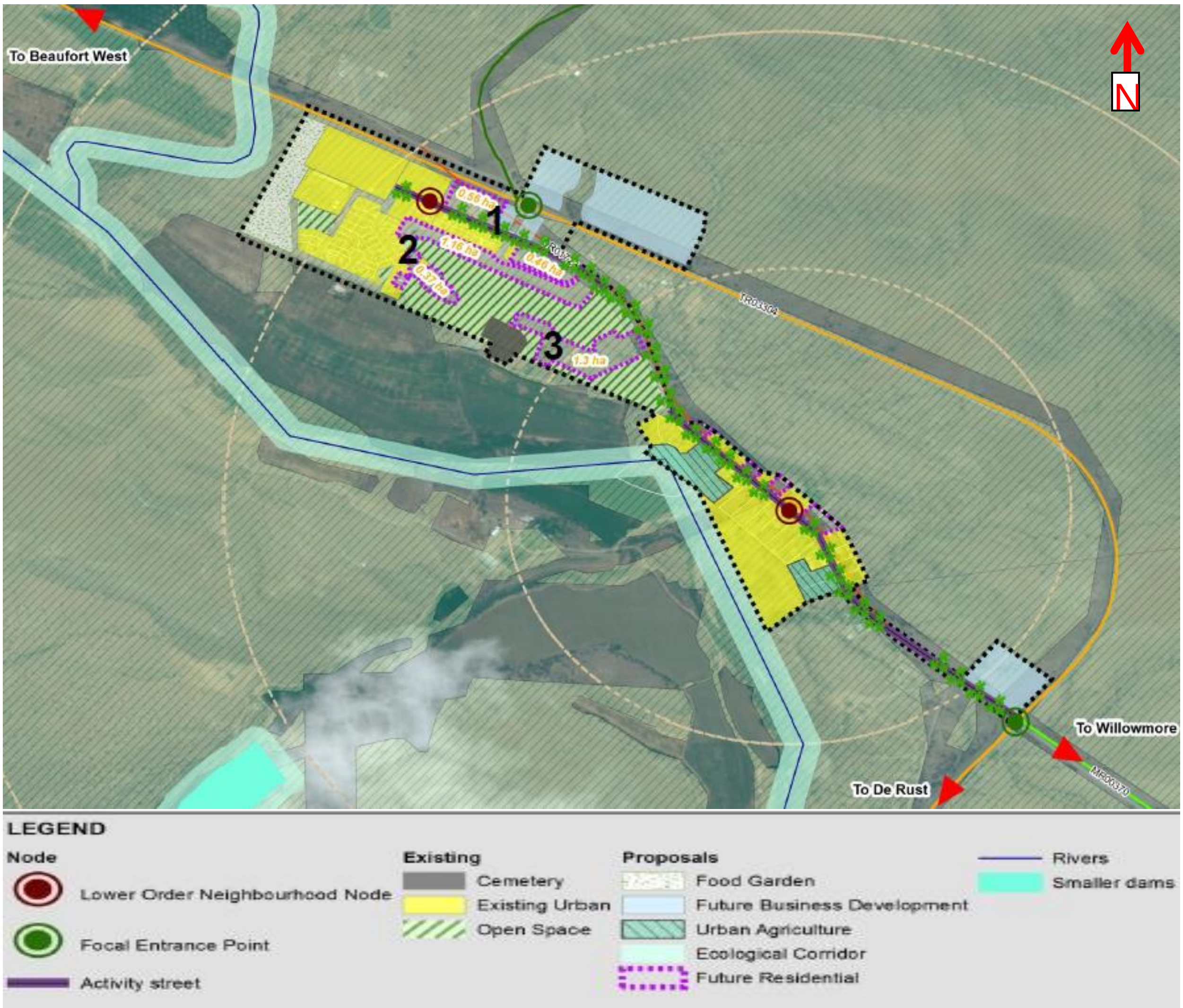
5.1.1.4 Klaarstroom

The future planned developments for Klaarstoom comprise (Aurecon, 2014):

- Approximately 3.44 ha of residential developments in the form of BNG housing to bridge the divide between north and south Klaarstroom, and
- Business and commercial opportunities located along the N12 which could be used for transport related services.

The existing and proposed layouts are shown in Map 5.4.

Map 5.4:Klaarstroom Future Development Plan Map



Source: Aurecon, 2014

5.1.2 Planned Stormwater Projects

There are only three known stormwater related projects planned by PALM:

5. The latest 2012 – 2017 PALM IDP identifies a project for upgrading stormwater infrastructure in Prince Albert and Leeu Gamka. The scope of works is for a stormwater upgrade including drainage and curbing for areas such as Adderley Street, North End and Bitterwater. The estimated cost is R5 000 000. Prince Albert upgrades to the North End were estimated at R 591,780 in 2012/13 and the upgrades for Leeu Gamka was estimated at R 492,400 in 2012/13.

6. The second project identified in the 2014 PALM SDF was a stormwater master plan for PALM which is being dealt with in this report. The budget was estimated at R400 000 in the SDF.

7. The Central Karoo District Bulk Infrastructure Master Plan identified that the flood line for Dorps River needs to be determined for relocating the Prince Albert WTW out of the floodplain. The project was allocated under bulk water projects and funding is to be received from Capital Improvements Program.

Although there is no indication of the location of the planned stormwater projects and services within the SDF, this stormwater master plan will take cognisance of the impacts of the proposed future town developments and the stormwater projects proposed in the IDP and Bulk Infrastructure Master Plan.

6 Methodology

6.1 Design Methodology

There are no existing policies and by-laws prescribed for PALM in terms of the maintenance, design and specifications of stormwater systems, the stormwater system planning will be done in accordance with the Guidelines for Human Settlement Planning and Design, Volume 2, Chapter 6 Stormwater Management, compiled by CSIR in 2009.

The calculations will be done using the Environmental Protection Agency Stormwater Management Model (EPA SWMM) V5.1.

The runoff calculations are based on the kinematic method of routing stormwater and the following inputs are required:

- Rainfall storm event information such as rainfall intensity and infiltration
- Catchment characteristics information such as area, surface roughness, length of runoff and imperviousness. All catchments were determined using Google Earths elevation profiles and catchment areas were measured off a scale aerial photograph in EPA SWMM v5.1
- Inputs are required for both the existing system and the future system. The future system will be based on the developments proposed in the SDF.
- Conduit information gathered from site visits and asset register information (See Appendix A - CD).

6.1.1 Rainfall storm event information

Any development must be designed to effectively manage stormwater runoff for less frequent major storms events and frequent minor storms events. Minor events should be comfortably handled by the town infrastructure and not endanger life or damage buildings. Major events are less frequent but can cause significant damage to buildings and cause of loss of life. The major event storm will have to be diverted away from the towns into downstream rivers.

The stormwater planning of the towns will be done for a 10 year recurrence interval minor storm event and a 50 year recurrence interval major storm event for flood routing in accordance with CSIR(2009).

6.1.1.1 Rainfall Intensity

The rainfall intensity of each catchmentwill be calculated using the Chicago distribution which uses the mean annual rainfall. The mean annual precipitation (MAP) for each town was obtained from DWAF meteorological stations, South African Weather Bureau (SAWB) stations, the All Town Study and estimated from an independent study conducted for DWA Hydrological Services (Nel, 2005). Table 4.1 summarises the MAP used for each town assessment in this SWMP.

Table 6.1: MAP of towns in PALM

Town	SAWB Station	Latitude	Longitude	MAP (mm)
Prince Albert	0048043W	33:13	22:02	169
Prince Albert Road	0068329W	32:59	21:41	107
Leeu Gamka	0049050W	32:47	21:59	117
Klaarstroom	0068857W	33:19	22:32	229

Source: SAWB

6.1.1.2 Infiltration

Rainfall can infiltrate into the soil until the soil reaches saturation upon which it reaches a minimum infiltration rate. The rainfall that does not infiltrate is stormwater runoff. Infiltration for the purposes of this SWMP will be calculated using Horton's method as described in the equation below:

$F_p = F_0 + (F_0 – F_c).\exp(-kt)$

Where:

- F_p Infiltration rate at time t (mm/hr)
- F_0 Initial or maximum infiltration rate (mm/hr)
- F_c Final infiltration rate (mm/hr)
- k decay constant (per second)
- t time elapsed in seconds

The maximum infiltration rate of sandy soil is approximately 120mm/hr but was reduced to 76mm/hr (loam soil) as a conservative approach (lower infiltration rates results in greater stormwater runoff and thus greater capacity for the detention ponds). The parameters used in the calculation of infiltration from the site were assumed to be those of a typical loam soil (Table 6.2).

Table 6.2: Infiltration parameters

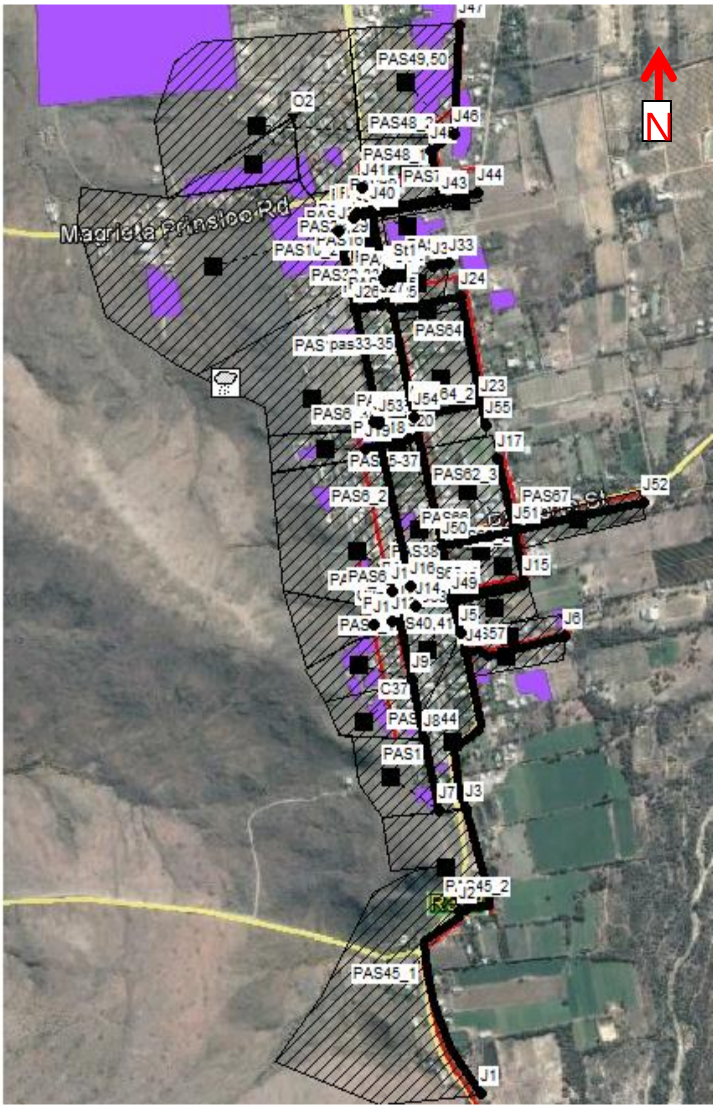
Maximum Infiltration Rate (mm/hr)	76
Minimum Infiltration Rate (mm/hr)	7
Decay Constant	4
Drying Time (days)	7

6.1.2 Catchments and Conduits

6.1.2.1 Prince Albert South

The catchments and conduits modelled for Prince Albert South in EPA SWMM are shown in Map 6.1. The existing areas are in see through hatched whilst future residential areas are in purple. These purple areas are assumed to be completely pervious for the existing development and 80% impervious for future development calculations.

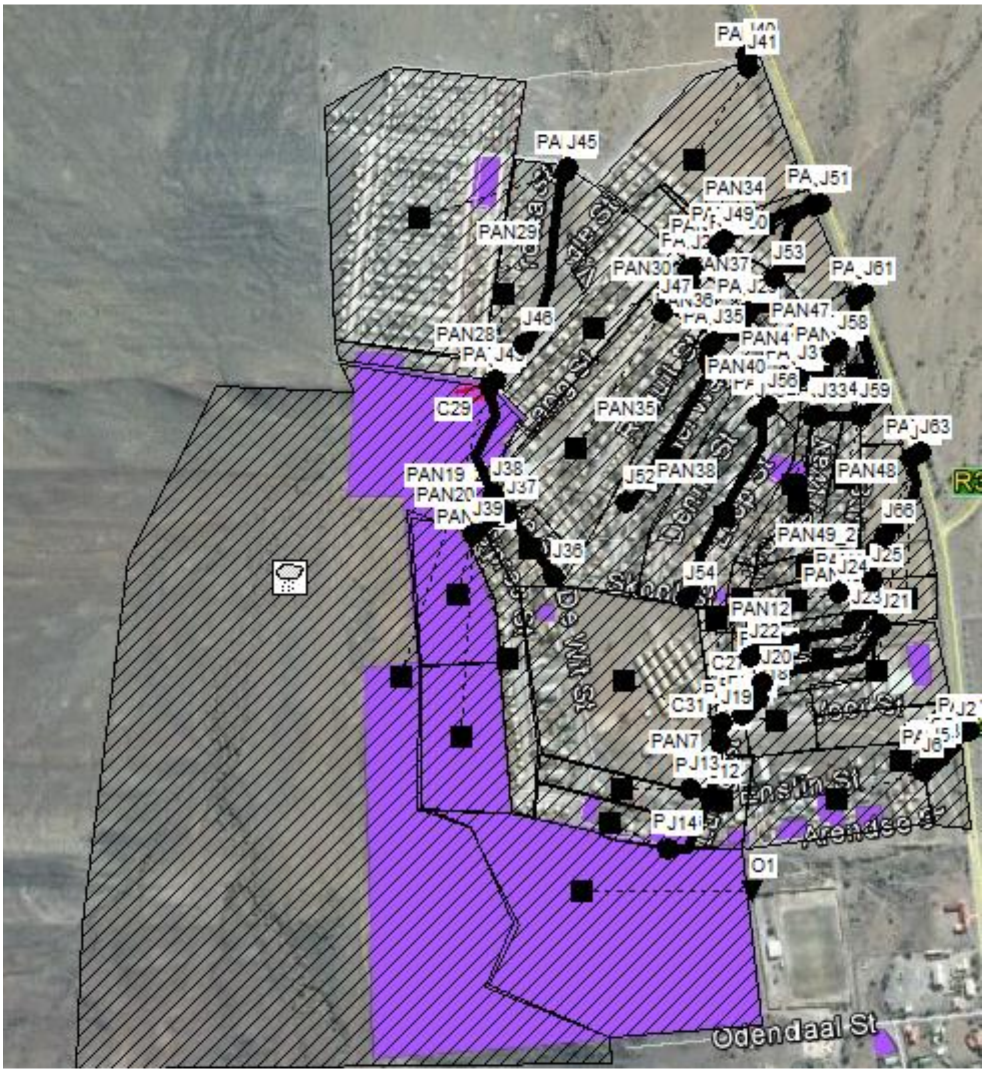
Map 6.1: Prince Albert South EPA SWMM Stormwater System Diagram



6.1.2.2 Prince Albert North

The catchments and conduits modelled for Prince Albert North in EPA SWMM are shown in Map 6.2. The existing areas are in see through hatched whilst future residential areas are in purple. These purple areas are assumed to be completely pervious for the existing development and 80% impervious for future development calculations.

Map 6.2: Prince Albert North EPA SWMM Stormwater System Diagram



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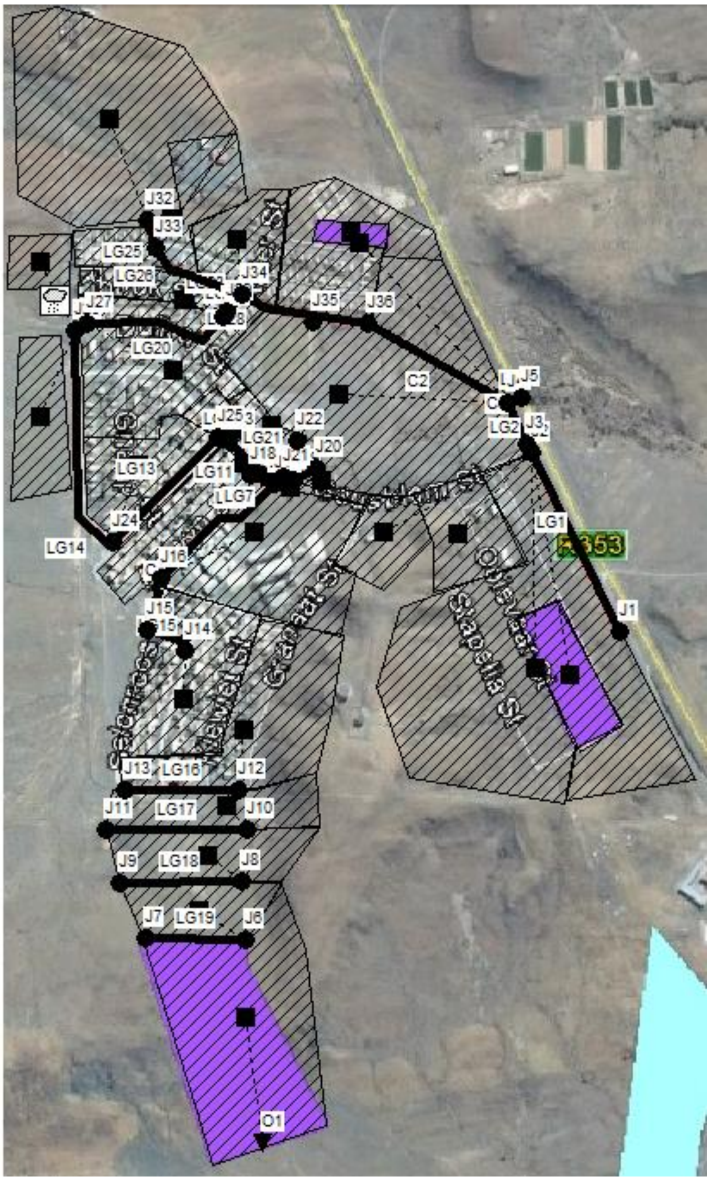
6.1.2.3 Leeu Gamka

The catchments and conduits modelled for Leeu Gamka North in EPA SWMM are shown in Map 6.3. The existing areas are in see through hatched whilst future residential areas are in purple. These purple areas are assumed to be completely pervious for the existing development and 80% impervious for future development calculations.

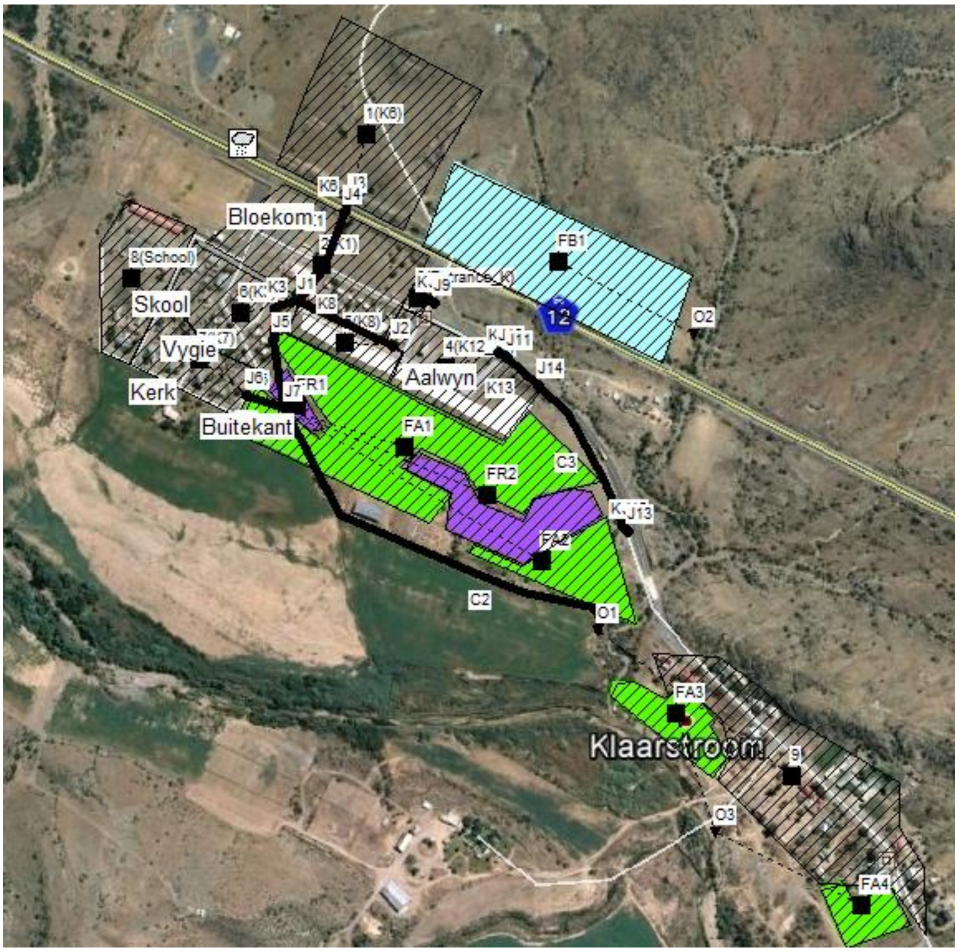
Map 6.3: Leeu Gamka EPA SWMM Stormwater System Diagram



6.1.2.4 Klaarstroom

The catchments and conduits modelled for Leeu Gamka North in EPA SWMM are shown in Map 6.3. The existing areas are in see through hatched whilst future residential areas are in purple. These purple areas are assumed to be completely pervious for the existing development and 80% impervious for future development calculations. Future business areas (light blue) and future agricultural areas (green) are assumed to be completely pervious in the existing system and 80% and 10% impervious for future systems respectively.

Map 6.4: Klaarstroom EPA SWMM Stormwater System Diagram



7 Findings and Discussion

7.1 Runoff

The difference between peak post development and pre-development flows in Prince Albert North and South is in the order of approximately 1000 LPS (1m^3/s) for 1 in 10 year storm and about 400LPS and 600LPS for Leeu Gamka and Klaarstroom respectively (Table 7.1).

The 1 in 50 year storms produce a discharge of almost 50% more than the 1 in 10 year storm and the 1 in 100 year storm is more than 100% greater than the 1 in 10 year storm.

Table 7.1: Peak stormwater runoff per town and storm return interval

	Prince Albert South		Prince Albert North		Leeu Gamka		Klaarstroom	
Return Interval	Peak Pre-development Runoff (LPS)	Peak Post-development Runoff (LPS)	Peak Pre-development Runoff (LPS)	Peak Post-development Runoff (LPS)	Peak Pre-development Runoff (LPS)	Peak Post-development Runoff (LPS)	Peak Pre-development Runoff (LPS)	Peak Post-development Runoff (LPS)
1 in 10	9051	10203	6345	7605	1909	2319	1290	1847
1 in 50	15065	16961	11261	13184	4521	5448	4011	4741
1 in 100	22170	24793	18054	20469	7250	8166	5377	6154

The hydrographs for the 1 in 10 year storm per town are shown in Figure 7.1 to Figure 7.4. The remainder of the results are displayed in Appendix B.

Figure 7.1: Prince Albert South 1 in 10 Year Storm Hydrograph

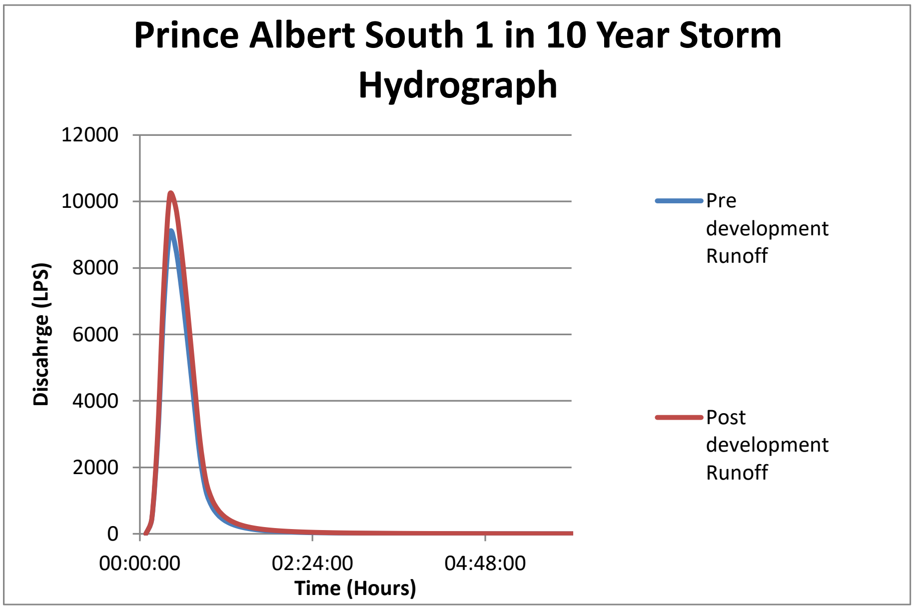


Figure 7.2: Prince Albert North 1 in 10 Year Storm Hydrograph

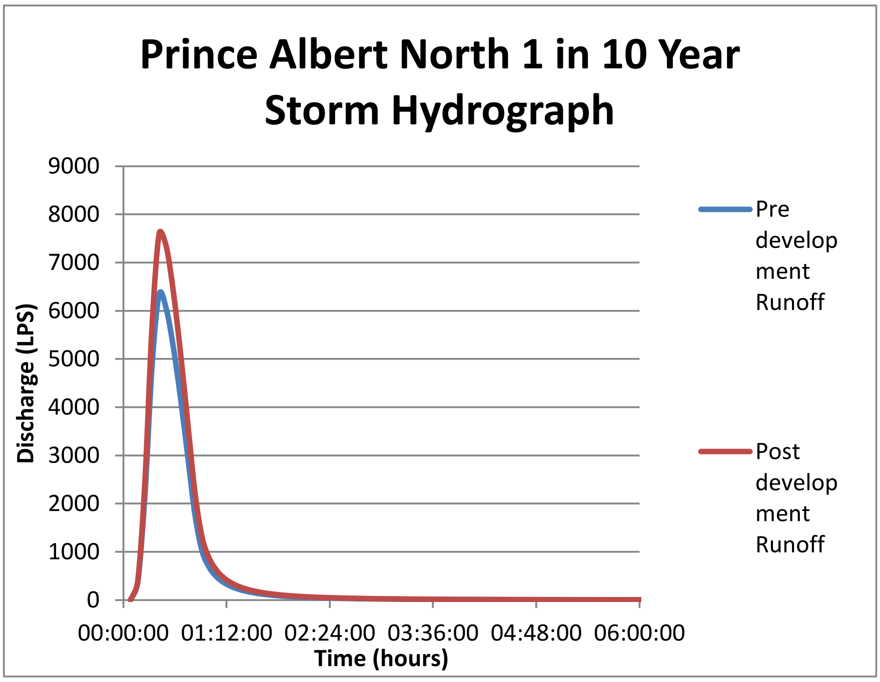


Figure 7.3: Leeu Gamka 1 in 10 Year Storm Hydrograph

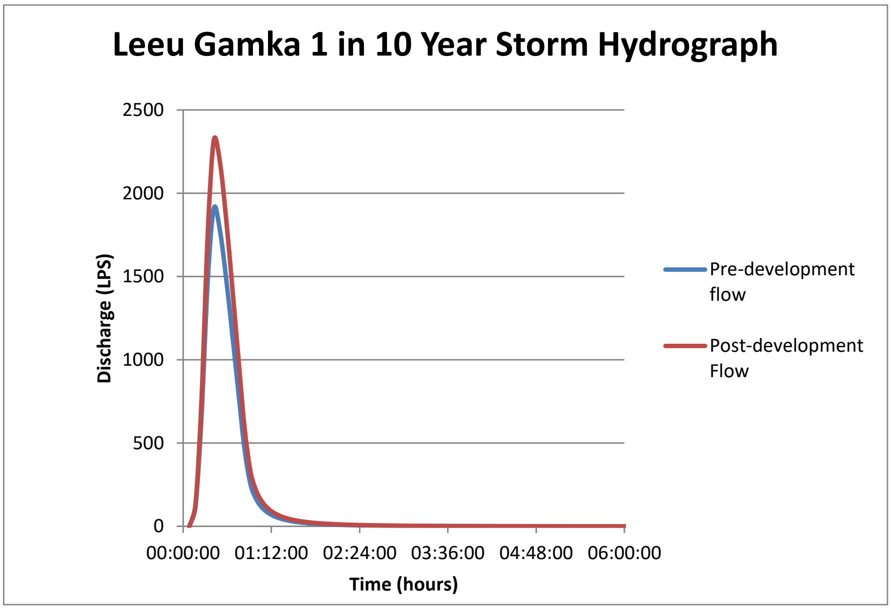
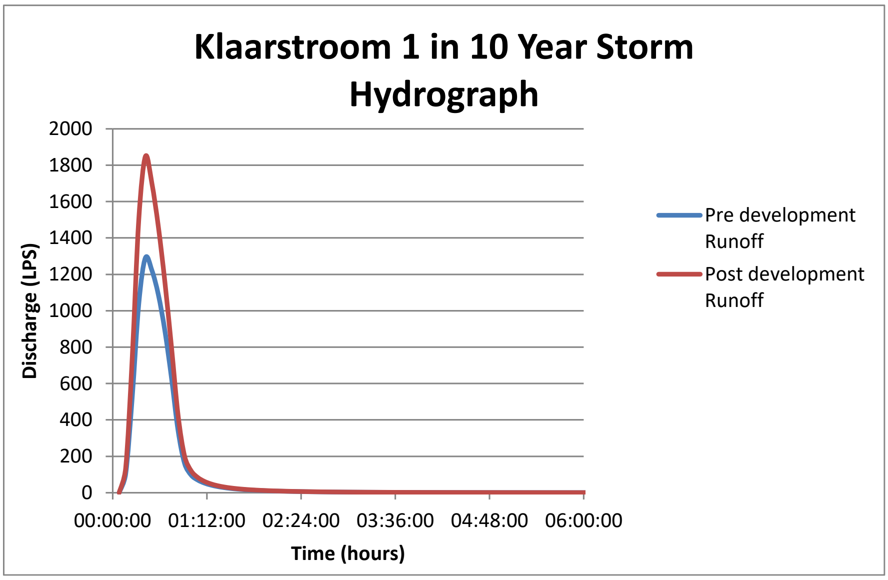


Figure 7.4: Klaarstroom 1 in 10 Year Storm Hydrograph



7.2 Storage

The storage requirements were calculated for a 1 in 10 year storm and are as follows:

Table 7.2: Storage requirements per town

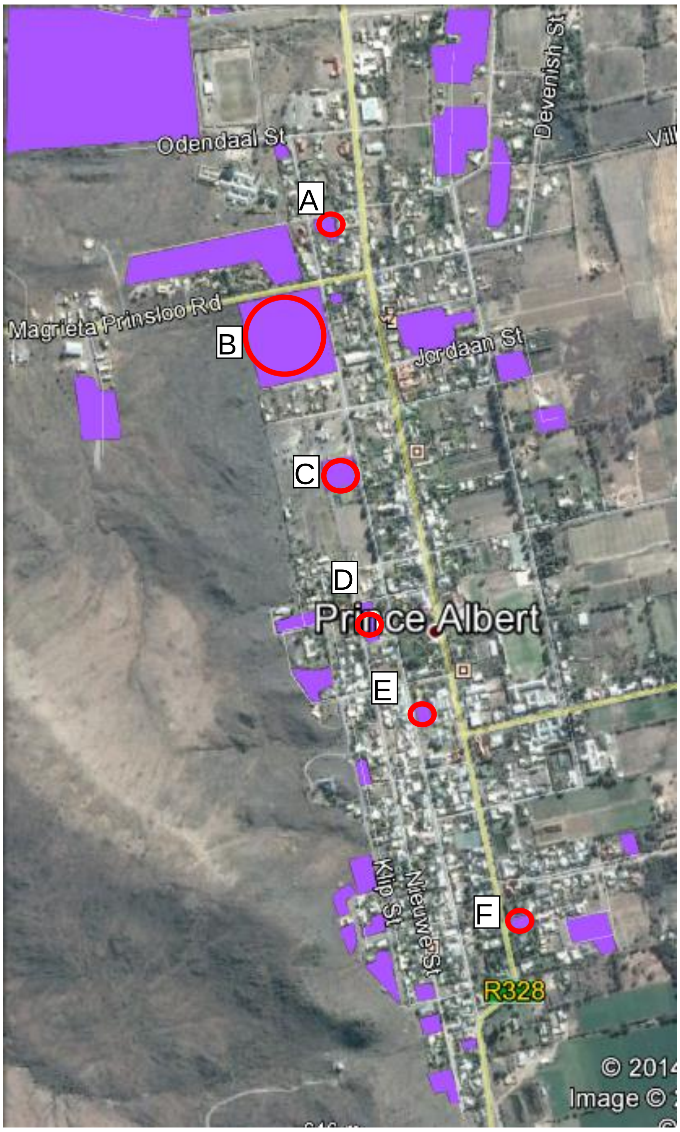
Town	Storage (m^3)
Prince Albert South	2433
Prince Albert North	2447
Leeu Gamka	1506
Klaarstroom	829

The storage areas per town are discussed below. The ponds can be used to control the stormwater runoff for the system by using outlets that are sized below pre-development flows.

7.2.1 Prince Albert South

The best areas for detention ponds (circled in red) in Prince Albert South are the areas designated for future residential development (purple), especially those located to the west of Church Street. The location of the most suitable detention pond will be subject to land zoning and geotechnical studies on the identified sites. Six areas have been identified for detention ponds. Ponds A to E will reduce the flow into Church Street from the hills to the west of the town. Pond F will serve as a buffer for stormwater flowing from the south along the R328 and could be discharged to the farmlands to the east.

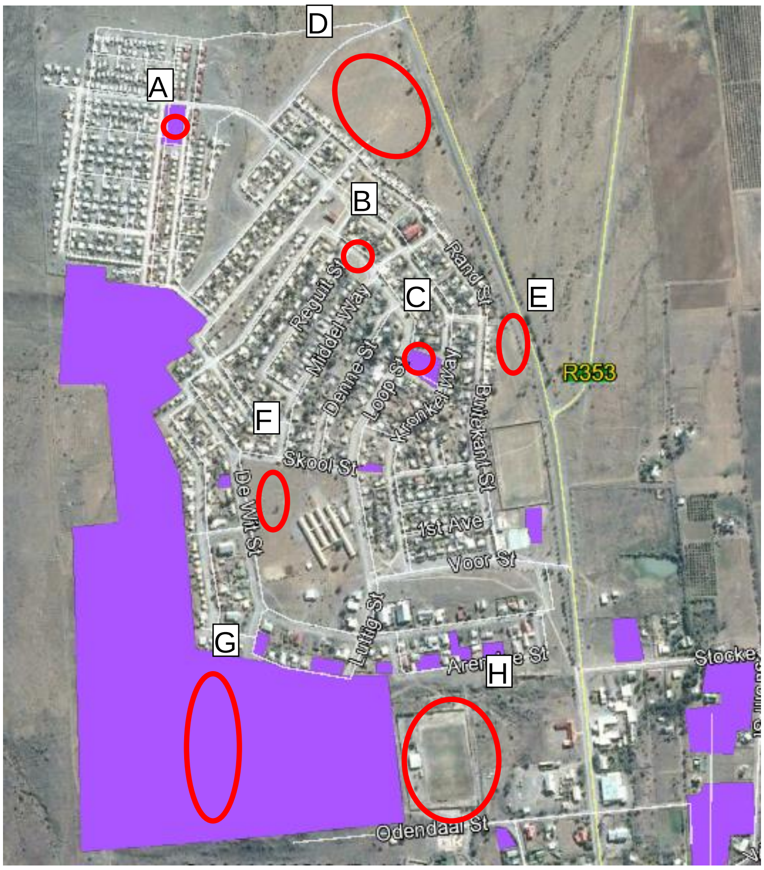
Figure 7.5: Candidate Sites for Stormwater Detention Ponds in Prince Albert South



7.2.2 Prince Albert North

The best areas for detention ponds in Prince Albert North are circled in red. The location of the most suitable detention pond will be subject to land zoning and geotechnical studies on the identified sites. Seven possible areas have been identified for detention ponds. Prince Albert North is difficult has little opportunity to store stormwater. The location and decision on what ponds (Ponds G and H) should be built will depend on the proposed design of the future developments. Ponds B and C are important for reducing the runoff and flooding in the north western part of Prince Albert North with Ponds D and E serving as a buffer and enabling protection of downstream environments.

Figure 7.6: Candidate Sites for Stormwater Detention Ponds in Prince Albert North



7.2.3 Leeu Gamka

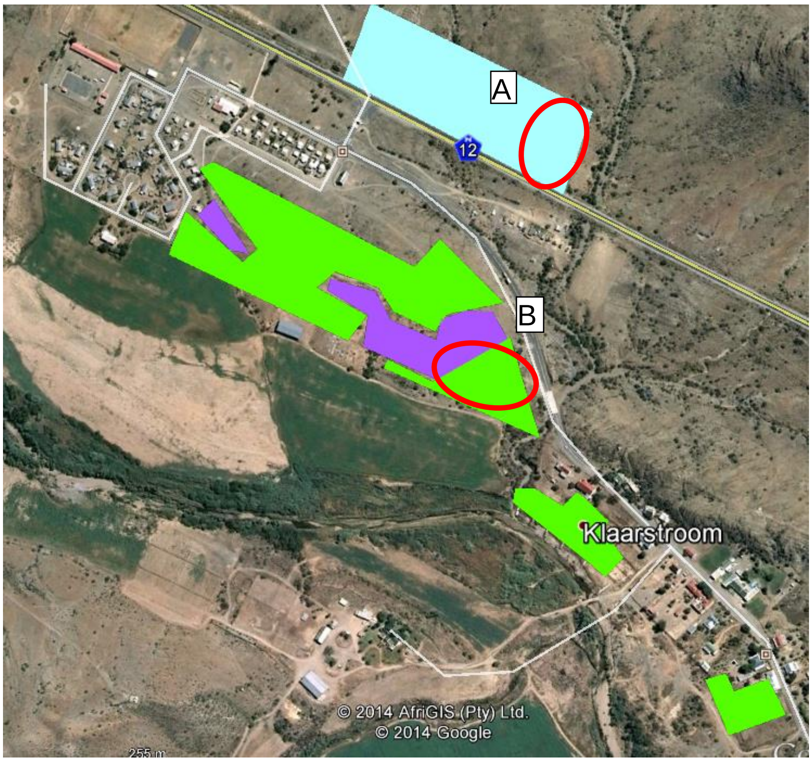
The best areas for detention ponds in Leeu Gamka are circled in red. The location of the most suitable detention pond will be subject to land zoning and geotechnical studies on the identified sites. Four possible areas have been identified for detention ponds. The playground at the bottom of Pofadder Street (Pond B) can be used to retain stormwater from the streets to the west, Pond C can receive stormwater from the community hall and future developments, Pond A will serve as the majority of the stormwater discharge from Leeu Gamka and the gabion channel and PondDmay serve the new housing developments to the south depending on the development design.

Figure 7.7: Candidate Sites for Stormwater Detention Ponds in Leeu Gamka

7.2.4 Klaarstroom

Klaarstroom only needs two detention ponds. Pond B will be on the southern side of the N12 for the residential and agricultural developments and Pond A will be on the northern side to accommodate stormwater from future business developments.

Figure 7.8: Candidate Sites for Stormwater Detention Ponds in Klaarstroom



7.3 Flood Route

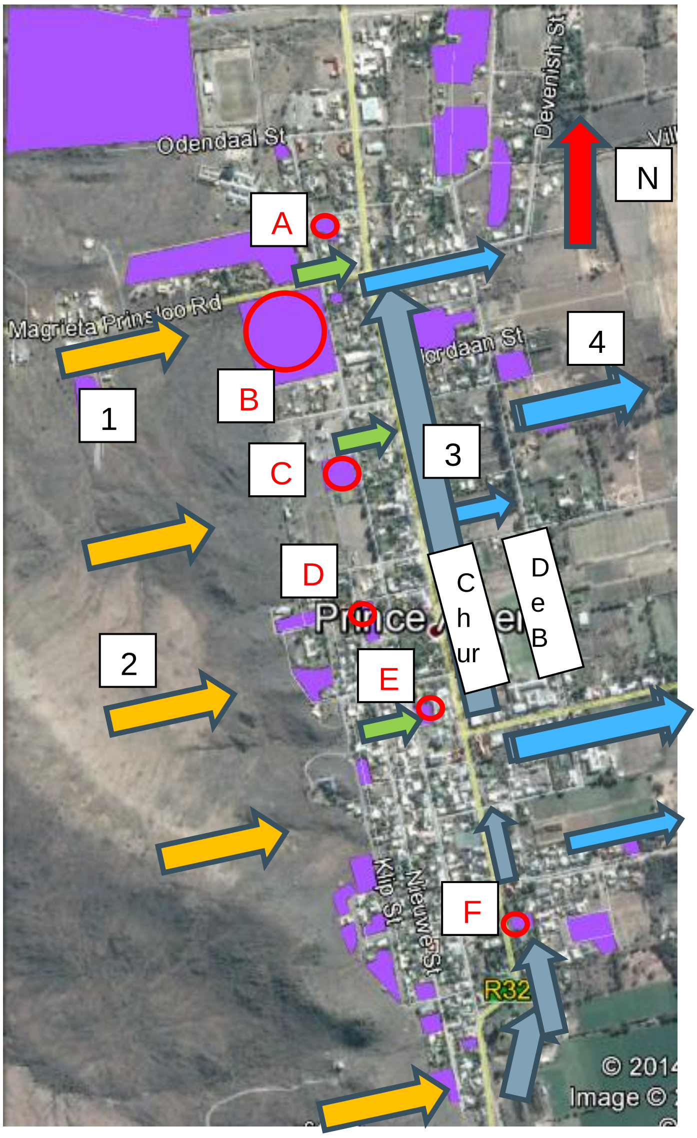
The flood route for minor and major flood events will be along the drainage paths as discussed in Section 4.1 but with the inclusion of the detention pond locations identified in Section 7.2.

7.3.1 Prince Albert South

Stormwater in PAS drainage paths during a storm event are indicated via arrows on Map 7.1:

1. Stormwater flows east-west down the hills to towards PAS and the streets of Klip, Bank and Nieuwe (light orange) and then into Ponds 1 to 5.
2. Stormwater then flows down the Ponds into Church Street (light green).
3. The stormwater from these upper streets are collected via stormwater channels and furrows in Church Street (dark blue). Stormwater from the south along the R328 flows into Pond 6.
4. The stormwater from Church Street passes from the main channel into channels on De Beer, Pastorie and Meiring and Stockenstrom Street.

Map 7.1: Prince Albert South Stormwater System Flood Route



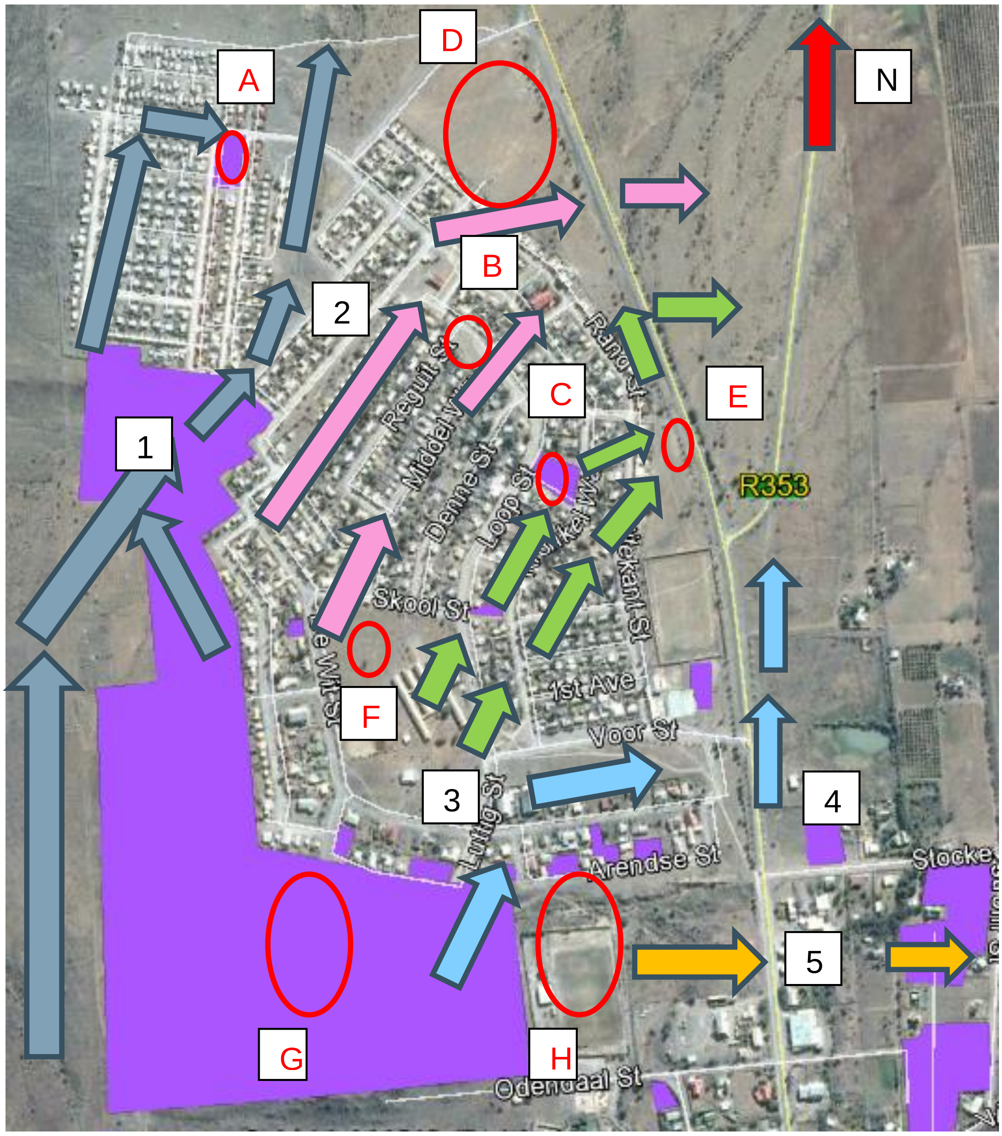
7.3.2 Prince Albert North

The main settlement has a series of channels, culverts, road crossings which drain from the south-west towards culverts in the R328 to the north-east.

The proposed stormwater system is shown as red lines in Map 7.2. Stormwater in PAN drains during a storm event via five main drainage paths which are indicated via arrows on Map 7.2:

1. The natural stream that flows through the northern settlement flows from MargarietPrinsloo through the gabion attenuation and gabion channel towards the R328 (dark blue). Stormwater from Rondomskrik and Karee and Spires Street also form part of this flow after being attenuated by Pond A.
2. Stormwater from Lang, Middelweg and Reguitis attenuated by Pond B and Pond D before exiting via a culvert in the R328 (pink).
3. Stormwater from Denne and Loop will drain into Pond C and then discharge back into the streets. Thestormwater is then attenuated further in Pond E and finally discharged through a culvert in the R328 (green)
4. Stormwater drains from Luttig via 1st avenue to Buitenkant Street, then through an open field to a culvert in the R328 (light blue). Stormwater from 2nd avenue and 3rd avenue also drain towards Buitenkant Street.
5. Stormwater from Enslin and Arendse drain across an open field to a culvert in the R328.
6. Stormwater from the new developments in the south will drain into Pond G or H depending on the development design.

Map 7.2: Prince Albert North Existing Stormwater System Flood Route



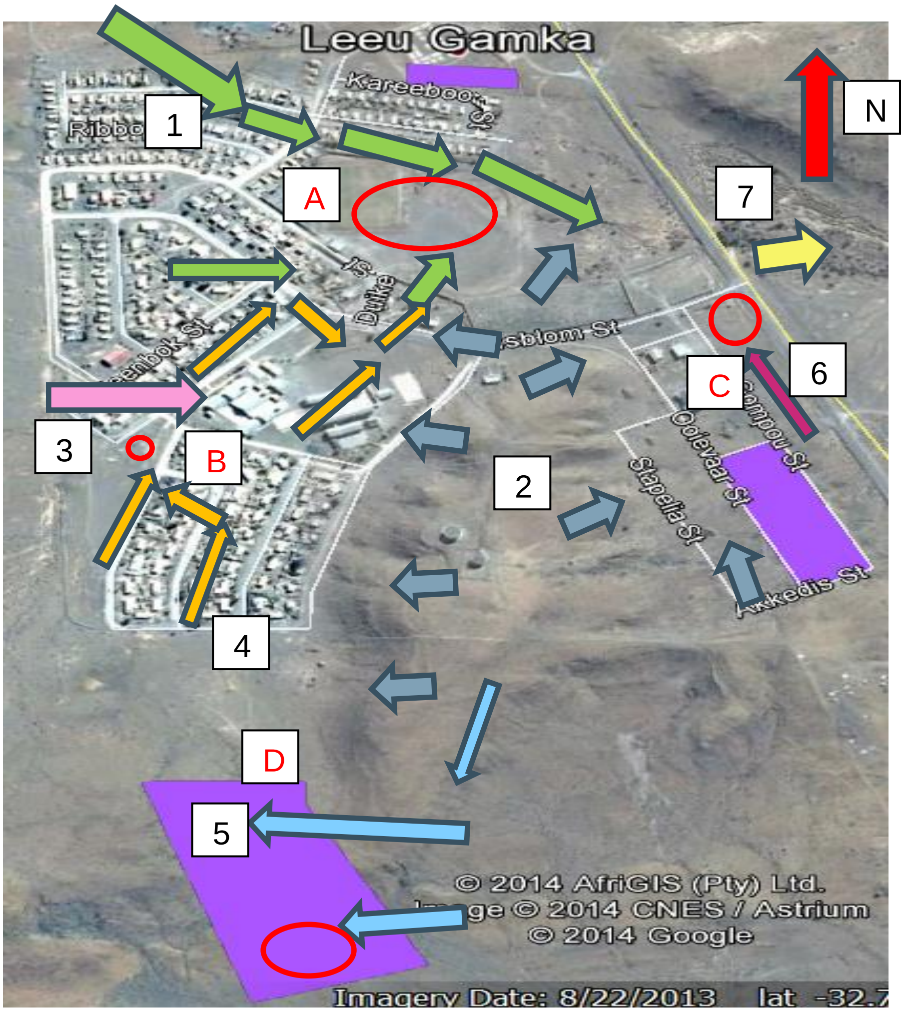
7.3.3 Leeu Gamka

The proposed stormwater system is shown as red lines in Map 7.3. Stormwater in Leeu Gamka drains during a storm event via seven main drainage paths which are indicated via arrows on Map 7.3:

1. The tributary flows through the gabion channel towards the R353 (green). Stormwater from Duiker and Aster Street also form part of this flow. The catchment of this tributary extends approximately 2km into the mountain range to the northwest of the settlement.
2. Stormwater from the hills flows into Granaat, Gousblom and Stapelia Street (dark blue).

3. Stormwater from hills to the east drain into Gousblom Street (pink).
4. Stormwater from Selonroos, Pofadder drains into Pond B, discharges into channels alongside Aalwyn and then flows through a low road crossing in Gousblom. This stormwater exits from a stone pitched channel into an open field (light orange).
5. The new housing has a series of v channels which drain towards the east. It is not apparent if this will join with the stormwater from Selonroos (light blue). If it does it will flow into Pond else it flow into Pond D before being discharged.
6. Stormwater from the open field adjacent and from some of the hills to the west flows into Pond C before being discharged to the culvert under the R353 (maroon).
7. Stormwater from 1, 4 and 7 drain into Pond A before being released through the culvert under the R328 towards the Gamka River.

Map 7.3: Leeu Gamka Existing Stormwater System Flood Route

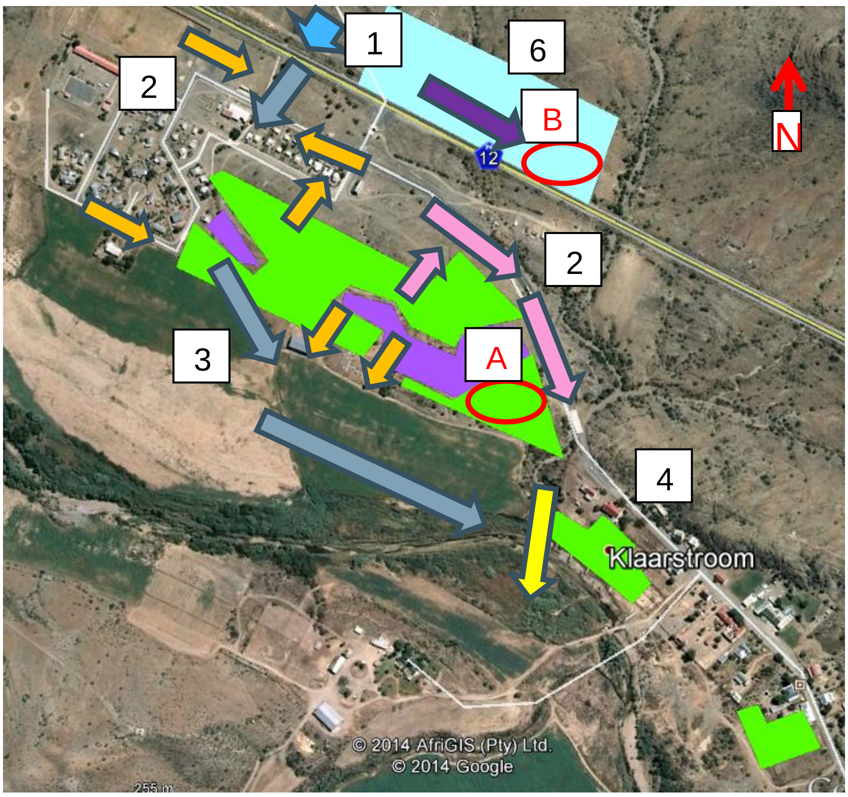


7.3.4 Klaarstroom

The proposed stormwater system is shown as red lines in Map 7.4. Stormwater in Klaarstroom drains during a storm event via six main drainage paths which are indicated via arrows onMap 7.4:

1. Stormwater from hills across the N12 (light blue) drains south through a culvert and then into a stormwater channel in Klaarstroom (dark blue).
2. Stormwater from hills in Klaarstroom flows towards the R407 to the North (pink) and stormwater from the southern side of the hill drains towards a natural channel to the south (orange).
3. Stormwater from Klaarstroom (orange) flows into a series of channels and low level road crossing which joins the natural stormwater channel (dark blue).
4. Stormwater from the R407 drains towards a low level bridge crossing (yellow) which drains towards the river.
5. Stormwater from the future business development flows into Pond B before being discharged.

Map 7.4: Klaarstroom Existing Stormwater System Flood Route



8 Stormwater Issues

The stormwater issues experienced in the towns in PALM are a mixture of historical issues as identified by residents, PALM and during site visits and also hydraulic issues identified from the stormwater analysis.

8.1 Historical Stormwater Issues

8.1.1 Prince Albert South

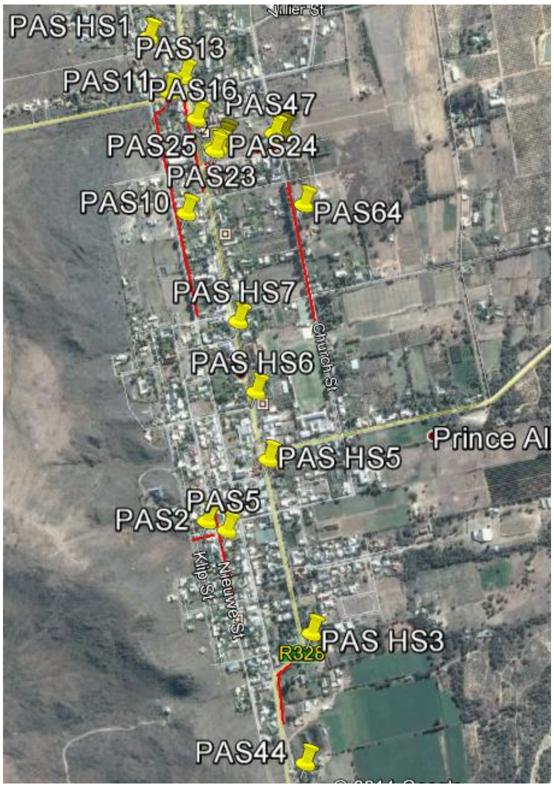
The stormwater issues identified in Prince Albert South are listed and described in Table 8.1 and are shown in Figure 8.1.

Table 8.1: Prince Albert South Historical Issues

Name	Town	Street	Structure	Material	Comments
PAS2	Prince Albert	Klip - Nieuwe	Channel	Stone Pitched	Stone pitching worn away and partially covered in dense vegetation
PAS5	Prince Albert	Niuewe	Channel	Concrete	Badly damaged. Crumbling and has poor slope and profile
PAS10	Prince Albert	Market	Channel	Cement	Partial vegetation and debris
PAS11	Prince Albert	Market - MagrietaPrinsloo	Channel	Grass	Dense vegetation
PAS13	Prince Albert	MagrietaPrinsloo	Culvert	Cement	Partially blocked by vegetation and debris
PAS16	Prince Albert	Church	Channel	Stone pitched /Unlined	Partially vegetated. Slope appears too flat too optimally
PAS23	Prince Albert	Jordaan and Church	Channel	Stone pitched	Greywater from prison flowing into system
PAS24	Prince Albert	Jordaan	Culvert	Concrete	Greywater from prison flowing into system
PAS25	Prince Albert	Jordaan	Channel	Concrete	Inlet blocked with vegetation
PAS26	Prince Albert	Jordaan	Detention Pond	Brick and Concrete	Inlet blocked with vegetation and vegetation growing in pond, concrete cracking
PAS27	Prince Albert	Jordaan	Detention pond outlet	Concrete	Outlet blocked by vegetation
PAS44	Prince Albert	Christina De Wit	Channel	Unlined / Stone pitched	Partially covered with vegetation
PAS46	Prince Albert	Jordaan and De Beer	Culvert	Concrete	Blocked with garbage
PAS47	Prince Albert	Jordaan and De Beer	Channel	Unlined	Poorly shaped and sloped. Vegetation growth and debris
PAS49	Prince Albert	Stockenstroom	Culvert	Cement	Blocked by vegetation
PAS64	Prince Albert	De Beer	Channel	Unlined	Covered with dense vegetation

Name	Town	Street	Structure	Material	Comments
PAS HS1	Prince Albert	Corner of Market Street and one street past MargarietPrinsloo			Ponding or flooding of stormwater onto properties
PAS HS2	Prince Albert	Corner of Odendaal Street and Market Street	Stormwater Channel	Earth	Stormwater channel flows through housing property
PAS HS3	Prince Albert	Corner of R328 (Gay's Dairy)			Stormwater flows into property
PAS HS4	Prince Albert	Parsonage Street into Church Street			Stormwater flows into street and has potential to pond
PAS HS5	Prince Albert	Bank Street into Church Street			Stormwater flows into street and has potential to pond
PAS HS6	Prince Albert	Chaplin Street into Church Street			Stormwater flows into street and has potential to pond

Figure 8.1: Map of Prince Albert South Historical Stormwater Issues



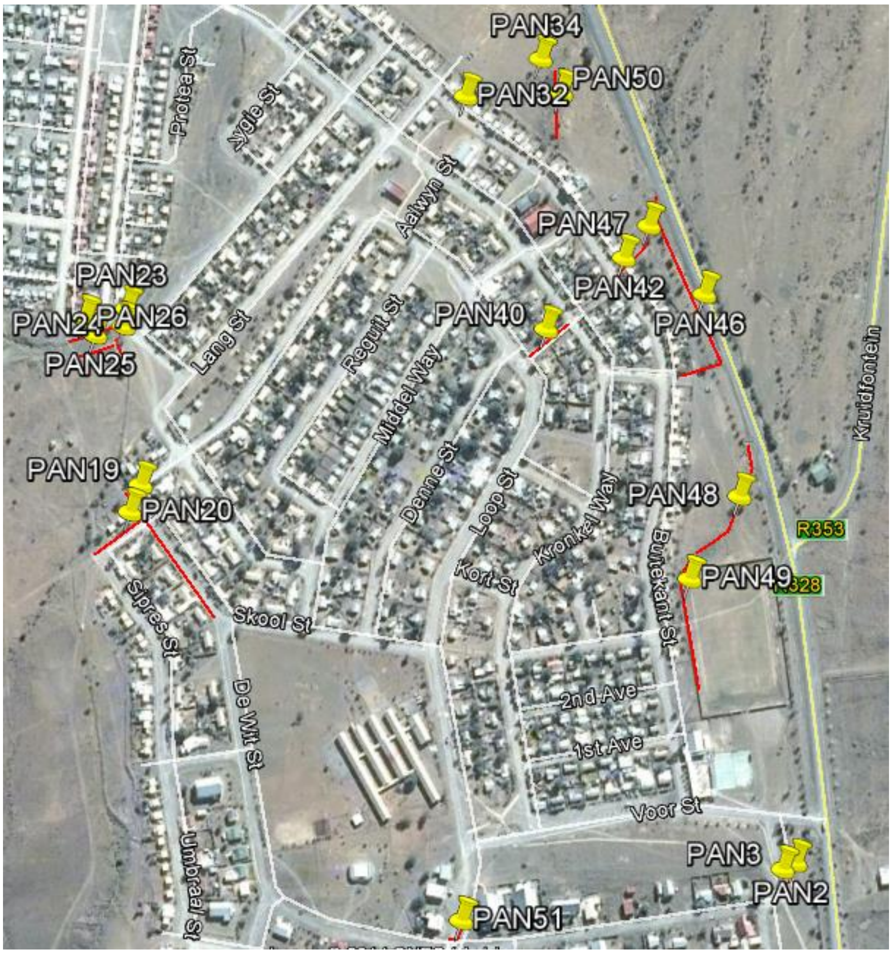
8.1.2 Prince Albert North

The stormwater issues identified in Prince Albert North are listed and described in Table 8.2 and are shown in Figure 8.2.

Table 8.2: Prince Albert North Historical Issues

Conduit	Street	Structure	Material	Comments
PAN2	Enslin	Culvert	Concrete	Blocked with some rubbish and vegetation
PAN3	Enslin walkway	Culvert	Plastic	Blocked with some rubbish and vegetation
PAN19	Karee	Channel	Concrete	Blocked by house driveways and debris. Slope too flat
PAN20	Spires and Karee	Channel	Concrete	Drains into an unlined informal channel
PAN23	Botterblom	Culvert	Concrete	Partially full with debris. Appears to be an illegal dumping hot spot.
PAN24	Botterblom	Gabion	Rocks and cement	Gabion slightly worn. Rocks missing
PAN25	Botterblom	Gabion	Rocks and cement	Gabion slightly worn. Rocks missing
PAN26	Botterblom	Gabion	Rocks and cement	Gabion slightly worn. Rocks missing
PAN32	Rand	Culvert	Concrete	Partially blokced with debris, rubbish and vegetation
PAN34	Rand to R328	Channel	Unlined	Unmaintained
PAN40	Loop- KronkelWeg	Channel	Concrete	Silted up
PAN42	Rand	Road Crossing	Concrete	Blocked with debris and vegetation
PAN46	Open field between Rand and R328	Channel	Unlined	Unmaintained channel. Partially covered in vegetation and debris
PAN47	Open field between Rand and R328	Channel	Unlined	Unmaintained channel. Partially covered in vegetation and debris
PAN48	Open field between Rand and R328	Channel	Unlined	Unmaintained channel. Partially covered in vegetation and debris
PAN49	Sports field	Channel	Stone Pitched	Slightly silted up with soil
PAN50	Open field to culvert PAN33	Channel	Unlined	Unmaintained channel. Partially covered in vegetation and debris
PAN51	Luttig intersection	Channel	Concrete	Accumulation of silt.

Figure 8.2: Map of Prince Albert North Historical Stormwater Issues



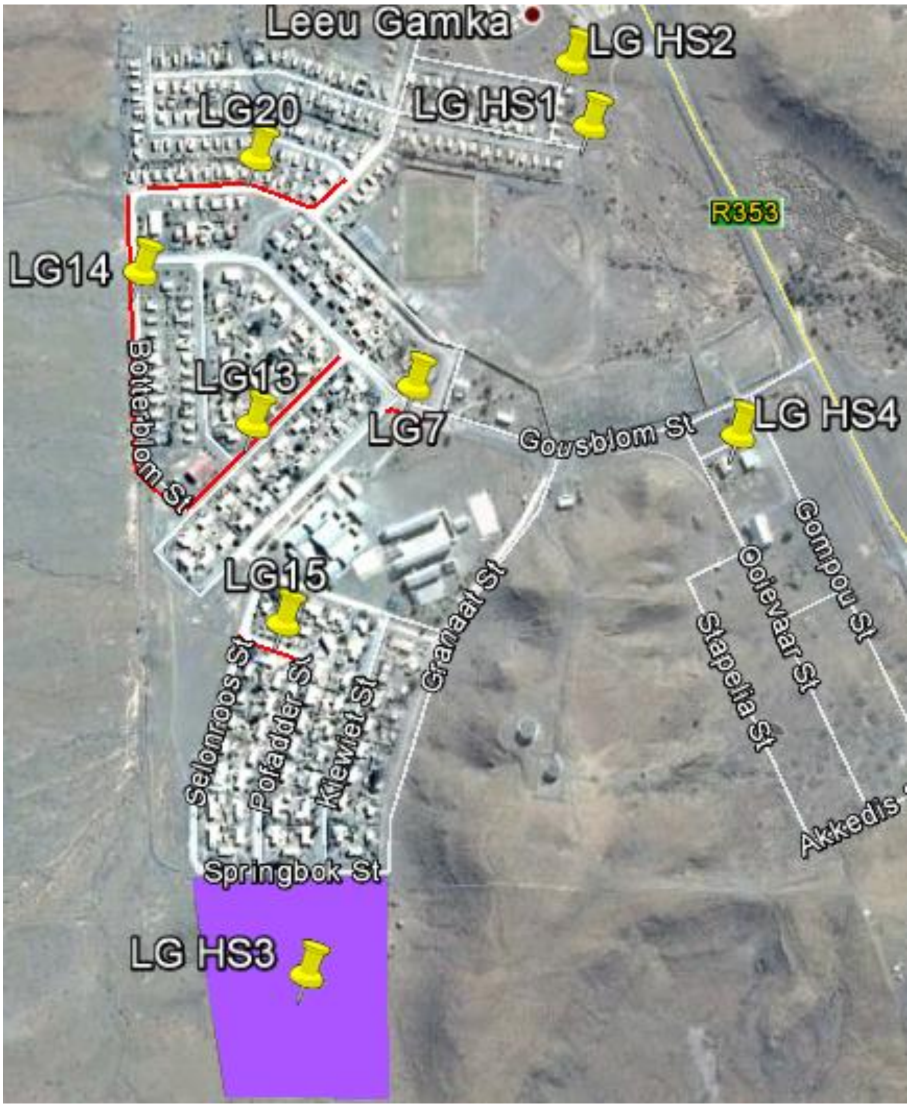
8.1.3 Leeu Gamka

The stormwater issues identified in Leeu Gamka are listed and described in Table 8.3and are shown in Figure 8.3.

Table 8.3: Leeu Gamka Historical Issues

Conduit	Town	Street	Component 1	Material	Comment
LG13	Leeu Gamka	Steenbok	Channel	Concrete	Low point at Vygie, very flat
LG14	Leeu Gamka	Botterblom	Channel	Concrete	Low point at Botterblom and Steenbok and Low point at Gousblom and Botterblom
LG15	Leeu Gamka	Poffader	Channel	Concrete	Low point near top, drains backwards
LG20	Leeu Gamka	Duiker - Aster	Channel	Concrete	Depth varies from 0.15 at start to 1m at culvert LG20

Figure 8.3: Map of Leeu Gamka Historical Stormwater Issues



8.1.4 Klaarstroom

The stormwater issues identified in Klaarstroom are listed and described in Table 8.4and are shown in Figure 8.4.

Table 8.4: Klaarstroom Historical Issues

Conduit	Street	Structure	Material	Comments
C3	Klaarstroom	Channel	Unlined	Dense vegetation which could cause ponding upstream
K8	Aalwyn	Channel	Concrete	Slope very flat water stands. Doesnot stop water from flowing into houses downstream
K12	Unknown and R407	Culvert	Concrete	Some rubbish blocking inlet
K13	R 407	Channel	Stone pitched and unlined	Poor condition

Figure 8.4: Map of Klaarstroom Historical Stormwater Issues

8.2 Stormwater Issues from Analysis

The following stormwater issues were isolated:

- Velocity - Conduits with velocity greater than 2m/s. If stormwater flows too fast it could cause accelerated deterioration of conduits.
- Supercritical – Supercritical flow of stormwater in conduits. Supercritical flow can flow over shallow channels and v-drains, essentially bypass the intended stormwater drainage path causing flooding to properties and unnecessary ponding.
- Flooding/Capacity – Stormwater conduits with insufficient capacity. Conduits with poor capacity can overflow and cause local flooding.

8.2.1 Prince Albert South

Most of the stormwater problems in Prince Albert appear to be with the collection of stormwater in the roads west of Church Street (Market Street) and also with the outlet of stormwater in the streets to the east of Church Street (Luttig, Stokenstrom and Jordaan). The stormwater issues identified in the analysis are listed in Table 8.5and shown in Figure 8.5.

Table 8.5: Prince Albert North Stormwater Issues

Conduit	Velocity	Super Critical	Flooding
PAS10_2	Yes	Yes	Yes
PAS49,50	Yes	Yes	Yes
PAS61	Yes	Yes	Yes
PAS62_1	Yes	Yes	Yes
PAS62_2		Yes	Yes
PAS62_3	Yes	Yes	Yes
PAS69	Yes	Yes	Yes
PAS25_2	Yes	Yes	
PAS1	Yes	Yes	
PAS10_1	Yes	Yes	
PAS19	Yes	Yes	
PAS21	Yes	Yes	
PAS25_1	Yes	Yes	
PAS31	Yes	Yes	
PAS32,33	Yes	Yes	
PAS4	Yes	Yes	
PAS48_1	Yes	Yes	
PAS5_2	Yes	Yes	
PAS59	Yes	Yes	
PAS6_2	Yes	Yes	
PAS6_3	Yes	Yes	
PAS66	Yes	Yes	
PAS8	Yes	Yes	

Figure 8.5: Identified Stormwater Analysis Issues in Prince Albert South

8.2.2 Prince Albert North

Prince Albert North has a lot of issues because of supercritical flowing stormwater. The channels are often too shallow and have sharp direction changes and therefore water just continues on its initial flow path into properties and onto the roads (Buitekant and KronkelWeg). The stormwater issues identified in the analysis are listed in Table 8.6 and shown in Figure 8.6.

Table 8.6: Prince Albert North Stormwater Issues

Conduit	Velocity	Super Critical	Flooding/Capacity
PAN5		Yes	
PAN6		Yes	Yes
PAN51	Yes	Yes	
PAN8		Yes	
PAN12		Yes	
PAN13	Yes	Yes	
PAN18		Yes	
PAN19_1	Yes	Yes	
PAN19_2	Yes	Yes	Yes
PAN20	Yes	Yes	Yes
PAN28		Yes	
PAN30	Yes	Yes	Yes
PAN32		Yes	
PAN34		Yes	
PAN35	Yes	Yes	
PAN37		Yes	
PAN39	Yes	Yes	
PAN42		Yes	

Figure 8.6: Identified Stormwater Analysis Issues in Prince Albert North

8.2.3 Leeu Gamka

Leeu Gamka's main stormwater problems are the culverts in Aster Street. Other issues include supercritical flow from the channels in the new housing development portion of the Leeu Gamka. The stormwater issues identified in the analysis are listed in Table 8.7 and shown in Figure 8.7.

Table 8.7: Leeu Gamka Stormwater Issues

Conduit	Velocity	Super Critical	Flooding/ Capacity
LG20		Yes	Yes
LG13		Yes	
LG15		Yes	
LG16	Yes	Yes	
LG17	Yes	Yes	
LG18	Yes	Yes	
LG19		Yes	

Figure 8.7: Identified Stormwater Analysis Issues in Leeu Gamka

8.2.4 Klaarstroom

Klaarstroom does not have sufficient capacity to convey stormwater away from the settlement (K17 and C3). In addition some local flooding occurs due to supercritical flow – stormwater flows past K8 on Aalwyn Street into properties on other side of street. The stormwater issues identified in the analysis are listed in Table 8.8 and shown in Figure 8.8.

Table 8.8: Klaarstroom Stormwater Issues

Conduit	Velocity	Super Critical	Flooding/Capacity
K8		Yes	
K1	Yes	Yes	
K12		Yes	
K13		Yes	

Conduit	Velocity	Super Critical	Flooding/Capacity
C6	Yes		
K14	Yes		
C3			Yes
K17			Yes

Figure 8.8: Identified Stormwater Analysis Issues in Klaarstroom

9 Stormwater Needs Assessment and Prioritisation

9.1 Project Needs and Solutions

The projects were assessed and categorised as having one the following needs:

9.1.1 Greater capacity

The conduit needs to be increased in cross sectional size to have a larger discharge capacity to avoid flooding and undesirable velocities of greater than 2m/s. For instance if the velocities in a stone-pitched stormwater channel are greater than the allowable velocity for the diameter of stone used, the stones can loosened and washed away from the frictional and gravitational forces exerted upon it.

9.1.2 Repair of channel and resurfacing

Repair of existing damaged structures to restore structural integrity and hydraulic capacity. Surfaces may also need to be regarded to ensure slopes adequate for drainage. Slopes should not be less than 0.5%.

9.1.3 Removal of vegetation and debris

Vegetation and debris can block and hamper the hydraulic capacity of hydraulic structures leading to flooding. Vegetation needs to be removed to restore the hydraulic capacity. This is seen as a once off as this should be part of routing maintenance. Hydraulic structures should be checked and cleaned as forth-nightly throughout the year to prevent vegetation and debris build up. It is assumed that routine maintenance will form part of the duties and budget of the PALM Roads and Stormwater Department.

9.1.4 Diversion of stormwater flow

Supercritical flow can cause flooding if channel and kerb bends are too tight and the stormwater flow is travelling too fast to change momentum with the bend. The flow continues on its initial trajectory by-passing the bend and can cause local flooding in streets and properties. This supercritical flow can be slowed to a manageable flow through expanding the channel size or by dissipating the energy and re-directing the flow using kerbs.

9.1.5 Storage

Storage of stormwater is primarily used to reduce stormwater post development peak runoff volumes to pre-development levels and also can serve as a means of improving stormwater quality.

9.1.6 Review of stormwater by-law

Whilst the by-laws cover the roles, activities, exceptions, penalties and enforcement of stormwater systems, the bylaw is outdated and does not cover the following issues:

- Stormwater management design flood requirements such as return intervals of storm events to be analysed for integrity of stormwater infrastructure, downstream users and floodplains.
- Stormwater best management practices such as sustainable urban drainage design systems such as detention ponds, artificial swales and permeable paving.
- Stormwater quality requirements in terms of pollutants reductions for phosphorus, nitrogen and total suspended solids (TSS).
- Buffers for floodplains of rivers and streams and the regulations, exceptions, penalties and enforcement of building within floodplains.
- Stipulation that all new developments in SLM must have a stormwater management plan which must be submitted and approved by a professional engineer and council before the development can proceed.

The by-law should be reviewed to encompass the above issues.

9.1.7 Safety

One of the main priorities of stormwater is to protect loss of life and damage to the environment and property. Large stormwater channels can pose a threat to human safety and should be fenced or have rail guards to prevent people or vehicles falling into the stormwater channel and incurring injuries.

9.1.8 Awareness and Pollution Prevention

Awareness needs to be created through the use of stormwater information signs which communicate the importance of stormwater channels and shouldadvise against dumping or littering in these. The signboards should also have contact information for any stormwater related issues.

9.1.9 Improving Repairs and Maintenance

A stormwater complaints register should be compiled to understand what hydraulic structures need attention for repairs and unscheduled maintenance. The complaints register should detail the problem, solutions and outcomes of each incident.

9.1.10 Stormwater Quality

Currently PALM has no stormwater quality targets, practices or infrastructure in place. Sustainable urban drainage infrastructure such as swales and infiltration trenches could be used but this will require additional area to accommodate the discharge and PALM has limited space for development. It is best to control stormwater quality before entry to the detention ponds. Stormwater quality can be controlled using sediment and litter traps.

9.2 Priority

The projects were then individually identified in terms of the types of needs they meet. The impact was rated in terms of the following impact categories:

- Damage to property – The potential impact that the hydraulic structure has on flooding of properties if no solution is implemented.
- Loss of Life/ Environment - The potential impact that the hydraulic structure has on damaging the receiving natural environment and risk that it poses to human safety.
- Structural Integrity - The potential impact that project will have on the longevity of the hydraulic structure
- Hydraulic Functionality – The potential impact that project will have on the hydraulic functionality (discharge, velocity, turbulence) on the hydraulic structure and stormwater system.
- Financial Impact -The potential impact that project will have on the hydraulic structure and stormwater system if left unattended to.

The above impact categories were then rated using the following scale of 1 to 5:

1. Very Low
2. Low
3. Medium
4. High
5. Very High

Each project was then rated in terms of priority for each category and the total of the impact categories gave an overall priority score.

10 Stormwater Project Proposals

10.1 Proposed Stormwater Projects

The ideology behind the stormwater for each town is discussed in this section. The project list for each category of project per town was grouped and summarised in terms of priority and cost in Table 10.1 to Table 10.4.

10.1.1 Prince Albert South

The projects in Prince Albert South aim at creating additional hydraulic capacity in the hydraulic structures on the East in Market and Nieuwe Street as these are the backbone of the stormwater system. Increase in capacity of these channels will also prevent quicker build-up of runoff into Church Street. Stormwater flow diversion structures between side roads and Church Street need to be installed to prevent water from flowing into properties on the western side. Cleaning and maintenance is also required as key stormwater system components such as the detention pond and channels are blocked with vegetation and debris. Additional detention ponds will need to be developed as part of the areas allocated for future developments. The costs of the detention ponds have been lumped into one sum as the number of detention ponds and the future development design is unknown at this stage.

10.1.2 Prince Albert North

The projects in Prince Albert North are to stormwater flow diversion structures between select roads and need to be installed to prevent water from flowing into properties and flooding the roads. Cleaning and maintenance is also required as key stormwater system components such as culverts and channels are blocked with vegetation and debris. Additionaldetention ponds need to be built in the open are to the north west between the edge of the town and the R353. The costs of the detention ponds have been lumped into one sum as the number of detention ponds and the future development design is unknown at this stage.

10.1.3 Klaarstroom

Klaarstroom requires upgrading of existing channels to improve conveyance of water away from the town towards the natural stream. Most of the projects are for the future developments in the form of providing detention storage areas and formalising unlined channels.

10.1.4 Leeu Gamka

The stormwater projects in Leeu Gamka are focused around building larger channels and diverting stormwater flow. Some channels such as the channel in VygieStreethas to be regarded to drain water away from the households. Leeu Gamka will need to increase the storage area before the culvert in downstream in the R353 and also use the playground at the bottom of Pofadder Street as a storage area for stormwater, to accommodate future development in the town.

10.1.5 General

The general stormwater projects are not discussed here as they were already discussed in sections 9.1.6 to 9.1.10.

Table 10.1: Prince Albert South Stormwater Project List

						Hydraulic Analysis Issues					Impact of Problem									
Conduit	Town	Street	Structure	Material	Comments	Velocity	Super Critical	Flooding	Needs	Possible Solutions	Damage to property	Loss of Life/ Environment	Structural	Hydraulic	Financial	Priority	Unit	Quantity	Unit Cost	Cost
PAS50	Prince Albert	Stockenstroom	Channel	Unlined		Yes	Yes	Yes	Greater capacity	Build larger stormwater channel	2	0	0	5	0	7	m	310	500	1 100
PAS61	Prince Albert	Luttig	Channel	Concrete		Yes	Yes	Yes			2	0	0	5	0	7	m	198	387	40 200
PAS62	Prince Albert	Luttig and De Beer	Channel	Cement		Yes	Yes	Yes			2	0	0	5	0	7	m	600	387	121 700
PAS69	Prince Albert	Meiring	Channel	Concrete		Yes	Yes	Yes			2	0	0	5	0	7	m	210	387	27 700
PAS1	Prince Albert	Nieuwe	Channel	Concrete		Yes	Yes				2	0	0	4	0	6	m	230	550	54 400
PAS10	Prince Albert	Market	Channel	Cement		Yes	Yes				2	0	0	4	0	6	m	572	460	148 700
PAS19	Prince Albert	Church and MagrietaPrinsloo	Culvert	Cement		Yes	Yes				2	0	0	4	0	6	m	8	5913	2 400
PAS21	Prince Albert	Church and MagrietaPrinsloo	Culvert	Cement		Yes	Yes				2	0	0	4	0	6	m	10	476	3 700
PAS31	Prince Albert	Church	Culvert	Cement		Yes	Yes				2	0	0	4	0	6	m	10	745	3 000
PAS4	Prince Albert	Nieuwe - Luttig	Channel	Concrete		Yes	Yes				2	0	0	4	0	6	m	56	664	19 300
PAS48	Prince Albert	Jordaan and De Beer	Channel	Cement		Yes	Yes				2	0	0	4	0	6	m	220	387	29 100
PAS5	Prince Albert	Niuewe	Channel	Concrete		Yes	Yes				2	0	0	4	0	6	m	270	423	107 800
PAS59	Prince Albert	Luttig	Channel	Concrete		Yes	Yes				2	0	0	4	0	6	m	10	519	5 200
PAS6	Prince Albert	Market	Channel	Concrete		Yes	Yes				2	0	0	4	0	6	m	625	664	206 800
PAS66	Prince Albert	Pastorie	Channel	Concrete		Yes	Yes				2	0	0	4	0	6	m	218	786	36 400
PAS8	Prince Albert	Market and Doordrift	Culvert	Brick/Cement		Yes	Yes				2	0	0	4	0	6	m	10	476	8 600
PAS16	Prince Albert	Church	Channel	Stone pitched /Unlined	Partially vegetated. Slope appears too flat too optimally				Repair of concrete channel and resurfacing Removal of vegetation and debris	Cleaning & Maintenance	2	0	2	3	0	7	m	273	645	16 400
PAS49	Prince Albert	Stockenstroom	Culvert	Cement	Blocked by vegetation	Yes	Yes	Yes	Removal of vegetation and debris		2	0	1	4	0	7	m	8	476	500
PAS10	Prince Albert	Market	Channel	Cement	Partial vegetation and debris	Yes	Yes	Yes			1	0	1	4	0	6	m	572	460	34 400
PAS11	Prince Albert	Market - MagrietaPrinsloo	Channel	Grass	Dense vegetation						2	0	1	3	0	6	m	65	29	3 900
PAS13	Prince Albert	MagrietaPrinsloo	Culvert	Cement	Partially blocked by vegetation and debris						2	0	1	3	0	6	m	15	5913	900
PAS25	Prince Albert	Jordaan	Channel	Concrete	Inlet blocked with vegetation	Yes	Yes				0	2	0	4	0	6	m	33	387	2 000
PAS44	Prince Albert	Christina De Wit	Channel	Unlined / Stone pitched	Partially covered with vegetation						2	0	1	3	0	6	m	230	359	13 800
PAS46	Prince Albert	Jordaan and	Culvert	Concrete	Blocked						2	0	1	3	0	6	m	8	476	500

						Hydraulic Analysis Issues					Impact of Problem									
Conduit	Town	Street	Structure	Material	Comments	Velocity	Super Critical	Flooding	Needs	Possible Solutions	Damage to property	Loss of Life/ Environment	Structural	Hydraulic	Financial	Priority	Unit	Quantity	Unit Cost	Cost
		De Beer			with garbage															
PAS47	Prince Albert	Jordaan and De Beer	Channel	Unlined	Poorly shaped and sloped. Vegetation growth and debris						2	0	1	3	0	6	m	50	6	3 000
PAS64	Prince Albert	De Beer	Channel	Unlined	Covered with dense vegetation						2	0	1	3	0	6	m	365	12	21 900
PAS27	Prince Albert	Jordaan	Detention pond outlet	Concrete	Outlet blocked by vegetation						2	0	1	3	0	6	m	2	72	200
PAS26	Prince Albert	Jordaan	Detention Pond	Brick and Concrete	Inlet blocked with vegetation and vegetation growing in pond, concrete cracking				Removal of vegetation and debris Repair of concrete floor surface	Cleaning, Maintenance & Repair of concrete channel and resurfacing	2	0	2	3	2	9	m2	256	472	4 400
PAS HS1	Prince Albert	Corner of Market Street and one street past MargarietPrinsloo						Yes	Divert flow of stormwater away from road into side kerbs	Diversion structure or Construct Channel	2	0	0	4	0	6		1		10 000
PAS HS2	Prince Albert	Corner of Odendaal Street and Market Street						Yes	Divert flow of stormwater away from house back into field across road crossing		2	0	0	4	0	6		1		10 000
PAS HS3	Prince Albert	Corner of R328 (Gay's Dairy)						Yes	Divert flow of stormwater away from road		2	0	0	4	0	6		1		10 000
PAS HS4	Prince Albert	Parsonage Street into Church Street						Yes	Flooding from PAS45 --> Divert flow of stormwater away from entrance into stormwater channel		2	0	0	4	0	6		1		10 000
PAS HS5	Prince Albert	Bank Street into Church Street						Yes	Divert flow of stormwater away from road		2	0	0	4	0	6		1		10 000
PAS HS6	Prince Albert	Chaplin Street into Church Street						Yes	Divert flow of stormwater away from road		2	0	0	4	0	6		1		10 000
PAS23	Prince Albert	Jordaan and Church	Channel	Stone pitched	Greywater from prison flowing into system				Diversion of sewage away from stormwater	Diversion structure Tie into sewer directly	2	0	0	2	0	4	m	22	396	5 000
PAS24	Prince Albert	Jordaan	Culvert	Concrete	Greywater from prison flowing into system				Diversion of sewage away from stormwater		0	2	0	2	0	4	m	9	164	5 000

Conduit	Town	Street	Structure	Material	Comments	Hydraulic Analysis Issues			Needs	Possible Solutions	Impact of Problem					Priority	Unit	Quantity	Unit Cost	Cost
						Velocity	Super Critical	Flooding			Damage to property	Loss of Life/ Environment	Structural	Hydraulic	Financial					
PAS5	Prince Albert	Niuewe	Channel	Concrete	Badly damaged. Crumbling and has poor slope and profile				Channel surfacing	Repair of concrete channel and resurfacing	0	0	2	1	1	4	m	270	423	107 800
PAS2	Prince Albert	Klip - Nieuwe	Channel	Stone Pitched	Stone pitching worn away and partially covered in dense vegetation				Stone pitching	Repair of stone pitching	0	0	2	1	1	4	m	60	733	8 800
PAS78	Prince Albert South	Use Future Development Areas	Detention Pond	Grass					Storage	Detention Pond	2	1	0	2	1	6	m³			86 900

Table 10.2: Prince Albert North Stormwater Project List

Conduit	Town	Street	Structure	Material	Comments	Hydraulic Analysis Issues			Needs	Possible Solutions	Impact of Problem					Priority	Unit	Quantity	Unit Cost	Cost	Cost
						Velocity	Super Critical	Flooding			Damage to property	Loss of Life/ Environment	Structural	Hydraulic	Financial						
PAN51	Prince Albert	Luttig intersection	Channel	Concrete	Accumulation of silt.	Yes	Yes		Removal of vegetation and debris	Cleaning & Maintenance	1	0	0	2	0	3	m	50	549.73	3 000	3 000
PAN34	Prince Albert	Rand to R328	Channel	Unlined	Unmaintained		Yes				1	0	0	2	0	3	m	150	12.15	9 000	9 000
PAN42	Prince Albert	Rand	Road Crossing	Concrete	Blocked with debris and vegetation		Yes				1	0	0	2	0	3	m	16	586.8	960	1 000
PAN2	Prince Albert	Enslin	Culvert	Concrete	Blocked with some rubbish and vegetation						1	0	0	2	0	3	m	14	945.3	840	900
PAN3	Prince Albert	Enslin walkway	Culvert	Plastic	Blocked with some rubbish and vegetation	Yes	Yes				1	0	0	2	0	3	m	4	814.15	240	300
PAN23	Prince Albert	Botterblom	Culvert	Concrete	Partially full with debris. Appears to be an illegal dumping hot spot.						1	0	0	2	0	3	m	10	15284	600	600
PAN40	Prince Albert	Loop-KronkelWeg	Channel	Concrete	Silted up			Yes			1	0	0	2	0	3	m	54.54	624.52	3 272	3 300
PAN46	Prince Albert	Open field between Rand and R328	Channel	Unlined	Unmaintained channel. Partially covered in vegetation and debris			Yes			1	0	0	2	0	3	m	208.03	12.15	12 482	12 500
PAN47	Prince Albert	Open field between Rand and R328	Channel	Unlined	Unmaintained channel. Partially covered in vegetation and debris			Yes			1	0	0	2	0	3	m	85.56	12.15	5 134	5 200
PAN48	Prince Albert	Open field between Rand and R328	Channel	Unlined	Unmaintained channel. Partially covered in vegetation and debris						1	0	0	2	0	3	m	145	12.15	8 700	8 700

Conduit	Town	Street	Structure	Material	Comments	Hydraulic Analysis Issues: Velocity	Super Critical	Flooding	Needs	Possible Solutions	Impact of Problem: Damage to property	Loss of Life/ Environment	Structural	Hydraulic	Financial	Priority	Unit	Quantity	Unit Cost	Cost	Cost
PAN49	Prince Albert	Sports field	Channel	Stone Pitched	Slightly silted up with soil						1	0	0	2	0	3	m	157	375.76	9 420	9 500
PAN50	Prince Albert	Open field to culvert PAN33	Channel	Unlined	Unmaintained channel. Partially covered in vegetation and debris						1	0	0	2	0	3	m	139	12.15	8 340	8 400
PAN19	Prince Albert	Karee	Channel	Concrete	Blocked by house driveways and debris. Slope too flat	Yes	Yes	Yes	Removal of vegetation and debris Divert Stormwater	Cleaning & Maintenance, Diversion Structure	1	0	0	3	0	4	m	150	324.27	46 500	46 500
PAN12	Prince Albert	2nd Avenue	Channel	Concrete			Yes		Divert Stormwater into channels	Diversion Structure	2	0	0	2	0	4	m	165		500	500
PAN13	Prince Albert	3rd Avenue	Channel	Concrete		Yes	Yes				2	0	0	2	0	4	m	48		10 000	10 000
PAN20	Prince Albert	Spires and Karee	Channel	Concrete	Drains into an unlined informal channel	Yes	Yes	Yes			1	0	0	3	0	4	m	63		10 000	10 000
PAN37	Prince Albert	KronkelWeg - Rand	Channel	Concrete			Yes				1	0	1	2	0	4	m	71.85	851.34	4 311	4 400
PAN26	Prince Albert	Botterblom	Gabion	Rocks and cement	Gabion slightly worn. Rocks missing				Repair	Repair	1	0	1	0	1	3	m	52	504	2 942	3 000
PAN24	Prince Albert	Botterblom	Gabion	Rocks and cement	Gabion slightly worn. Rocks missing						1	0	1	0	1	2	m	27	504	2 942	3 000
PAN25	Prince Albert	Botterblom	Gabion	Rocks and cement	Gabion slightly worn. Rocks missing						1	0	1	0	1	2	m	36	504	2 942	3 000
PAN53	Prince Albert	New Area by berm	Channel	Grass					Stormwater needs to be conveyed	New channels	2	1	0	2	0	5	m	450			17 300
PAN54	Prince Albert North	Excavate existing areas upstream of culverts	Detention Pond	Grass					Storage	Detention Pond	2	1	0	2	1	6	m^3				308 100

Table 10.3: Klaarstroom Stormwater Project List

Conduit	Town	Street	Structure	Material	Comments	Hydraulic Analysis Issues: Velocity	Super Critical	Flooding	Needs	Possible Solutions	Impact of Problem: Damage to property	Loss of Life/ Environment	Structural	Hydraulic	Financial	Priority	Unit	Quantity	Unit Cost	Cost
K12	Klaarstroom	Aalwyn Street and R407	Culvert	Concrete	Some rubbish blocking inlet		Yes		Removal of vegetation and debris	Cleaning & Maintenance	1	0	0	2	0	3	m	9	60	600
C1	Klaarstroom	Natural channel	Channel	Unlined		Yes			Removal of vegetation and debris		2	0	0	2	0	4	m	50	60	3 000
C3	Klaarstroom	407	Channel	Unlined	Dense			Yes	Removal of		1	0	0	3	0	4	m	86	60	5 200

Conduit	Town	Street	Structure	Material	Comments	Hydraulic Analysis Issues: Velocity	Hydraulic Analysis Issues: Super Critical	Hydraulic Analysis Issues: Flooding	Needs	Possible Solutions	Impact of Problem: Damage to property	Impact of Problem: Loss of Life/ Environment	Impact of Problem: Structural	Impact of Problem: Hydraulic	Impact of Problem: Financial	Priority	Unit	Quantity	Unit Cost	Cost
					vegetation downstream which could cause ponding upstream				vegetation											
K13	Klaarstroom	R 407	Channel	Stone pitched and unlined	Poor condition.		Yes		Repair	Repair surface	1	0	2	1	0	4	m	254	0	13 100
K8	Klaarstroom	Aalwyn	Channel	Concrete	Slope very flat water stands. Does not stop water from flowing into houses downstream		Yes		Divert stormwater flow	Diversion Structure	3	0	0	2	0	5	m	120	500	60 000
K14	Klaarstroom	Dirt road and R407	Culvert	Concrete		Yes			Insufficient area	Increase culvert size	2	0	0	3	0	5	m	4		10 300
K17	Klaarstroom	Bloekom into the existing Vdrain to K3	Channel	Concrete							2	1	0	2	0	5	m			31 700
K18 (C1)	Klaarstroom	Natural channel	Channel	Concrete					Stormwater needs to be conveyed	New channels	2	1	0	2	0	5	m			29 200
K19 (C3)	Klaarstroom	R 407	Channel	Concrete							2	1	0	2	0	5	m			12 000
K20	Klaarstroom	Residential and Agricultural	Detention Pond	Grass					Storage	Detention Pond	2	1	0	2	1	6	m^3			66 300
K21	Klaarstoom	Business	Detention Pond	Grass							2	1	0	2	1	6	m^3			102 600

Table 10.4: Leeu Gamka Stormwater Project List

Conduit	Town	Street	Structure	Material	Comments	Hydraulic Analysis Issues: Velocity	Hydraulic Analysis Issues: Super Critical	Hydraulic Analysis Issues: Flooding	Needs	Possible Solutions	Impact of Problem: Damage to property	Impact of Problem: Loss of Life/ Environment	Impact of Problem: Structural	Impact of Problem: Hydraulic	Impact of Problem: Financial	Priority	Unit	Quantity	Unit Cost	Cost
LG22	Leeu Gamka	Aster	Culvert	Concrete					Greater capacity & Cleaning	Build larger culvert	3	0	0	5	0	8	m	10	2644	26 500
LG20	Leeu Gamka	Duiker - Aster	Channel	Concrete	Depth varies from 0.15 at start to 1m at culvert LG20		Yes	Yes	Greater capacity	Build larger stormwater channel	3	0	0	5	0	8	m	200	1155	231 100
LG23	Leeu Gamka	Aster	Channel	Concrete					Greater capacity		3	0	0	5	0	8	m	32	931	29 900
LG17	Leeu Gamka	New houses - unnamed street	Channel	Concrete		Yes	Yes		Divert flow of stormwater	Diversion Structure	3	0	0	1	0	4				10 000
LG18	Leeu Gamka	New houses - unnamed street	Channel	Concrete		Yes	Yes		Divert flow of stormwater		3	0	0	1	0	4				10 000
LG19	Leeu Gamka	New houses - unnamed street	Channel	Concrete			Yes		Divert flow of stormwater		3	0	0	1	0	4				10 000

						Hydraulic Analysis Issues					Impact of Problem									
Conduit	Town	Street	Structure	Material	Comments	Velocity	Super Critical	Flooding	Needs	Possible Solutions	Damage to property	Loss of Life/ Environment	Structural	Hydraulic	Financial	Priority	Unit	Quantity	Unit Cost	Cost
LG16	Leeu Gamka	Springbok	Channel	Concrete		Yes	Yes		Divert flow of stormwater		2	0	0	1	0	3				10 000
LG15	Leeu Gamka	Poffader	Channel	Concrete		Yes	Yes		Divert flow of stormwater		2	0	0	1	0	3				10 000
LG15	Leeu Gamka	Poffader	Channel	Concrete	Low point near top, drains backwards		Yes		Divert flow of stormwater		1	0	0	1	0	2				10 000
LG14	Leeu Gamka	Botterblom	Channel	Concrete	Low point at Botterblom and Steenbok and Low point at Gousblom and Botterblom	Yes	Yes		Regrade channel	Regrade channel	2	0	1	1	1	5	m	330	597	197 100
LG13	Leeu Gamka	Steenbok	Channel	Concrete	Low point at Vygie, very flat		Yes		Regrade channel		1	0	1	1	1	4	m	210	545	114 500
LG30 (C1)	Leeu Gamka	Through Playground at the bottom of Pofadder Street	Channel	Concrete						Build new channels	1	1	0	2	0	4	m			29 300
LG31	Leeu Gamka	Community Hall to Gousblom	Channel	Concrete							2	1	0	2	0	5	m			38 300
LG32	Leeu Gamka	Existing or new - school playground or new	Detention Pond	Grass					Storage	Detention Pond	2	1	0	2	1	6	m^3			96 600

11 Final Projects, Programme and Cashflow

Common projects per town were grouped into packets and were given approximate durations, a programme and costs. The list of all project packets is shown in Table 11.1. The total cost of projects is approximately R3.3 million. However, this is spread out over three financial years 2014/15 to 2016/17. SLM currently has allocated R2 million for stormwater projects and therefore has allocated enough money for most projects in starting 2014/15. Additional funding will need to be acquired through road upgrade projects and possibly the Municipal Infrastructure Grant.

Stormwater funding should be built into 15% of road project costs. The replacement of hydraulic structures has not been included as most infrastructure in PALM will only need upgrading in 10 to 15 years. Preferably the stormwater master plan should be reviewed in fiveyears to assess progress made towards stormwater management and also highlight the needs with respect to the updated SDF.

Table 11.1: Prince Albert Local Municipality Stormwater Project List, Programme and Cashflow

Project Number	Description	Hydraulic Structure	Project Cost	Duration	Start Year	End Year	Year		
							2014/15	2015/2016	2017/2018
SWMP_PAS1	Constructing new culverts and channels	PAS50, PAS61, PAS61, PAS62, PAS69, PAS1, PAS10, PAS19, PAS21, PAS31, PAS4, PAS48, PAS5, PAS59, PAS6, PAS66, PAS8	R 816 100	24 months	2014/15	2016/17	R 136 017	R 408 050	R 272 033
SWMP_PAS2	Constructing diversion structures	PAS HS1, PAS HS2, PAS HS3, PAS HS4, PAS HS5, PAS HS6, PAS23, PAS24	R 70 000	12 months	2014/15	2015/16	R 23 333	R 46 667	
SWMP_PAS3	Cleaning of hydraulic structures	PAS16, PAS49, PAS10, PAS11, PAS13, PAS25, PAS44, PAS46, PAS47, PAS64, PAS27	R 97 500	3 weeks	2014/15	2015/16	R 97 500		
SWMP_PAS4	Repair of hydraulic Structures	PAS26, PAS5, PAS2	R 121 000	1 month	2014/15	2015/16	R 121 000		
SWMP_PAS5	Constructing new stormwater ponds	PAS78	R 308 100	6 months	2014/15	2015/16	R 205 400	R 102 700	
Total Cost for SWMP_PAS			**R 1 412 700**						
SWMP_PAN1	Constructing diversion structures	PAN19, PAN12, PAN13, PAN20, PAN37, PAN53	R 88 700	12 months	2014/15	2015/16	R 29 567	R 59 133	
SWMP_PAN2	Cleaning of hydraulic structures	PAN51, PAN34, PAN42, PAN2, PAN3, PAN23, PAN40, PAN46, PAN47, PAN48, PAN49, PAN50	R 62 400	2 weeks	2014/15	2015/16	R 62 400		
SWMP_PAN3	Repair of hydraulic Structures	PAN26, PAN24, PAN25	R 9 000	1 month	2014/15	2015/16	R 9 000		
SWMP_PAN5	Detention Pond	PAN54	R 308 100	6 months	2014/15	2015/16	R 205 400	R 102 700	
Total Cost for SWMP_PAN			**R 468 200**						
SWMP_LG1	Constructing new culverts and channels	LG22, LG20, LG23, LG30 (C1), LG31	R 355 100	8 months	2014/15	2015/16	R 177 550	R 177 550	
SWMP_LG2	Constructing diversion structures	LG17, LG18, LG19, LG16, LG15, LG15	R 60 000	12 months	2014/15	2015/16	R 20 000	R 40 000	
SWMP_LG3	Regrading channels	LG14, LG13	R 311 600	4 months	2014/15	2015/16	R 103 867	R 207 733	
SWMP_LG5	Detention Pond	LG32	R 187 900	6 months	2014/15	2015/16	R 125 267	R 62 633	
Total Cost for SWMP_LG			**R 914 600**						
SWMP_K1	Constructing new culverts and channels	K14, K18 (C1), K19 (C3)	R 51 500	6 months	2014/15	2015/16	R 34 333	R 17 167	
SWMP_K2	Constructing diversion structures	K8	R 60 000	4 months	2014/15	2015/16	R 60 000		
SWMP_K3	Cleaning of hydraulic structures	K12, C1, C3	R 8 800	1 week	2014/15	2015/16	R 8 800		
SWMP_K4	Repair of hydraulic Structures	K13	R 13 100	1 month	2014/15	2015/16	R 13 100		
SWMP_K5	Detention Pond	K20, K21	R 168 900	6 months	2014/15	2015/16	R 112 600	R 56 300	
Total Cost for SWMP_K			R 302 300						
SWMP_Gen1	Review of stormwater by-law		R 75 000	6 months	2014/15	2015/16	R 50 000	R 25 000	
SWMP_Gen2	Safety railguards		R 30 000	2 months	2014/15	2015/16	R 30 000		
SWMP_Gen3	Stormwater Information signs		R 15 000	2 months	2014/15	2015/16	R 15 000		
SWMP_Gen4	Stormwater Complaints Register		R 10 000	1 month	2014/15	2015/16	R 10 000		
SWMP_Gen5	Stormwater Quality - Sediment and Litter Traps for Detention Ponds		R 100 000	Should be part of detention pond construction	2014/15	2015/16	R 100 000		
Total Cost for SWMP_Gen			R 230 000						
Total			**R 3 327 800**				**R 1 750 133**	**R 1 305 633**	**R 272 033**

12 Conclusion

Prince Albert requires the following stormwater projects to improve the current stormwater system situation and also to cater for future development:

- Constructing new culverts and channels,
- Constructing diversion structures,
- Cleaning of hydraulic structures,
- Repair of hydraulic structures,
- Constructing new stomwater ponds,
- Review of stormwater by-law,
- Safety rail guards,
- Stormwater Information signs,
- Stormwater Complaints register, and
- Stormwater Quality - sediment and litter traps for detention ponds.

The projects could be built over a 3 year financial period between 2014/15 to 2016/17 and will cost approximately R3.3 million. PALM only has made R2 million available for 2014/15 but will need to acquire additional funding.

13 Recommendations

The major recommendations emerging from this report are as follows:

- PALM should implement the projects list as prescribed in this report to remedy the stormwater system.
- Funding for future stormwater projects should be secured for the years 2015/16 and 2017/18.
- The Stormwater Master Plan should be revised every 5 years as PALM is still developing.
- The location of detention ponds requires initial design investigations.

14 References

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