PAPER 14

Augmentation of Markman main sewer phase 3:
diversion at Grit Chamber and pipeline to Fish Water Flats

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ABSTRACT
The Augmentation of Markman Main Sewer Phase 3 entails the construction of a 1 000 mm diameter HDPE lined reinforced concrete sewerage pipe from just beyond Settlers Bridge, the N2 crossing of the Swartkops River, to the Fish Water Flats Wastewater Treatment Works (WWTW). Phase 1 and Phase 2 of the augmentation project have been completed before through earlier construction projects.

Phase 1 of the augmentation entailed the construction of a 1 000mm diameter GRP sewer main from the Grit Chamber in Blue Water Bay to Settlers Bridge and an 800mm diameter pipe crossing of the bridge. Phase 2 entailed the lowering of stormwater pipes in the vicinity of the Grit Chamber to allow the completion of the new 1 000mm diameter pipe at this location.

The current and future sewage flow in the Markman Main Sewer exceeds the capacity of the existing sewer from the Grit Chamber in Blue Water Bay to the Fish Water Flats Wastewater Treatment Works. The project aims to alleviate this problem by providing a new sewer with the capacity to convey the full current and future peak flow in this section of the Markman Sewer, whilst retaining the existing sewer to serve as backup. A bypass chamber at the Grit Chamber will be constructed to divert the sewage flow into either the new or the existing main sewer from the Grit Chamber to the treatment works. This will reduce the risk of sewage spillage into the environmentally sensitive Swartkops River Estuary, by providing adequate conveyance capacity and a diversion sewer to convey the flow when maintenance to either of the two sewers is required.

Phase 3 consists of the following:
- Grit Chamber Bypass Structures, Sluice Gates, Dealing with Sewage flows whilst connecting into the existing pipework or grit chamber
- Investigations for the Functionality and Condition of the Grit Chamber.
- Connecting and access chamber into existing pipe.
- Dealing with shoring & traffic accommodation & steep embankment & slope protection along the N2 National Road, for the confined installation of the 120m RC Pipe along embankment.
- 120m 1 000mm dia RC Class 100D HDPe lined RC Pipe along embankment & steep grade.
- Hydraulic Jump Chamber – the purpose of the chamber is to force the sewerage hydraulic grade line to form hydraulic jump to facilitate the flow downstream of the structure. An alternative considered was to utilize a high drop structure to step off the N2 embankment.
- 2.2km long 1 000mm dia RC Class 100D HDPe lined pipe flat grade confined working space, dewatering and shoring, either in trench condition (up to 5m deep) and pipe fill embankment conditions.
- Crossing of live 900mm dia Sewer pump main cannot be decommissioned, shoring and protection, over a 30m section of pipe installation
- Connection to existing pipework at Fishwater Flats WWTW, including structure and flow metering.
- Hydraulic Design and Flow Regime Parameters, steep grade conversion to flat grade, inclusion of hydraulic jump chamber, for the control of hydraulic grade line.
- Dealing with Environmental Constraints, including restricted working space, transportation and placement of construction materials, specific planting requirements, and monitoring of water pollution by taking water sampling and analysing, in terms of the WULA approval.
- Compliance with Health and Safety requirements, including safety of trench excavations, shoring, traffic accommodation.
- Inclusion, Management and Training of EME Sub Contractor's as part of the construction process, a total of 11 EME's were deployed from Ward and Metro.
- The contractual administration and construction monitoring posed specific challenges

INTRODUCTION
The paper covers the planning and construction of Phase 3 of the Markman Collector Gravity Bulk Sewer, consisting of 2.2km of 1 000mm dia Pipeline, from an existing Grit Chamber, via an existing 1 000mm dia GRP pipeline section to the Settlers Bridge over the Swartkops River, to traverse along the edge of the Swartkops Estuary to connect into the FWF WWTW.

The design of the sewer proved to be challenging in many respects, such as difficult ground and high water table, restricted working space, selection of the most suitable pipe materials, design of pipeline route including longitudinal profile, given the restrictive levels, hydraulic and environmental constraints, construction of various structures including manholes, connections and tie in structures, as well as the employment of EME subcontractors.

TECHNICAL DETAILS
Overall Purpose & Scope of Project:
i. The Markman Sewer drains the catchment of Motherwell's some 10 000 residents, Coega IDC.

The existing Markman Sewer traverses from Markman Industrial Area to Grit Chamber, crosses the N2 and then runs along the N2 before traversing over the Swartkops River estuary to the Fishwater Flats Waste Water Treatment Works (FWF).

The new Markman Sewer was implemented to cater for future growth and increase in wastewater flows from the catchment area. The design allows for operation of the two (old and new) pipelines simultaneously, if required. Either of the pipelines can be operated independently for maintenance purposes by diverting flow at the division chamber. This will also allow for refurbishment of the existing sewer.

ii. The Markman Sewer has/is being upgraded in 3 Phases from 2010 to 2019, namely:

- Phase 1: The construction of a 1km long 1 000mm dia GRP from the Grit Chamber traversing along the N2 road reserve and installation of a 300m long 1 000mm dia GRP pipe over the N2 Bridge over the Swartkops

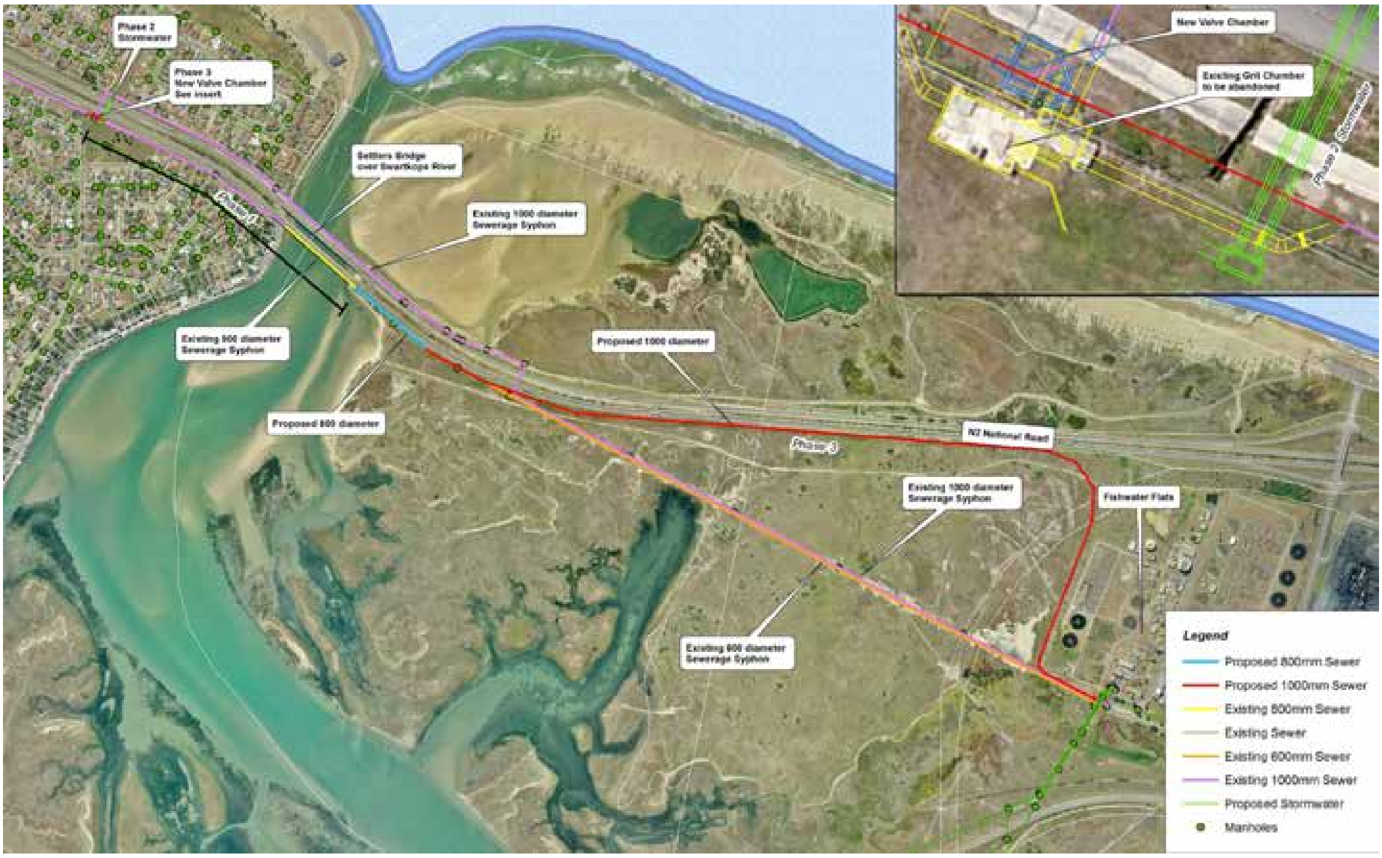

FIGURE 1: Sewer Locality Plan

River. Phase 1 was completed in 2012.

- Phase 2: The diversion of stormwater infrastructure at the grit chamber, to allow for the imminent relay of the new sewer. Phase 2 was completed in 2015.
- Phase 3: The construction of a 2.2km long 1 000mm dia RC HDPe lined pipeline from the N2 bridge pipe crossing to FWF, with connections into the existing GRP pipelines at the Grit Chamber and N2 bridge, and FWF. Phase 3 construction commenced in February 2018, and expected completion October 2019.

iii. This paper covers the planning and implementation of Phase 3.

iv. Markman Sewer Phase 3 scope of work consists of the construction of 2.2km long 1 000 mm dia RC HDPe lined pipe, Grit Chamber Bypass with 4 connections namely Grit Chamber pipework, N2 Bridge GRP pipe crossing, and connection to FWF.

Pipeline:

Pipe Route:

The pipe route traverses from the grit chamber along/within the N2 road reserve connecting into the existing 1 000 dia GRP pipeline at the grit chamber, and connecting into the existing 1 000 dia GRP pipeline, and along the edge of the road embankment down to the base of the embankment to the hydraulic jump chamber, at a vertical gradient of 1:50, from the grit chamber to the hydraulic jump chamber. From the hydraulic jump chamber, the pipe traverses along the edge of environmentally sensitive river estuary/plain of the Swartkops River, to connect into FWF, at a vertical alignment of 1:720.

The route and construction working space was restricted to less 15m, due to the limitations of space along the road embankment, environmental authorization corridor due to proximity of the Swartkops Estuary, existing sewer and close proximity of other existing services.

Crossing the estuary, the pipeline is below the 1:100 floodline. The trench excavation was subject to tidal flooding due to proximity to the sea tidal zone, and therefore extensive dewatering and pumping was required.

Dewatering was carried out on the length of the pipeline, using a well-pointing system. Shoring was required along the entire length of the pipeline, due to confinement of working space, fine silty soil conditions, deep trench excavations up to 5m, method of pipe installation as well as the high ground water conditions, with high rate of water infiltration, all which made the trench excavations unstable.

Hydraulics:

The pipeline is designed for a Peak Dry Weather Flow of 553ℓ/s and Peak Wet Weather Flow of 1 107ℓ/s, based on the future growth of the Markman Sewer catchments, for 2020. The pipe vertical gradient consisted of a relatively steep gradient of 1:50 from the grit chamber, over the N2 bridge pipe crossing, to the base of the N2 road embankment. From the base of the N2 road embankment, the vertical gradient is flat at 1:720 to the connection at FWF. The gradient was fixed by the entry level at the grit chamber and the connection into the existing sewer at FWF, as well as the ground profile, resulted in a significant change in gradient.

As a result of the high flow velocity (4 m/s) of the steeper gradient, and the

FIGURE 2: AKS HDPe Lining Prior to Casting into

FIGURE 3: RC Pipe with AKS Lining

need to maintain a minimum low flow velocity (1m/s) due to the flat gradient, and given the change of flow regime from PDWF to PWWF, a hydraulic jump would form. This hydraulic jump would move upstream or downstream, depending on the pipe flow, resulting in a reduction of the discharge capacity of the pipeline, and possible overflow at manholes.

Investigation was carried out on an energy dissipation structure, either in the form of drop type structure positioned at the exit of the bridge crossing, or provision of hydraulic jump facility. Ultimately a hydraulic jump structure was decided on. Details of the hydraulic jump structure is given below.

Pipeline Materials:

A pipe materials investigation was carried out of the alternative pipeline materials namely Structured Wall HDPE, Glass Fibre Reinforced Polyester (GRP), Solid Wall HDPE, Steel Reinforced HDPE, Reinforced Concrete and HDPE Lined Reinforced Concrete (RC). The investigation concluded that the most suitable pipe for this project is the HDPe lined reinforced concrete pipe. HDPE Lined RC Pipes are manufactured in Port Elizabeth by Rocla. Anchor Knob System (AKS) high density polyethylene sheeting is cast into the inside of the concrete pipe to form an HDPE lining acting as an integral part of the pipe.

Due to the high salinity of the ground conditions, PFA was specified in the concrete mix design for the pipes. The use of PFA increases the durability of the concrete to withstand chloride attack. The resultant pipe provides the advantages and corrosion resistance of HDPE on the inside and the rigidity and strength of reinforced concrete on the outside.

The weight and relatively short pipe lengths of individual pipe sections are a relative drawback, but the rigidity, forgiving nature, high strength and longevity of the reinforced concrete pipe offers strong advantages. A concern is the continuation of the HDPE lining through joints and access points to manhole chambers. The 1 000mm diameter Markman sewer would however allow man-entry and the manufacturer's solution is the welding of a 200mm wide strip on the inside to cover each joint to ensure continuity of the HDPE lining throughout the system. Access to pipes may be allowed through 600 x 700mm openings in the top of pipes with the lined manhole ring shaft constructed over the opening.

Pipeline Installation:

The pipeline traverses along the Swartkops Estuary, consisting of loose silty loose sand, with a high groundwater table.

The pipe installation consisted of site clearance over 15m strip within allowed 15m working construction width, removal and stockpiling of top soil, insert well pointing before commencing trench excavation to lower the groundwater table to reduce presence of water in the trench(well pointing continuous during the trench excavation and pipe is bedded, backfilled and installed), installation of shoring to support trench excavations, installation of U24 Bidim to trench bottom, installation of 7mm stone bedding on top of U24 trench floor to 200mm thick, installation of 1 000mm dia Reinforced Concrete Pipe on top of 200mm stone layer, and connect by means of the spigot and socket joint to the next pipe, installation of 7mm stone bedding to half way up pipe diameter on either side and compact to 90% MOD AASHTO DENSITY, wrapping the U24 Bidim over pipe both ways to wrap and contain the stone bedding, installation of selected fill(sand) bedding on top of U24 Bidim half way up diameter to 300mm on top of pipe soffit, and compact 90% MOD AASHTO DENSITY, removal of well pointing and shoring and backfilling the pipe from top of selected fill bedding to ground level.

The jointing of the pipe sections was external sealed with rubber seal of the RC pipe spigot/socket joint, and internally a 200mm wide HDPe strip welded to the pipe integral HDPe liner, over 360º of the pipe.

The pipeline was installed in a trench embankment condition to max 2.5m below ground, as well as embankment condition with pipe 1m above ground, requiring the earth berm constructed over the pipe from surplus excavated materials from site as well as imported G7 material, compacted 90% MOD AASHTO DENSITY. The pipeline was installed along the edge of the N2 road raised embankment, requiring careful restricted excavation and backfill due to steep grade, over a 120m section.

The pipeline is situated in the floodplain of the Swartkops River. The 1:50 floodline was obtained, requiring that cover levels of all manholes located in the floodplain be 300mm above the floodline. A pipe buoyancy calculation based on the floodline, pipe type and backfill material was carried out to determine pipe flotation restraints requirements.

Strict adherence to traffic accommodation specifically for the construction over 300m section within the N2 road reserve, and limitations for the offloading and transport of pipes and materials along fixed corridors instead from the N2, required careful logistical planning by the Contractor's operations.

Pipe installation permissible tolerances is on SANS LD, and is to be within 12mm of the design invert level at each manhole and allows for a maximum of 10% fall less than design gradient between two successive manholes. Levels of each pipe installed was taken to ensure quality of workmanship.

Pipeline Structures:

Manholes:

Manholes are installed every 170m, as well as the start and end of each radial curves. Manholes comprised Precast integral HDPe Lined RC pipes with straight short section with access opening were manufactured by ROCLA. A shaft consisting of 1.6m dia RC precast manhole sections was installed

FIGURE 4: Installation of Pipeline (Dry conditions)

FIGURE 5: Leveling of pipes

FIGURE 6: High Water Table at the FWF WWTW Tie-in (also existing 900 mm RE pipe to be crossed)

FIGURE 7: De-watering System being Installed

FIGURE 8: Trench Filling up as a Result of Tidal Flow from Swartkops River

FIGURE 9: Difficult Wet Working Conditions

on top of the manhole pipe, integrally cast together with in situ concrete. Bends consist of precast integral HDPe Lined RC pipes also manufactured by ROCLA.

Other structures:

FWF Tie in Structure, consisting of 3.6m x 3.7m x 4.5m deep reinforced concrete structure, purpose is for the connecting up the RC pipe to the existing GRP pipeline at the FWF Works. A concrete/GRP Extended VJ coupling flanged with 316 Stainless Steel bolts, was used for connecting up the Concrete RC pipeline to the GRP pipeline. A flow meter is installed at the connection, consisting of a velocity flow sensor and ball valve, together with an additional pressure transmitter to provide the hydrostatic height of the water in the pipe for times when the pipe is flowing partially full. Flows are recorded and information relayed to a central flow recording databank for all incoming sewer flows at FWF Treatment Works.

Pipe Bridge Crossing consisting of the construction of a temporary steel bridge 20m long comprising girders 0.45m deep, together with shoring, to support an existing 900mm dia return effluent concrete pipeline which had to be kept in operation, required for the construction of the Markman Sewer underneath the return effluent pipeline.

The Grit Chamber at the head of the Markman Sewer consists of a 20m x 3.5m x 2.5m deep RC structure, purpose of which is for the capturing sediments and grit, reducing the volume of grit flowing downstream into the existing and new Markman Sewer. The existing and new Markman sewer tie into the Grit Chamber, and with new sluice gates installed, flows can be diverted into either the existing or new Markman Sewer. A Grit Chamber By-pass Pipeline, together with valves and new sluice gates, is under construction as part of the project, for the diversion of flows around the grit chamber, to facilitate easier access and maintenance of the grit chamber.

N2 Bridge Tie In Structure consisting of a connecting the existing GRP

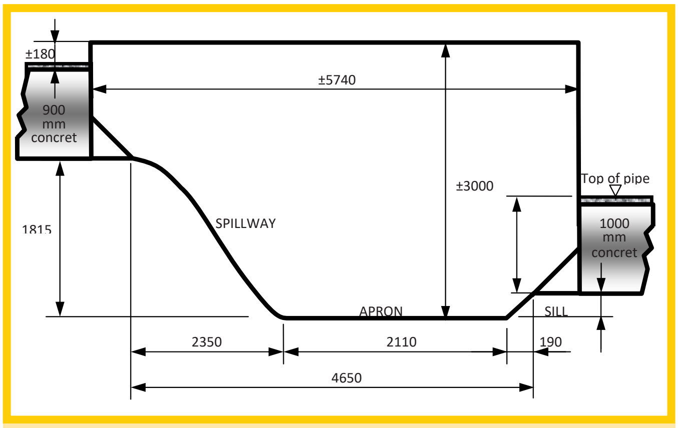

FIGURE 10: Section through Drop Structure giving Internal Dimensions (not to scale)

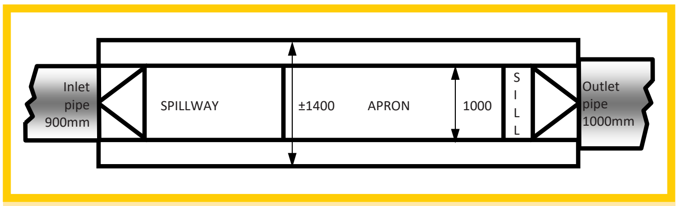

FIGURE 11: Sectional Plan through Drop Structure with Roof Removed (not to scale)

pipeline, previously installed on the N2 bridge Swartkops River Crossing, by use of VJ Coupling, and Reinforced Concrete Structure. Construction took place under confined space between the edge of the road embankment, bridge structure and N2 roadway, and required temporary safety barriers.

Hydraulic Jump/Drop Structure consists of a 10m long x 1m wide x 3m deep Reinforced Concrete Structure, consisting of a spillway, apron and sill. The drop structure has been designed for a 900 mm diameter sewer at the required PWWF capacity of 1 107ℓ/sec when flowing at a depth/diameter ratio of 41.0 % in the upstream pipe and at depth/diameter ratio of 100% in the 1 000mm downstream pipe. The spillway profile and the sill are sized for the maximum flow.

The flow channel through this structure is kept the same width as the downstream pipe diameter to ensure that there are self-cleansing velocities downstream of the hydraulic jump at low flows. The sill is needed to ensure that a stable hydraulic jump will occur within the structure at low flows.

The sill has a sloping surface to assist with the washing out of silt that could occur at low flows. The spillway, apron and sill are to be rectangular in section with a width of 1 000mm and the walls must be higher than that maximum energy level downstream of the jump (1 400mm). (Goyns, 2018)

Details of the hydraulic jump/drop structure are indicated in Figures 10 and 11.

Corrosion Protection of Structures

Investigation was carried out of alternative corrosion protection measures inter alia in-situ HDPE lining, Epochem RA500M Epoxy Coating, Sikagard 720 Epocem and Sikagard 63N three layered system and Sewpercoat (CAC product).

Based on the various considerations including costs, application times and practicalities, SewperCoat is being applied to internal of all structures and manholes. The application of the SewperCoat to the concrete surface consists of the cleaning and chipping of the existing surface to ensure adhesion, high pressure wash, checking pH of the substrate, pre-wetting and applying of the SewperCoat using a Putzmeister worm pump. Bonding test is conducted 24 hours after application, using a small hammer, to ensure bonding of the lining application to the structure. Guniting/Spraying seamless coating to prevent water ingress.

EME (Emerging Management Enterprises)

30% of the value of the Contract was allocated in the form of 11 Packages of R650 000 each, to EME Contractor's. EME Contractor's were nominated from the City Council and Ward lists. The deployment and social facilitation was carried out by a Social Facilitator, and on site by the EME Construction Manager. Each EME Contractor was employed for 3 weeks, 2 weeks of which was for Training (of the specific operations, and compliance with Health, Safety and Construction Regulations, and 1 week was deployed on site, specifically integrated with the Contractor's team involved with the pipe laying operations.

Environmental Considerations & Compliance

As the pipeline traverses through an environmental sensitive estuary of the Swartkops River, which is regulated by the Swartkops Environmental Trust, the Environmental Authorization issued by the Department of Environmental Affairs and Tourism issued strict adherence to environmental authorization compliance.

The piping material proposed for the Markman Main Sewer upgrade is high density polyethelene lined reinforced concrete (HDPE lined RC). An investigation of the most appropriate piping material arose because the existing Motherwell GRP Sewer Pipe, has recently burst at a number of different locations, resulting is serious sewage spills into the Swartkops estuary. Due to these failures of the Motherwell GRP sewer piping, concern was expressed by various stakeholders including Zwartkops Conservancy regarding the use of GRP which was initially proposed. In the light of the above concerns, two reports which investigated the most suitable pipe material was completed. The failures of GRP pipelines referred to by the Zwartkops Conservancy can be attributed to poor construction methods and inadequate bedding material. There appear to be no inherent problems associated with using GRP piping for this project and this material is considered highly suitable for transporting corrosive fluids (sewage) within the corrosive salt marsh environment.

However, due to the fact that sub-contracting inexperienced EME Contractors to construct the pipeline is a policy decision strictly enforced by the Municipality, it was accepted that the integrity of GRP piping will be placed at risk if high construction standards and strict specifications for laying the pipes are not adhered to. It was also recognized that it is unlikely that the EME Contractors will be able to meet the required construction standards. These issues as well as the robustness and strength of the various piping material, concluded that the choice of piping material for this project HDPe lined RC pipe.

Two alternative pipe routes that could be used for the proposed sewer from Settlers Bridge to the inlet works at the FFWWTW was considered. As the pipeline has to traverse a section of very sensitive and important estuarine salt marsh, it is critical to consider the potential impacts of the alternative routes. Option 1 (N2 Route) is from Settlers Bridge south parallel to and about. 2-5m west of the N2 road reserve for 1.25km and then turning west along the northern edge of the FFWWTW site towards the inlet works. This route avoids the very sensitive intertidal areas of the Swartkops estuary salt marsh and is largely confined to previously-disturbed supra-tidal areas near the N2 and along the edge of the raised FFWWTW site.

Initially consideration is for the route traversing parallel to the existing old 600mm and 1 000mm dia sewer pipelines from Settlers Bridge to the inlet works of the FFWWTW, to cross diagonally over the intertidal areas of the estuarine salt marsh as it goes diagonally across the salt marsh, and is the shortest route. A large tidal inlet is encountered about halfway along the Salt Marsh Route pipeline route between Settlers Bridge and the FFWWTW. Estuarine water inundates the pipeline route during high tide at this point, which not only highlights the environmental sensitivity of this locality, but will ensure very difficult working conditions during pipeline construction.

The high water table and tidal fluctuations will inundate excavations for the pipeline trench and the wet, soft substrate will make access for machinery and vehicles very problematic. To enable vehicular access south of this tidal inlet along the existing pipeline route, it will be necessary to make a new access track leading off the existing old haul road. This old haul road running roughly parallel to the N2 is slightly elevated above natural ground level and has a firm hard surface. This is to be used as an access road for machinery during the construction of the pipeline.

Based on the comparative sensitivity and ecological importance of the habitats traversed by the two alternative routes, concluded that Option 1 (N2 Route) poses a significantly lower risk to the estuarine environment during both the construction and operational phases of the project, compared to Option 2 (Saltmarsh Route).

The necessary Water Use Licence Application or WULA approval was obtained from the Department of Water Affairs, which was based on the Baseline Botanical Assessment.

A specialist estuarine botanist was appointed to conduct a plant survey. Based on this study, the vegetation type in the Study Area, namely Swartkops River Salt Marsh, has been classified as Critically Endangered in a recent conservation assessment and plan for the Municipality. In addition, the Study Area falls within a designated Critical Biodiversity Area due to the presence of critically endangered habitats and because the locality functions as an ecological process area.

The recommended land use for the Swartkops River Salt Marsh ecosystem is that this critical ecosystem process area should not undergo further loss through disturbance and development. In addition, before site clearance took place, a "Search and Rescue" operation to identify and transplant all plants of concern present along or near the pipeline route was necessary, before commencement of construction of the pipeline, to mitigate negative impacts on salt marsh vegetation and birdlife

Most of the above concerns associated with and dependent on the construction methods to be employed by the contractor and the conduct of the contractor and his construction workers, as well as the concerns regarding destruction of plant species and disturbance of birdlife, was addressed in the construction environmental management plan (CEMPr). The CEMPr will specify the construction methods to be employed and the appropriate mitigation to be undertaken in order to avoid or reduce the potential impacts on vegetation and birdlife to acceptable levels. These include a search and rescue operation prior to construction and replanting of the vegetation soon after backfilling of the various sections of the pipeline trench is complete. In addition, adherence to the conditions as set out in the construction CEMPr is regularly audited and strictly enforced.

The risk of water pollution during construction, and appropriate mitigation to prevent water pollution during the construction phase of the project are given in the CEMPr. Water sampling was carried out before and after dewatering/pumping of water from the trench, and point of disposal of water, after pumping of water. The chemical constituents in the water is not be altered from pre – to post trench excavation.

An environmental control officer (ECO) was appointed to conduct regular audits to ensure compliance by the contractors to the environmental specifications listed in any authorization granted by DEDEAT.

FIGURE 12: Water Samples Taken for Testing

Health & Safety Compliance

A Health & Safety Officer was appointed to work directly with the Contractor to ensure compliance by the Contractor with the provisions of the Occupational Health and Safety Act, 1993 (Act 85 of 1993).

The Health and Safety Plan and Health and Safety File, as well Construction Works Permit issued by the Department of Labour and approved by the Municipality, was required before Contractor commenced Works Operations.

Regular monthly audits was completed by the Health and Safety Officer, which inter alia included audits of administrative and legal requirements (OHS Programme/Plan, Induction/Safety Training regarding difficult construction operations of trench excavations and pipe laying, risk assessments, cranes and lifting equipment, PPE), education and training (General OHS and induction training), public safety, security measures & emergency preparedness and traffic accommodation, and appointments in terms of H & S Regulations.

CONCLUSIONS

- Many factors and considerations were allowed for in the technical design of the pipeline including routes, environmental and practical constraints, poor ground conditions, extensive groundwater, tight gradients, hydraulic designs given the high flow rate, steep and flat gradient necessary for the placement of a hydraulic jump facility, restricted working space, crossing of existing services and maintaining these in operations during the crossings, pipe material suitability investigations, as well as for the various structures at the tie ins and manholes, environmental constraints and compliance with health and safety regulations, marked this project quite unique and challenging.
- The construction of the pipeline was completed some 9 months ahead of schedule, and given the difficult conditions, it is a unique construction, client and professional team accomplishment to have completed the project, with a high quality of workmanship.
- The innovative and holistic approach to the design and construction of the pipeline and associated structures which was carried out, ultimately resulted in the successful construction and completion of the pipeline, given the severe conditions on site and other restraints.

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