WIND GARDEN WIND FARM

Report for the Handling and Disposal of Sewage During Construction and Post-Construction

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Revision 1

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1 Introduction

1.1 Report Framework

Engineering Advice and Services Pty (Ltd) were requested to compile a Report for the Handling and Disposal of Sewage for the Wind Garden Wind Farm.

The report will determine the volumes of sewerage to be disposed by the Contractor's site camp, as well as permanent offices and maintenance depots. The volumes of effluent for each of the facilities will be determined by reviewing Industry Norm literature, such as *The Neighbourhood Planning and Design Guide, commonly referred to as the "Red Book"*, as well as reviewing the quantities produced on similar previous Wind Farm projects.

The report will further review the various technologies currently available that can be utilised in dealing with the effluent, as well as the Environmental Requirements that need to be complied with for each.

Based on the above, a matrix will be developed in which the information will be set out which will assist in determining which solution, will be applicable for the various facilities mentioned above.

1.2 Initial Scope of Project

The project involves the construction of 47 wind turbines, in an area located north-west of Grahamstown, as depicted in Figure 1 overleaf.

The following methodology will be followed in determining the most efficient form of sanitation for the various facilities:

- Assume positions for the Contractor's site camp
- Assume position of the permanent office park, operation and maintenance depot facilities
- Determine the estimated number of staff using the temporary and permanent facilities mentioned above
- Determine the anticipated sewage discharge from the above facilities
- Obtain the treatment capacity of the existing WWTW in Grahamstown, as well as any spare capacity
- Review current sewage treatment technologies
- Review environmental requirements of the above technologies
- Review DWS requirements for the above technologies
- Identify and highlight the specific constraints associated with each type of technology
- Prepare conceptual / preliminary cost estimates for the proposed technologies recommended for each of the facilities
- Document findings in engineering conceptual feasibility report.

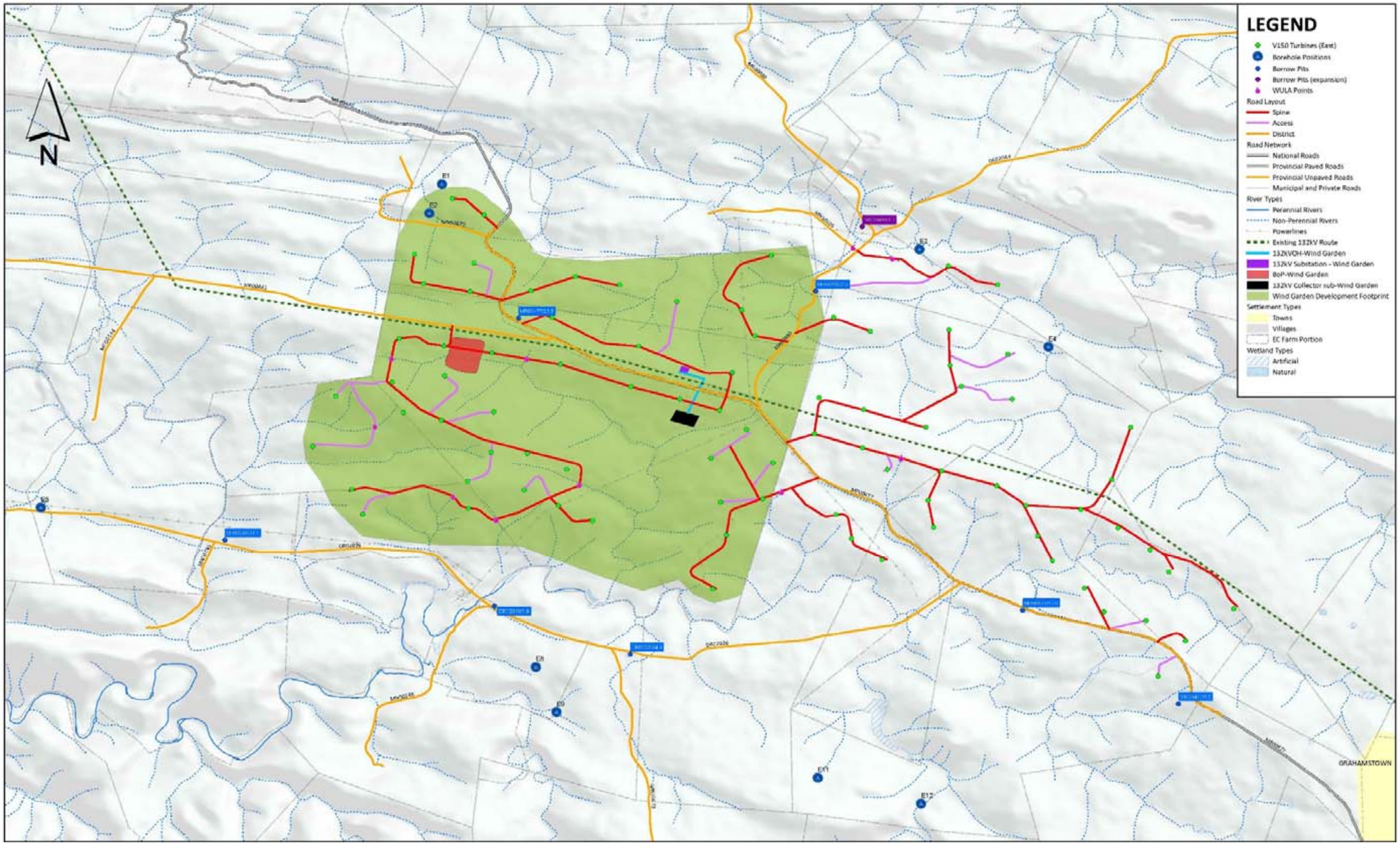


Figure 1 – Locality of Wind Garden Wind Farm

2 Location of Facilities

The project will require a number of facilities during the construction phase and post-construction phase, and are required to be within close proximity to the wind turbines. The facilities which will form part of the project are as follows:

- Contractor’s Site Camp
- Operation and Maintenance Depot
- Permanent Office Park

The above facilities are expected to be located within the Balance of Plant (BoP) area, and the Collector Sub area. The BoP area is highlighted in red in Figure 2, and the Collector sub area highlighted in green. The yellow shaded area, represents the development footprint of the Wind Garden wind farm. The BoP area is defined as the location where all the infrastructure, supporting components and auxiliary systems of a wind power plant needed to deliver the energy, other than the wind turbines, are to be located. This area is located approximately 20.9km north-west of Grahamstown along the R350. The collector sub area, will house the permeant infrastructure post-construction. The coordinates of a point within the centre of both the BoP and Collector Sub areas are listed below:

	Latitude	**Longitude**
Balance of Plant	33°12'39.58"S	26°21'17.34"E
Collector Sub	33°13'21.20"S	26°23'15.08"E

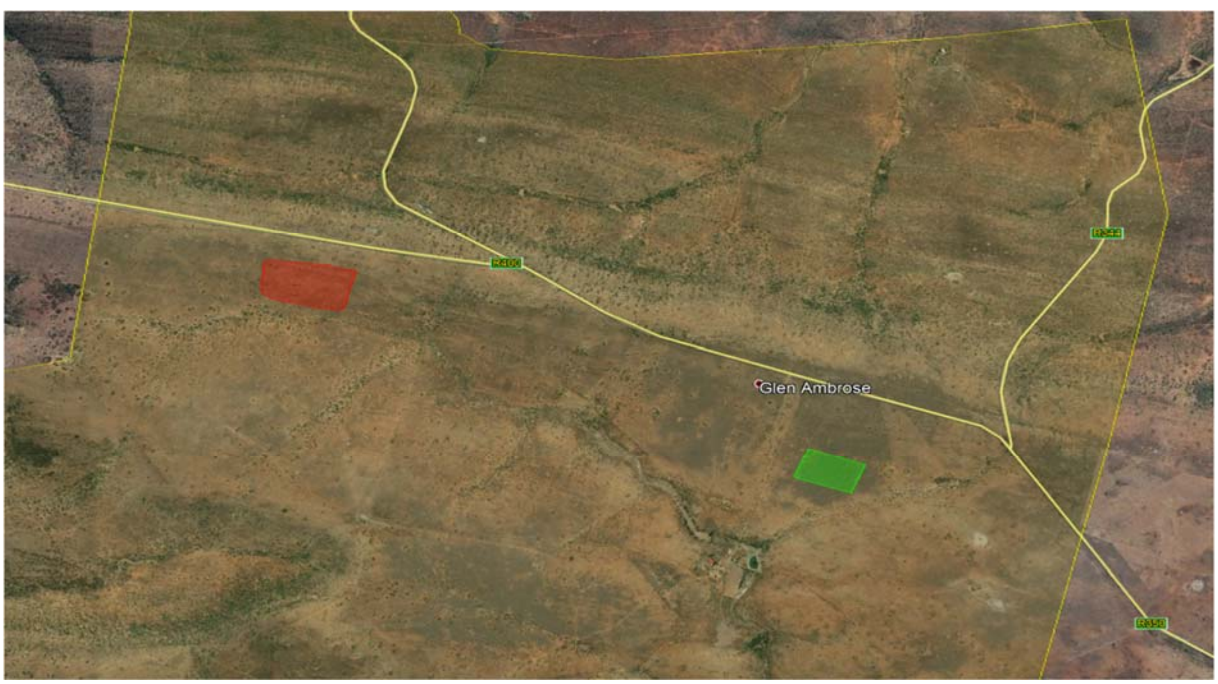


Figure 2 – Location of the BoP area and Collector Sub area for Wind Garden wind farm

The Contractor shall have one fixed site camp within the region, which shall serve as the Contractor's base of operations during the construction phase. All tools, materials, equipment and plant shall be housed at the site camp. The Contractor's site camp is most likely to consist of temporary containers and other temporary structures.

The operations and maintenance depot, and the permanent office park, will both be permanent structures, and will form part of the post-construction phase. These buildings will typically have the following facilities:

- Toilets
- Work areas
- Board room
- Training room
- Various storage areas
- Collection areas
- Kitchen area

3 Anticipated Number of Staff

The total anticipated number of staff, both during and post construction, were based on the number of wind turbines constructed. Table 1 below contains the number of anticipated staff during construction, whom will be living on site, and Table 2 contains the anticipated number of staff post construction. The off-site staff are expected to travel to the site each day, but live off of site, on a nearby farm or in a nearby town.

Table 1 – Total anticipated number of staff during construction

On Site Staff	**Construction Phases & Estimated Durations**			
	Start-up 2 months	**Growth** 12 months	**Peak** 12 months	**Commissioning** 4 months
Road Construction Teams	18	30	30	0
Foundation Construction Teams	0	116	116	0
Electrical Teams	13	43	43	26
Crane & Erection Teams	0	0	22	22
Total Workers living on site	**31**	**189**	**211**	**48**
Off Site Staff	**26**	**43**	**43**	**26**
Total Number of Staff on Site	**57**	**232**	**254**	**74**

Table 2 – Total anticipated number of staff post-construction

Number of Turbines	47
Anticipated number of Post construction staff	**15**

It should be noted that the number of staff on site will increase and **peak over time**, as more components are constructed. The number of staff will also diminish towards the end of construction. Therefore, the total number of staff during the peak period of **254** shall be designed for, as this represents the *worst-case scenario*, which the sewage handling system must be able to accommodate. In the event that the total number of actual staff on site during construction is *less than 254*, the service interval for the sewage handling system may be extended.

4 Anticipated Sewage Demand

In order to determine the water demand and hence the sewage demand for the project, Section J (Water Supply) and Section K (Sanitation) of *The Neighbourhood Planning and Design Guide*, were used to determine the theoretical water demand for the project. The Neighbourhood Planning and Design Guide was published in 2019 by the Department of Human Settlements as an update to the Guidelines for Human Settlement Planning and Design.

4.1 Theoretical Sewage Demand

Table 3 and Table 4 overleaf are extracts from *The Neighbourhood Planning and Design Guide,* and show the different demands for various land use types.

Table 3 alongside was used to determine the Average Annual Daily Demand (AADD) during and post construction. Table 3 does not explicitly contain a unit demand for a construction site, and therefore a land use type with a similar expected unit demand was required. The water demand during construction was determined for both the on-site staff and the off-site staff, as set out below.

4.1.1 On-Site Staff AADD

Currently the Eastern Cape is experiencing a drought, and due to this both domestic and commercial water usage is reduced, when compared to previous records. The staff living on site are expected to have similar water requirements to that of a hotel or hostel, as highlighted in red in Table 3 alongside. However, due to the current drought, and water scarcity it is anticipated that the water consumption shall be significantly less, and therefore a value of **100 l/p/d** was used in the determination of the anticipated sewage for the **on-site staff**.

Table 3 – Typical AADD unit demands for special land use categories

Land use		Unit demand	Unit of measure
Residential type of development			
Living units, student housing, tenement buildings, orphanages and hostels (units between 20 m² and 40 m²)	According to bed	0.30	kL/bed
	Building according to FAR	1.20	kL/100m²
	Grounds only	12	kL/ha
Business type of development			
Abattoir	Cattle	0.80	kL/cattle head
	Pig	0.40	kL/pig head
	Sheep	0.14	kL/sheep head
	Fowl	0.80	kL/100 fowl
Brewery (usage for the production of 1 L of beer)		10	L/1 L of beer
Car wash facility	Wash bay	10	kL/wash bay
	Cars	0.20	kL/car
Fuel depot		0.40	kL/100 m²
Garage or filling station		0.80	kL/100 m²
Industrial (wet)	Development specific	-	kL/100 m²
Motor city/retail park as a single zoning (car sales + limited offices 100 m²)		0.60	kL/100 m²
Taxi rank (with ablution facilities)		0.30	kL/100 m²
Wellness centre, gymnasium		2.40	kL/100 m²
General type of development			
Cemetery		12	kL/ha
Club	Buildings only	2.40	kL/100 m²
	Grounds only	12	kL/ha
Church	Buildings only	0.30	kL/100 m²
	Grounds only	12	kL/ha
Nursery	Buildings only (sales area)	0.80	kL/100 m²
	Planting and production area	12	kL/ha
Park	Buildings only	0.40	kL/100 m²
	Grounds only	12	kL/ha
Parking grounds (car park)		3	kL/ha
Private open space		12	kL/ha
Roads		0	kL/ha
School, crèche, educational	Buildings only	60	L/student
	Grounds only	12	kL/ha
Sport grounds	High intensity < 2 ha	50	kL/ha
	High intensity 2 to 10 ha	40	kL/ha
	High intensity >10 ha	30	kL/ha
	Low intensity	12	kL/ha
Stadiums	Buildings only	1.50	kL/1000 seats
	Grounds only	12	kL/ha
Zoological activities	Buildings only	0.60	kL/100 m²
	Grounds only	12	kL/ha
Various uses			
Airports		20	L/passenger
Camps	Campers	60	L/camper
	Resorts	200	L/person
Factories		100	L/worker
Garages		400	L/vehicle
Hotels		200	L/person
Picnic spots		60	L/picnicker
Restaurants		10	L/person
Schools	Live-in student	300	L/student
	Day student	60	L/student
Theatres		20	L/seat

4.1.2 Off-Site Staff AADD

As previously stated, the Eastern Cape is experiencing a drought, and due to this reduced water consumption is expected. The water used by **off-site staff** shall be for hygiene reasons and food preparation and not for typical domestic purposes, such as showering or bathing and cleaning of clothes. The water demand for the project, both during and post construction is expected to vary between 40 and 60 litres per person per day (l/p/d). Therefore, to be conservative a water demand of **60 l/p/d** was used in the determination of the anticipated sewage. This value of 60 l/p/d correlates to a school day student, as highlighted in red in Table 3, which is a similar water usage type, as the water is not used for domestic purposes, and only during typical business hours.

Table 4 alongside was used to determine the amount of sewage to be discharged, based on the previously determined AADD. Making use of the Education land use in Table 4, one can see that the sewer flow is expected to be 65% of the water demand (AADD), as highlighted in red in Table 4. However, this value of 65% was deemed to be unindicative of what is expected to occur on the various sites. Therefore, a value of 85% of the water demand was adopted.

Table 4 – Demands and hydrographs for different land use categories

Land use		Density [#1] units/ha	Stand size [#2] m²	Unit of measure	Water demand (AADD) kL/ha/d	Water demand (AADD) kL/unit/d [#3]	Sewer flow (excl. infiltration) (Unit PDDWF) [#4] % AADD	Sewer flow kL/unit/d [#3]	Sewer flow Unit Hydrograph (UH)
Flats	Very high density	100 to 80	80 to 100	kL/unit	25	0.25 to 0.30	100% to 98%	0.25 to 0.29	UH6
	High density	80 to 60	100 to 130	kL/unit	23	0.30 to 0.35	98% to 97%	0.29 to 0.34	UH6
	Medium density	60 to 50	130 to 160	kL/unit	21	0.35 to 0.40	97% to 96%	0.34 to 0.38	UH6
	Low density	50 to 40	160 to 200	kL/unit	19	0.40 to 0.45	96% to 95%	0.38 to 0.43	UH6
Agricultural holdings	Including irrigation	< 3	< 2670	kL/unit	12	4.00	40%	1.60	UH1
	Domestic water only	< 3	< 2670	kL/unit	6	2.00	80%	1.60	UH1
Golf estate - excl. golf course water requirements		< 3	< 2670	kL/unit	9	3.00	40%	1.20	UH2
Retirement village		20 to 12	400 to 670	kL/unit	11	0.60 to 0.80	80% to 70%	0.48 to 0.56	UH5
Business/commercial		FAR – 0.4	n.a.	kL/100m² [#2]	21	0.65	80%	0.52	UH7
Industrial		FAR – 0.4	n.a.	kL/100m² [#2]	13	0.40	80%	0.32	UH10
Government institutions		FAR – 0.4	n.a.	kL/100m² [#2]	13	0.40	80%	0.32	UH9
Warehousing		FAR – 0.4	n.a.	kL/100m² [#2]	10	0.30	80%	0.24	UH11
Institutional		FAR – 0.4	n.a.	kL/100m² [#2]	20	0.60	80%	0.48	UH9
Municipal services		FAR – 0.4	n.a.	kL/100m² [#2]	20	0.60	80%	0.48	UH9
Educational		FAR – 0.4	n.a.	kL/100m² [#2]	20	0.60	65%	0.39	UH8
Cemeteries		n.a.	n.a.	kL/ha	12	n.a.	n.a.	n.a.	n.a.
Parks		n.a.	n.a.	kL/ha	12	n.a.	n.a.	n.a.	n.a.
Sports fields		n.a.	n.a.	kL/ha	12	n.a.	n.a.	n.a.	n.a.

Notes:

#1 - Assumed net area factor – 0.8 x gross area (20% allowance for roads, servitudes and open spaces)

#2 - Floor area

#3 - Unit type as defined in column 'Unit of measure'

#4 - Regular flow + leakage and base flow

FAR (Floor Area Ratio) is the ratio of the floor area of a building to its site area. Also referred to as FSR (Floor Space Ratio).

On-Site Staff

85% of the 100l/p/d determined previously equates to **85 l/p/d** of sewage discharge for the project for on-site staff.

Off-Site Staff

85% of the 60 l/p/d determined previously, equates to **51 l/p/d** of sewage discharge for the project for off-site staff, which would also be applicable for the post construction phase of the project.

Therefore, using the above sewage discharge figures, and the peak staff numbers from Table 1 and Table 2, on page 4, the total sewage discharge per day post construction is depicted in Table 5 below, and during the peak of construction in Table 6 overleaf.

Table 5 – Total Sewage Discharge Post Construction

Post-Construction	
Number of Staff Post Construction	15
Sewage Discharge/Person/Day (l)	51
Total Sewage Discharge (l/day)	**765**

Table 6 – Total Sewage Discharge During Construction

	Construction Phases & Estimated Durations			
	Start-up 2 months	**Growth** 12 months	**Peak** 12 months	**Commissioning** 4 months
On Site Staff	31	189	211	48
Sewage Demand (l/p/d)	85	85	85	85
Total Sewage Discharge (l/d)	**2 635**	**16 065**	**17 935**	**4 080**
Off Site Staff	26	43	43	26
Sewage Demand	51	51	51	51
Total Sewage Discharge (l/d)	**1 326**	**2 193**	**2 193**	**1 326**
Total Staff using Site Facilities	57	232	254	74
Total Sewage Discharge both on and off site (l/d)	**3 961**	**18 258**	**20 128**	**5 406**

It must be noted that the discharge associated with the peak number of staff during construction **(20 128 l/d)** is based on the assumption that all staff live on site. There is unlikely to be a constant daily figure. This figure represents the *worst-case scenario*, and thus what the on-site system needs to be able to accommodate during the peak construction period. It is expected that on regular day-to -day cases, the sewage discharge shall be less than that of the above, and as a result will allow for a longer service interval on certain technologies, such as a sceptic tank, which requires periodic servicing. Furthermore, this peak value is based on the assumption that all staff live on-site. There may be a situation where staff have the option or choose to live within town, and therefore there will be a *lower sewage discharge* based on the actual number of staff on site.

5 WWTW Capacity in Grahamstown

The town of Grahamstown's sewage network is divided into two distinct drainage areas. One in the North which drains to the Mayfield Wastewater Treatment Works (WWTW) and a second in the South which drains into the Belmont Valley WWTW.

According to the Makana Municipality Integrated Development Plan (IDP) for 2019-2020:

- The Belmont Valley Wastewater Treatment Works (WWTW) is a 5.4Ml biological filter plant currently being operated at an average inflow of between 7 and 8Ml/d. The plant is servicing the CBD and Western side and 60% of the Eastern side.
- The Mayfield WWTW has a stated existing hydraulic capacity of 2.5 Ml/day and currently treats flows from the areas known as Mayfield, Makanaskop, Kings Flats, Transit Camp and Extensions 6 and 7.

Upon inspection of the Grahamstown Industrial area, a number of **vacant serviced plots** exist. Traditionally this is typically an indication of capacity availability of the services provided to the plot, as the services have been allowed for.

6 Sewage Treatment and Handling Technologies

Several different sewage technologies were researched to determine the most suitable technology for the Project. These technologies vary from simplistic, yet effective, technologies such as septic tanks, to modern on-site treatment technologies. Technologies for on-site treatment are envisaged to be used during construction at the Contractor's main site camp, where a large demand is expected, as well as the main buildings post construction. The different sewage handling technologies (VIP toilets, portable chemical toilets etc) should be used at the various locations where construction is occurring, such as the turbine sites and along the constructed spine and access roads.

The information to follow is a brief outline to give one a general understanding of the proposed sewage technologies. For more detailed information, refer to Annexure A, which contains more detailed literature on the respective technologies.

6.1 Septic Tank

Septic tanks form part of the sewage disposal system that can be connected to the outlet of any water-flush latrine. An advantage of a septic tank is that the user has all the benefits of the conventional waterborne sanitation with on-site disposal. The disadvantage is that it requires the periodic removal of sludge.

The basic septic tank system consists of a buried tank and subsurface drainage field, such as a soakaway or French drain. Waste water flows into the septic tank, where it is held for a sufficiently long enough period to allow for the solids within the waste water to settle out, forming "sludge" at the bottom of the tank. Any oils and grease within the waste water rise up to the top of the water surface and form a "scum" layer. The remaining water in the middle of the tank flows off into the drainage field, where it percolates into the soil, which provides final treatment by removing harmful bacteria, viruses, and nutrients. Suitable soil is necessary for successful wastewater treatment. Figure 3 overleaf depicts a typical septic tank system.

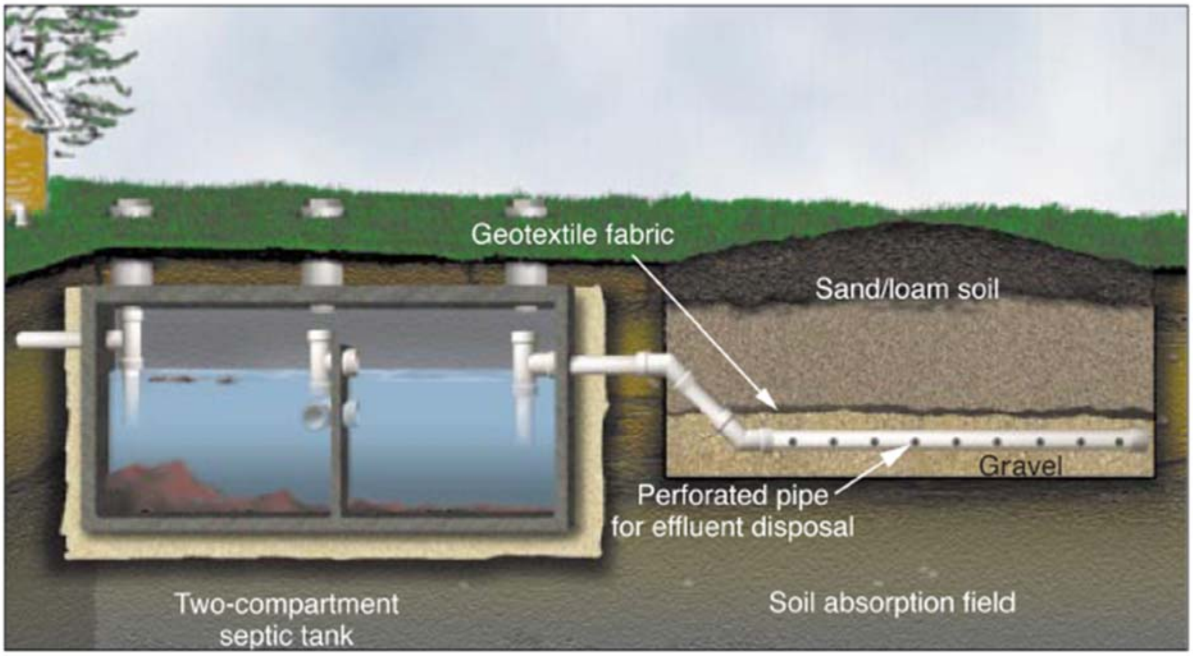


Figure 3 – Typical Septic Tank Setup

Should the site subsoil conditions on not be suitable for an effective soakaway, a septic tank in conjunction with a reed bed may be considered.

6.1.1 Reed Bed

Reed beds operate in a similar way to conventional waste water treatment systems. Primary settlement occurs within the septic tank, after which the effluent will pass into the reed bed and undergo secondary aeration, provided by the plants (reeds). The reeds draw oxygen down to the roots via the leaves, where it becomes available for aerobic bacteria. Tertiary polishing is carried out if the reed bed is constructed sufficiently large enough, providing further removal of nitrogen and phosphorus.

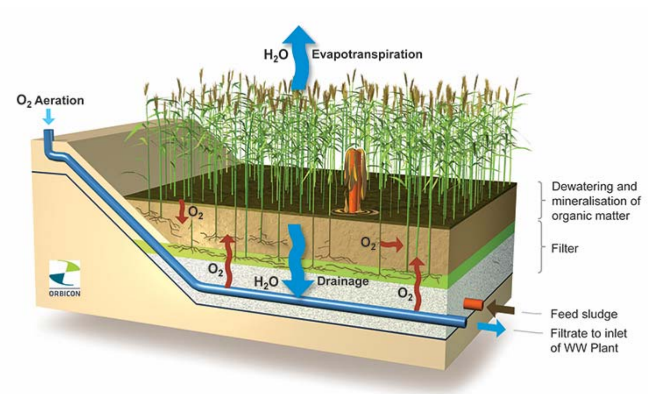


Figure 4 – Typical Reed Bed

6.2 Portable Chemical Toilet

A chemical toilet stores excreta in a holding tank that contains a chemical mixture to prevent odours caused by bacterial action. The contents of the holding tank must be emptied periodically and conveyed to a sewage works for treatment and disposal. Some units have a flushing mechanism using some of the liquid in the holding tank to rinse the bowl after use. The chemical mixture usually contains a powerful perfume as well as a blue dye. Chemical toilets can range in size from the very small portable units used by campers to the larger units supplied with a hut. Figure 5 alongside depicts a typical portable chemical toilet. The system can provide an instant solution and is particularly useful for temporary applications where the users are accustomed to the level of service provided by a waterborne sanitation system.

Figure 5 – Typical Chemical Toilet

6.3 Khusela Dry Sanitation Toilet

The Khusela Dry Sanitation Toilet (DST) is an innovation that replaces the traditional open pit latrines. The Khusela DST is an improvement to existing pit latrines that addresses the health and safety shortfalls and servicing problems, whilst ensuring that environmental and underground contamination cannot occur.

The system comprises of a rotary toilet bowel, which prevents foreign objects entering the storage bladder, which is housed below the toilet. All waste is stored within a durable “bladder” with a volume of 2 000 litres, and thus the waste has no interaction with the natural environment. The bladder can be removed and replaced, or the bag can be left in place and the contents removed via a vacuum tanker. Figure 6 above depicts a typical DST outer structure, as well as the bladder which is connected to the toilet system.

Figure 6 – Typical Khusela Dry Sanitation Toilet

7 Environmental Requirements of the above Technologies

The information below is provided as an overview to **raise awareness**, and is not an exhaustive list, of the environmental requirements associated with the handling and disposal of sewage.

There are a number of environmental requirements which pertain to the handling and disposal of sewage, and the associated materials. The primary directive is to prevent contamination of the natural environment and water sources. The overarching regulations are outlined in Table 7 below.

Disposal Option	On-site disposal (Within co-ordinates of WWTP)	Off-site land disposal (Outside co-ordinates of WWTP)	Off-site marine disposal (Outside co-ordinates of WWTP)
Applicable Act Governing Practice	National Water Act (Act No. 36 of 1998)	Environmental Conservation Act (Act No. 73 of 1989) Natural Environment Management - Waste Management Act	National Water Act (Act No. 36 of 1998)
Authorisation Required	Water Use Authorisation	Disposal Site Permit or Water Use Authorisation (irrigated sludge)	Water Use Authorisation
Lead Authority	DWAF	DEAT DWAF (irrigated sludge)	DWAF
Regulatory Instrument	Water use licence (Or general authorisation or existing lawful water use)	Disposal Site Permit	Water use licence
Regulatory Guidelines	Sludge Guidelines (Volume 3) and Minimum Requirements (latest version)		Operational Policy for the disposal of land-derived water containing waste to the marine environment of South Africa

Table 7 – Sewage Technology Environmental Requirements

Upon review of the National Environmental Management Act Listing Notices, the following **potential triggers** in terms of Basic Assessment or Environmental Impact Assessment, were noted:

- The development and related operation of facilities or infrastructure for the treatment of effluent, wastewater or sewage with a daily throughput capacity of more than 2000 cubic metres but less than 15000 cubic metres. (Listing Notice 1)

- The development of infrastructure or structures with a physical footprint of 10 square metres or more; where such development occurs - (a) within a watercourse; (b) in front of a development setback; or (c) if no development setback has been adopted, within 32 metres of a watercourse, measured from the edge of a watercourse. (Listing Notice 3)

8 Department of Water and Sanitation Requirements of above Technologies

The National Norms and Standards for Domestic Water and Sanitation Services published by the Department of Water and Sanitation in September 2017, covers a host of details pertaining to the use and management of both water and sanitation in the South African context. This section of the report shall briefly outline some of the requirements stipulated for the aforementioned technologies.

8.1 Safe Disposal of Excreta

Regarding the safe disposal of excreta, the National Norms and Standards for Domestic Water and Sanitation Services states the following:

Safe disposal of human excreta is a major priority for the health of all beings. The goal thereof is ensuring that the environment is free from human faeces. To this effect:

1. A services authority shall ensure that, in the disposal of all excreta, the following are adhered to:
    a) Appropriate excreta containment measures shall be implemented at all times throughout the sanitation service chain;
    b) All excreta disposal and/or containment measures shall protect surface water, groundwater and groundwater sources from faecal contamination. Therefore:
        i. All excreta containment measures, i.e. trench latrines, VIP toilets and soakaway pits, shall be at least 50 metres away from any groundwater source. This distance needs to be increased for fissured rocks and limestone, or decreased for fine soils.
        ii. The bottom of any toilet or soak-away pit shall be at least 1.5 metres above the water table. Again, this distance needs to be increased for fissured rocks and limestone, or decreased for fine soils.
        iii. Drainage or spillage from sanitation facilities shall not contaminate freshwater resources or create health risks for people or the environment.

2. In any event, a service authority shall ensure that open defecation does not compromise the excreta containment measures of a sanitation service. In this regard:
    a) The necessary by-laws and penalties shall be put in place and enforced at all times to reduce and ultimately prevent and end open defecation.
    b) The necessary measures and training shall be put in place and enforced to raise awareness and change practices to ensure that babies' and children's faeces shall be safely disposed of immediately and hygienically at all times.

8.2 Management of Waste Water and Sludge Management

Regarding the management of Waste Water and Sludge Management the National Norms and Standards for Domestic Water and Sanitation Services states the following:

Wastewater is mostly generated as a by-product of the potable water service, and generates substantial external costs, if not properly managed. The goal thereof is that sanitation services shall implement effective and sustainable wastewater and sludge management practices to protect public health and prevent pollution of the environment. To this effect:

1. Wastewater and sludge shall be managed by local authorities and service providers in an environmentally acceptable manner by adhering to the *Guidelines for the Utilisation and Disposal of Wastewater Sludge Volumes 1 to 6* (Herselmann & Snyman, 2006). These guidelines replace all previous guidelines that are currently being implemented by the local authorities.

2. Emptying:
    a) Sludge from all forms of on-site sanitation shall, at intervals, be removed from the pit or tank and conveyed to some treatment or disposal facility. If the pit or tank contains fresh sewage, the sludge shall be treated or disposed of in a way that will not be harmful to the environment or a threat to health.
    b) If the waste matter has been allowed to decompose to the extent where there are no longer any pathogens present, such as in a VIP toilet, the sludge can be spread on the land as compost in a way that will not be harmful to the environment or a threat to health.
    c) Sludge shall be disposed of only in accordance with the prescribed methods set out in the guidelines: *Guidelines for the Utilisation and Disposal of Wastewater Sludge Volumes 1 to 5* (Herselmann & Snyman, 2006a).
    d) It is possible to empty pits manually, using scoops and buckets, and to dig out the thicker sludge with spades, but this poses obvious health risks to the workers involved. In these cases workers shall be issued with protective gear, such as masks, gloves, rubber boots and overalls. The use of ventilated improved double-pit toilets can overcome this unpleasantness by allowing the excreta to decompose into a pathogen-free, humus-rich soil, after storage in the sealed pit for about two years.
    e) The most suitable method of emptying a pit/septic tank mechanically involves the use of a vacuum tanker. The use of a vacuum is preferred to other pumping methods because the contents do not come into contact with the moving parts of the pump, where they can cause damage or blockages. Workers shall still be issued with protective gear, such as masks, gloves, rubber boots and overalls, to prevent contact with excreta and subsequent health problems.

3. Treatment:
    a) The nature of the sludge can vary widely and this shall be taken into account when designing the treatment works.

b) The technology or combination of technologies used at a treatment works shall depend on the quality of the effluent to be treated; the contributions of any unusual constituents (derived from light or heavy industrial effluents) to the domestic wastewater stream; the volume of effluent to be treated and its rate of increase in volume over time; the sensitivity of the receiving river system where the effluent is discharged; the financial resources available to the local authority responsible for operating the treatment works; and any specific conditions contained in the plant's wastewater discharge licence (Ashton, et.al., 2012).
c) Emptying facilities at treatment works shall consist of an apron onto which to discharge the contents of the vehicle and a wash-down facility.
d) Pond systems can be very effective in treating sludge from on-site sanitation systems. If the ponds treat only sludge from VIP toilets it may be necessary to add water to prevent the ponds from drying out before digestion has taken place.
e) Sludge from on-site sanitation systems can be treated by composting at a central treatment works, using forced aeration.
f) Although it is still necessary to treat sludge from on-site sanitation systems, the cost of treatment is lower than for fully waterborne sanitation. This is because partial treatment has already taken place on the site through the biological decomposition of the waste in the pit or tank. In addition, the treatment works do not have to be designed to handle the large quantities of water that must be added to the waste for the sole purpose of conveying solids along a network of sewer pipes to the treatment and disposal works.

4. Disposal:
   a) Unless the sludge has been allowed to decompose until no more pathogens are present, it may pose a threat to the environment, particularly where the emptying of pits is practised on a large scale. The design of disposal facilities for the disposal of sludge shall be careful considered, as the area is subject to continuous wet conditions and heavy vehicle loads.
   b) The type of equipment employed in the disposal effort shall be known to the designer, as discharge speed and sludge volume need to be taken into account.
   c) Cognisance shall be taken of the immediate environment, as accidental discharge errors may cause serious pollution and health hazards.
   d) Pit-toilet sludge can be disposed of by burial in trenches of at least 0.8m to 0.9m wide, 6.0m long and 2.0m deep. These trenches shall only be allowed at appropriate and licensed disposal sites.
   e) Dehydrated faecal matter from urine-diversion toilets can be safely re-used as soil conditioner, or, alternatively, disposed of by burial or incineration.
   f) Dehydrated faecal matter may be co-composted with other organic waste.
   g) Sludge from septic tanks, aqua-privies, etc, shall be disposed of only in accordance with the prescribed methods in the *Guidelines for the Utilisation and Disposal of Wastewater Sludge Volume 3: Requirements for the on-site and off-site disposal of sludge* (Herselmann & Snyman, 2009).

9 Technology Constraints

The table below outlines some of the constraints associated with each of the technologies reviewed within this report and those within Annexure A. The constraints associated with each technology are not limited to this list, and are provided to merely give an indication of the typical constraints associated with each technology.

Technology	Constraints
BIOROCK Sewage Treatment Plant	• High Upfront Capital Investment • Specialised Equipment • Annual Maintenance • Gravity System, therefore needs to have sufficient grade • Requires water to operate
Septic Tank	• Requires water to operate • Soil conditions – not suitable for rocky areas, or where the water table is high (drainage field) • Location restricted relative to natural ground water sources
Bio Sewage Systems Treatment Plant	• Requires water to operate • High Upfront Capital Investment • Specialised Equipment • Requires electricity • Requires pumps • High Upfront Capital Cost
VIP Toilet	• Soil conditions – not suitable for rocky areas, or where the water table is high • Must be positioned downwind of work areas • Lack of airflow can create unpleasant environment • Capacity limited to size of pit • Requires sufficient distance between pit and ground water sources
Composting Toilet	• More maintenance than other technologies for similar purpose • Carefully controlled environment to ensure sufficient composting • Electricity supply required for some variations • Ash, lime, sawdust, earth, or vegetable matter must be added regularly • Space is required to relocate the latrine on a regular basis and to plant trees once full • May be culturally unacceptable to use human excreta for this purpose
Portable Chemical Toilet	• Small capacity on single units • Regular servicing required • Sewage is stored in a tank within the toilet, therefore susceptible to bad odour • Need to service agent in the vicinity of site
Khusela Dry Sanitation Toilet	• Disposal of waste within bladder at suitable approved site – extra handling of waste

10 Technology Matrix

Wind Garden						
During Construction						
Reviewed Technology	Number of Staff to Accommodate	Total Anticipated Sewage Discharge per day (litres)	Capacity of a Single Unit or System of Respective Technologies	Number of Units Required based on Total Anticipated Sewage Discharge per Day	Preferred Technology Solution	Proposed Number of Units of Preferred Technology
Temporary Facilities – To be used where needed for construction of Turbines, Platforms and Roads, and at the Balance of Plant Site						
VIP Toilet	254	20 128	3663	6	No	-
Serviced Chemical Toilet	254	20 128	265	76	Yes	-
Khusela Dry Sanitation Toilet - Sanitech	254	20 128	2000	11	**Yes**	**22**
Compost Toilets	254	20 128	3663	6	No	-
On Site Treatment – To be used at the Balance of Plant location						
Septic Tank	254	20 128	15000	2	**Yes**	**3**
BioRock - Ecorock 5000	254	20 128	15000	2	No	-
Bio Sewage Systems - BioBee Container Plant	254	20 128	15000	2	No	-
Post Construction						
Reviewed Technology	Number of Staff to Accommodate per Below Site Type	Total Anticipated Sewage Discharge per day (litres)	Capacity of a Single Unit or System of Respective Technologies	Number of Units Required	Preferred Technology Solution	Proposed Number of Units of Preferred Technology
Septic Tank	15	765	1500	1	**Yes**	**1**
BioRock - Ecorock 2000	15	765	1500	1	No	-
BioSewage Systems - Flush n Spray	15	765	1300	1	No	-

Based on the information available for the various technologies, as well previous experience from similar projects it is recommended that Balance of Plant site make use of a **Septic Tank** system and a combination of the **Khusela Dry Sanitation Toilet** and **Portable Chemical Toilets** for where temporary work is being completed, such as the turbine sites and along the roads being constructed.

The bladder of the Khusela dry sanitation units provide a large capacity (2000 l) so are ideal for use at *temporary locations*, where work will be carried out over an extended period of time. The portable chemical toilets have a smaller capacity, and are suitable for temporary areas such as alongside the roads being constructed. The portable toilets can be easily moved as the construction of the roads progresses. The combination of the two should provide flexibility to meet the needs on site.

The number of proposed Septic Tanks for during construction in the above Technology Matrix is three, as this will allow for a backup system should one septic tank be temporarily decommissioned. The number of toilet facilities (Khusela or Portable Chemical) would vary depending on the number of staff, and the number of areas being worked on. It is probable though to supply one toilet for each gender, and additional toilet facilities to accommodate the number of staff working, so that there should be sufficient facilities available.

Table 8 overleaf lists some of the motivations for the proposed choice of sewage technologies.

Table 8 – Motivation for Choice of Technology

Technology	Motivation for Proposed Technology	Preliminary Cost of Proposed Technology
Septic Tank	• Simple system, which does not require specialised equipment • Cost effective when compared to alternatives for large scale treatment • Familiar technology with a long-term proven history of success • The required capacity is achievable, and with modern plastic modular units, augmentation is relatively seamless. • Small footprint when compared to alternatives • Durable and long lasting • Low maintenance • Soakaway can be replaced by reed bed, if subsoil conditions are unsuitable	Plastic septic tank: 12.5kl - R 70 000.00 8kl – R 60 000.00 Per unit installed.
Khusela Dry Sanitation Toilet	• Low risk of environmental contamination when compared to other options, due to the bladder • Large capacity compared to traditional portable chemical toilets • No need for chemicals • No need to dig several pits, as once the bladder is full, the bladder is replaced or emptied via a vacuum tanker • Can be coupled with prefabricated toilet structures which are readily available	R 10 810.00 per installed unit. (excl. delivery)
Portable Chemical Toilet	• Good odour control • Serviced by third party supplier, therefore Contractor does not need to handle any waste • Easy to move from one temporary site to another • Widely and readily available	R 1 000 per monthly hire of single unit, incl. 1 service per week

11 Conclusion

There are numerous sewage handling and disposal technologies readily available globally. These technologies range from relatively new on-site packaged treatment works, such as those offered by BIOROCK, to older established technologies such as a septic tank, and VIP toilets. However, not all of the technologies which are available globally are suited to the unique local conditions in South Africa.

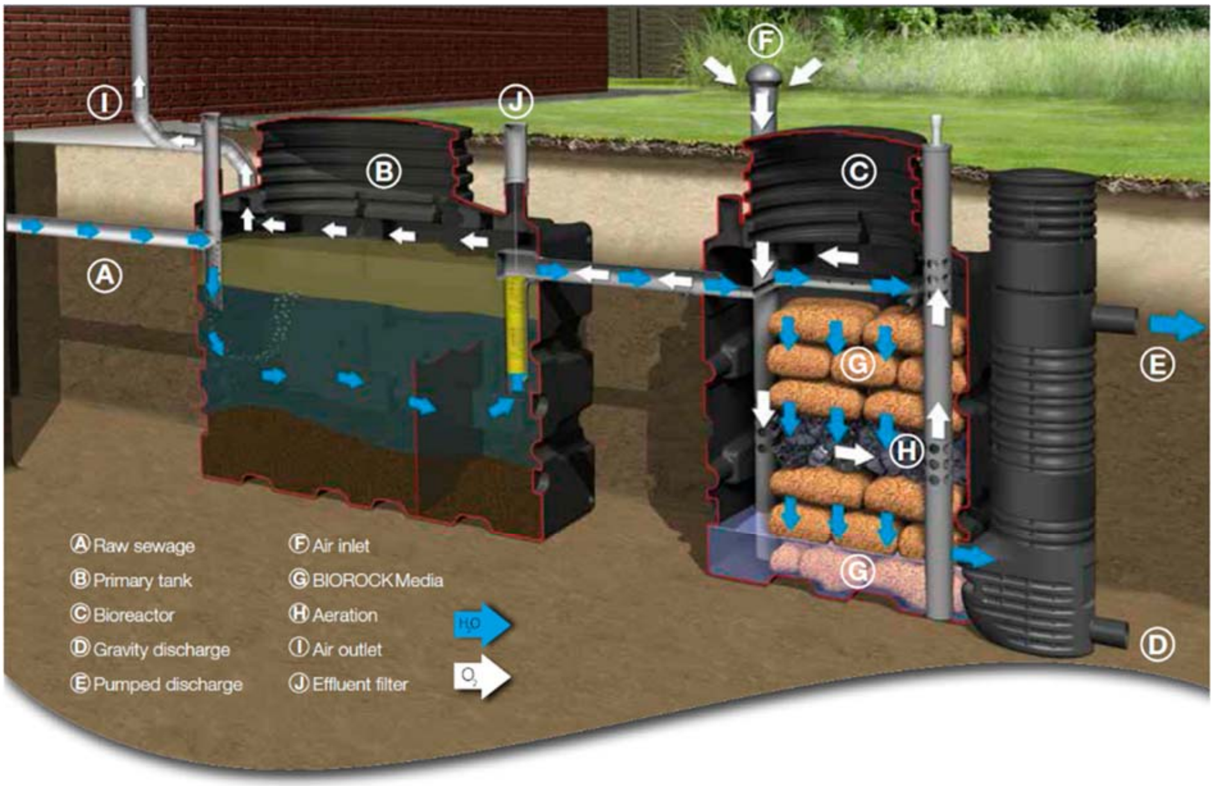
In the ethos of the project, which is geared towards renewable and environmentally friendly sources of energy, it is believed that the recommended sewage technologies are a harmonious match. The effluent resulting from the septic tank treatment may be reused for irrigation purposes, such as small gardens which can be developed at the respective sites. The bladder of the Khusela Dry Sanitation toilet ensures that there is no contact between the produced sewage and the environment, therefore greatly reducing the risk of environmental contamination. The Portable Chemical toilets, allow for a hassle-free solution for where work is being completed in remote areas.

Having reviewed the sewage technologies readily available, and being cognizant of the associated constraints, the local legislature and environmental requirements it is recommended that the project make use of **Septic Tanks** and a combination of the **Khusela Dry Sanitation Toilets and Portable Chemical Toilets.**

Annexure A – Sewage Technology Literature

BIOROCK Sewage Treatment

The BIOROCK Waste Water Treatment system is a standalone gravity system, able to treat sewage on-site, and discharge the treated effluent into the natural environment. The Figure below schematically illustrates the treatment process.



Raw sewage (A) enters the primary tank (B), which provides the separation and the breakdown of organic solids. This process is the Primary Treatment. The sewage then passes through an effluent filter, prior to discharging into the BIOROCK® unit which incorporates an aerobic digestion process (Secondary Treatment) and filtration process (Tertiary Treatment). BIOROCK uses a material with a large surface area which allows settlement of the necessary bacteria, a process which is essential for the effective treatment of domestic wastewater. The BIOROCK media is highly resistant to degradation and remains extremely stable over the long term.

The BIOROCK sewage treatment plant will allow for the onsite treatment of sewage effluent, with no need to rely on local Municipal infrastructure nor periodic servicing by a service provider to remove effluent.

BIOROCK products are modular and are able to be installed in parallel with one another, thus allowing one to increase the capacity of the treatment plant as a whole. The BIOROCK ECOROCK-5000 has the ability to treat 3 750 litres of effluent per day, which can be increased by installing multiple ECOROCK-5000s to meet the required demand.

Bio Sewage Systems Treatment Plants

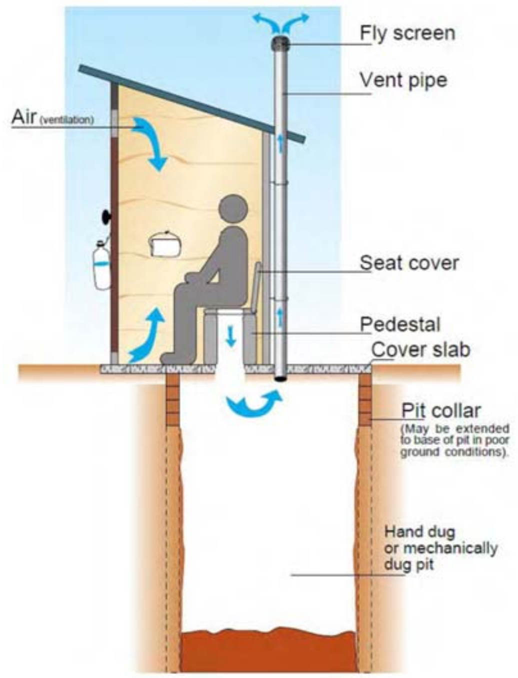
Bio Sewage Systems (BSS) enables the effective treatment of black and grey water using a modular or containerized plant. It uses a simple and robust technology with minimal mechanical components and has the added advantage of being able to tolerate high peak flows. There are 3 stages of BSS sewage treatment, which are as follows:

1. Reducing the organic load using an anaerobic process,
2. Reducing the nitrogen load.
3. Reducing the pathogen load.

The raw sewage is channelled to a submerged tank where nonbiodegradable products are separated. The sewage is then pumped into the first reactor tank which contains bacteria growing on media and where the nitrification takes place. From the first nitrification reactor tank, the sewage is gravity fed into the second reactor tank where de-nitrification occurs, also with bacterial reaction. The pre-treated effluent is gravity fed into the cone-shaped clarification tank where any solids that escape the first 2 tanks are collected and sent back to the second stage of the collection tank to start the process again. From the clarification tank the now clean and treated water overflows into the last tank where sterilisation occurs using Ozone technology. In the sterilisation tank is a submersible pump which will automatically pump out the treated water for irrigation or other purposes. The Figure below illustrates a typical setup of the Bio Sewage Systems treatment plant.

The Bio Sewage System, also provides container plants, which can treat 8 000 to 15 000 litres per day sewage and are easily transported. Therefore, once work is completed in one region, the plant can be transported to the next region, if used at the Contractor’s main site camp.

Ventilated Improved Pit (VIP) Toilet



The VIP is a pit latrine with a vent pipe fitted to the pit and a screen at the top outlet of the pipe, as depicted in the Figure alongside. The VIP system produces a continuous airflow through the ventilation pipe. The airflow vents away odours, assists waste breakdown by drying action, and acts as a very effective fly control mechanism. Despite the simplicity, well-designed VIPs can be completely smell free, and be more pleasant to use than some other water-based technologies.

Continuous ventilation is achieved by air movement across the top of the vent pipe causing a venturi effect, and by sunlight heating the vent pipe causing a convection effect.

Venting the pit dries the waste which assists natural decomposition and destruction of potential pathogens, ultimately rendering a safe waste product.

Organic soil is preferred over mineral soil, with un-lined soil pits contributing to the break-down of the waste by introducing natural soil micro-organisms. Soil micro-organisms also compete with pathogens. Small amounts of organic soil can be added periodically to lined pits for the purpose of introducing soil micro-organisms.

Composting will occur naturally when a health micro-organism community is present, but can be further promoted by the addition of small amounts of carbon in the form of dry organic matter such as sawdust, straw or twigs. Composting will increase pit temperature to some degree, with any increase in temperature assisting with destruction of pathogens.

The VIP toilet is a pit toilet with an external ventilation pipe. It is both hygienic and relatively inexpensive, provided that it is properly designed, constructed, used and maintained.

Composting Toilets

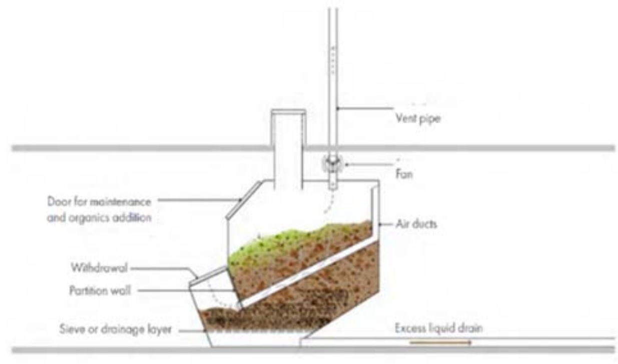
The composting toilet is similar to the VIP toilet and the same design aspects for the superstructure and substructure need to be considered and incorporated.

Three variations of composting toilets are as follows:

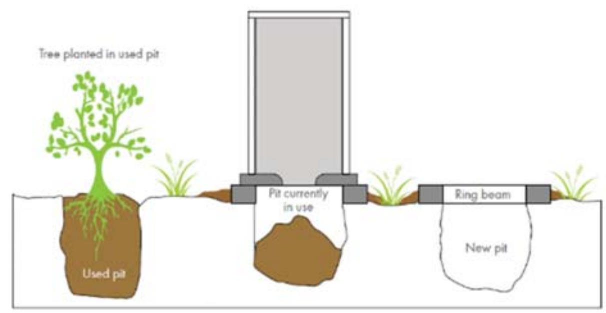
1. Traditional Composting Toilet
2. Arboloo
3. Fossa Alterna

The above three variations are briefly outlined below.

In the traditional composting toilet, as depicted alongside in the Figure, compost is produced continuously. Waste falls into a tank or container to which ash or vegetable matter is added. The mixture will decompose to form a good soil conditioner in approximately four months. Pathogens are killed in the dry alkaline compost, which can be removed for application to the land as a fertiliser.



The Arborloo is a shallow pit on which a tree can be planted after it is full, while the toilet superstructure, ring beam and slab are moved to a new pit in a continuous cycle (usually moved once every 6 to 12 months). The pit should be about 1 to 1.5 m deep and should not be lined as it would prevent the tree or plant from growing properly. The tree or plant should not be directly planted in the raw excreta. It should be planted in the soil on top of the pit, allowing its roots to penetrate the pit contents as it grows. The Figure alongside illustrates a typical Aborloo.



The Fossa Alterna uses two containers to produce compost in batches, as depicted in the Figure alongside. As with the traditional composting toilet, soil and other materials are added to the pit after every use. When the first pit fills, it is covered with top soil, while the structure and toilet slab are moved to the second pit. When the second pit is full, the contents of the first pit have completed composting and can be shovelled out and used for gardening. Then the slab and superstructure are moved again and the process is repeated.