



TWO CASE STUDIES: DELIVERY OF DECENTRALIZED WASTEWATER SOLUTIONS IN ONTARIO AND INDIA

Gillian C. Dumencu
Clearford Water Systems Inc., Canada

Yuxin Wang
Clearford Water Systems Inc., Canada

Wilf G. Stefan
Clearford Water Systems Inc., Canada

ABSTRACT

This paper presents two case studies for the delivery of wastewater servicing solutions: one in Ontario, Canada and the other in Gujarat State, India. In each case a decentralized small diameter gravity sewer wastewater collection and treatment system was implemented for servicing residential development—with some interesting differences and similarities. The first case is a small private mobile home park in Eastern Ontario under a Ministry of Environment Order to address failing on-site septic systems. The Municipality was obliged to take over operation of the on-site systems; however, there were not adequate funds available to rectify the failing systems. A group of local companies initiated the process to find and deliver a solution featuring a Design-Build-Operate-Finance model for a private communal sewage system showcasing advanced wastewater technology. The second case is a rural Indian village without wastewater servicing infrastructure, but with considerable political incentive to implement a new low-maintenance communal sewage system funded through a government-regulated corporate social responsibility program. The completion of the project will enable this village to be cited as the first open defecation free village in Gujarat State; however, success will ultimately be measured by long-term user buy-in. Each case study will discuss the project context; implementation of design, approvals and construction; financial and delivery model; and key success factors and lessons learned. Both case studies will highlight how using unconventional technology and innovative funding enabled the implementation of decentralized wastewater solutions in each situation.

Keywords: Decentralized Wastewater, Infrastructure Financing, Ontario, India, Open Defecation Free

1. INTRODUCTION

Decentralized wastewater systems provide on-site sewage collection and treatment near the source of wastewater generation, either on individual properties or for a cluster of properties. Whereas urban areas are typically serviced by vast collection networks and a large centralized treatment facility, lower density and isolated communities (suburban, peri-urban and rural) are often better served by decentralized systems. The most common configuration of on-site system is a septic tank with subsurface leaching bed. However, more advanced forms of decentralized servicing are becoming more popular as a result of more stringent environmental regulations and the decreasing cost of wastewater treatment technologies.

One such form of decentralized wastewater servicing is a small diameter gravity sewer (SDGS) system, which features sewage solids separation and digestion in on-site interceptor tanks and conveyance of liquid effluent through small diameter gravity sewers to a final treatment facility. This system enables the benefits of solids-free wastewater conveyance with the efficiency of a dedicated treatment facility and a single effluent discharge. The quality of wastewater treatment can be tailored to meet the local environmental requirements—anything from communal leaching beds to aerobic treatment units to packaged mechanical plants. Clearford Water Systems is a

provider of SDGS servicing solutions. The technology was developed from an assignment by the Ontario Ministry of the Environment in 1985 to determine a cost effective wastewater collection solution for northern communities situated in areas with shallow bedrock. Over the past decades, the company has refined the design and delivery of SDGS systems to communities in Ontario, Alberta, Peru, Colombia and India. Experience has proven that this type of decentralized system offers many advantages for construction and operation, and is suited to many more communities than just those with geotechnical constraints. The following case studies are presented to show how the delivery of decentralized SDGS systems allowed for effective servicing solutions in two communities in Ontario and India.

2. FETHERSTON MOBILE PARK, ONTARIO, CANADA

2.1 Project Context

Fetherston Mobile Park is a privately owned year-round residential development located approximately 8 kilometres from Kemptville, Ontario in the Municipality of North Grenville (Municipality). The site now has forty-one (41) mobile homes that were originally serviced by private communal on-site water and wastewater systems. The underground infrastructure was constructed piecemeal as the development expanded, starting circa 1970, including a drinking water well and distribution piping, sewage collection piping, several pumping chambers and five (5) septic systems. More recently in 2006, a small treatment plant was constructed to provide filtration and disinfection for drinking water.

The official records noted several occurrences of raw sewage being discharged to ground dating back to 1974. These discharges were attributed to the breakdown of the sewage collection system and subsurface disposal beds. Several Provincial Orders were issued by the Ontario Ministry of the Environment (MOE) to the former owner over concerns about public health and environmental effects. One Order required the owner to prepare and submit an assessment of the sewage works and to implement the recommendations; however, the work was never completed and the owner continued to neglect maintenance and repairs, resulting in increasingly poor performance of the existing system. MOE attention intensified from 2000 to 2002, until an Order was issued that required the Municipality to monitor the failing sewage system on a weekly basis and take action to deal with sewage breakouts. Despite continued pressure from MOE and the Municipality, the owner was financially unable or failed to take action until the Park went into bankruptcy in 2008. The bankruptcy trustee who took control of the property abandoned the development because of the high cost associated with fixing the failing septic system.

This left the residents and the Municipality in a difficult position. The Municipality was now responsible for operating the failing sewage system and addressing the Provincial Orders, but could not spend public money to replace infrastructure on a private site. The residents were owners of their homes, but did not have the means or the legal structure in place to become owners of the land. The Municipality searched for a buyer to assume control of the development from 2009 to 2012, but all were deterred by the high cost of replacing the on-site sewage system. The Municipality was forced into a grim course of action in 2013—eviction notices were distributed to the tenants of the Fetherston Mobile Park. Residents rallied to keep their homes and contacted local media in hopes of saving their community. Media coverage attracted interest from an Ontario water industry leader, who worked to assemble a team of interested industry partners to develop a solution for the troubled site.

2.2 Delivery Model

The solution had to meet the public health and environmental objectives, and more challengingly, to limit the upfront and long-term costs to residents so they could afford to remain in their homes. Two facts became clear as the options were investigated: the Park residents themselves are the most suitable landowners for the development, and private funding with a financing component would be required to implement a sewage servicing solution. The industry partners, residents and Municipality worked together to develop a plan for implementing the ownership, funding and responsibility mechanisms.

In order for the residents to take control of running the Park, they had to legally form their own Park Association under the Ontario Condominium Act. With support from the Municipality, the property was transferred from the bankruptcy trustee to the new Park Association. Once the land ownership was resolved, the industry partners (hereafter called “service provider”) engaged with the Park Association to discuss terms for a water and sewage

service agreement. Although the Park could not afford the upfront capital cost of replacing the sewage system, residents agreed that they could afford a monthly user fee. Since the Park would also have to pay for operating costs, it was decided that the service agreement should include both capital and operating costs. The scope of services was defined for design, build, financing and operation of the new water distribution and wastewater systems, with all-inclusive operation, maintenance and management services by a qualified licenced operator and full compliance with regulatory requirements. Given the projected capital and operating costs for the new water and sewage systems, the service provider determined that the term of contract should be 32 years in order to provide a suitable return on investment for the private financier. The monthly service fee is subject to increase only for additional units connected to the system, for inflation, and to account for additional level of effort and consumables related to every 25 additional units.

In accordance with Ontario policy, municipalities are directed to establish municipal responsibility agreements for privately owned communal water and sewage systems. Such an agreement enables a responsible municipal authority to assume control of a malfunctioning system to protect the environment and public health if the owner of a privately operated system has insufficient funds to remediate the problems. The local Municipality required that a responsibility agreement be drafted for the new servicing at Fetherston Park. Based on provincial guidelines, specific responsibilities, conditions and best practices were established regarding proper construction, operation and maintenance, as well as providing secured reserve funds for remedial measures that may be required. In this way, the Municipality is assured of the quality and condition of servicing should they be required to assume control. The municipal responsibility agreement was signed by the Park, the Municipality and the service provider.

2.3 Implementation

Once the ownership and funding components were established, the technical aspects of implementation were worked out. In Ontario, new wastewater facilities for residential developments with daily flow greater than 10,000 litres/day are subject to the regulatory requirements of the Municipal Class Environmental Assessment (MCEA). MCEA is an environmental planning process for municipal infrastructure projects that promotes public consultation and traceable decision-making. The Fetherston MCEA study identified the project objectives and environmental constraints. Several alternative solutions were evaluated, including replacement of the on-site septic systems and construction of a new sewage forcemain to convey sewage 8 kilometres to a municipal sewer in Kemptville. Based on the environmental evaluation criteria, the preferred solution was a decentralized system consisting of a SDGS collection system to a communal wastewater treatment facility with surface water discharge. Different wastewater treatment processes were considered, such as extended aeration and moving bed bioreactor. Finally, a membrane bioreactor (MBR) process was selected for secondary and tertiary treatment because of its compact size and reliably high quality treated effluent. The evaluation identified treatment process efficiencies enabled by the use of a SDGS collection system, namely, no headworks or primary sedimentation since these processes are provided by the interceptor tanks at each home.

The SDGS system provides primary treatment and partial digestion of raw sewage in interceptor tanks on each lot. Interceptor tanks were designed to achieve a minimum hydraulic retention time based on the average daily sewage flow from each home and in-tank sludge storage capacity. Effluent wastewater from the interceptor tanks is conveyed through small diameter variable grade sewers to a lift station and equalization tank, then to the MBR treatment plant. A design-build request for proposal process was completed to identify an appropriate treatment plant supplier. Due to time and space constraints, it was decided that a containerized MBR treatment plant should be manufactured and delivered to site. The MBR plant design includes an aeration tank with alum injection, a membrane tank, and ultraviolet (UV) disinfection. The discharge from the plant is an open pipe outfall to a drainage ditch that flows into a tributary of the South Nation River. The high quality treated effluent meets the MOE discharge criteria with a stringent total phosphorus limit due to water quality concerns in the mainly agricultural South Nation watershed. One of the conditions of surface discharge was participation in a phosphorus trading program for point and non-point source polluters in the watershed.

In Ontario, proposed sewage works are reviewed by MOE and issued an Environmental Compliance Approval (ECA). A full design package was submitted including design drawings and a report containing all the technical design parameters and details for the proposed SDGS system and MBR treatment plant. Because of the history of sewage system non-compliance at the site, the ECA review was expedited to allow an immediate start to construction. Building permit approval was also required from the Municipality for plumbing connections to the

new sewer system and for the replacement drinking water distribution piping that would be installed in a common trench with the sewers. A general contractor was selected in a tender process while the treatment plant supplier started final procurement of equipment and assembly of the MBR plant.

Construction commenced at the site in September 2015. There were considerable challenges associated with construction phasing so as to maintain water and sewage servicing to residents for the duration of construction. The location of existing services was poorly documented; therefore, any excavation carried the risk of breaking the existing buried water and sewer services, thereby disrupting service to residents and potentially causing a sewage spill. To avoid these negative effects, drinking water distribution was supplied through a temporary aboveground watermain system connected to the existing water supply and treatment plant. A UV- and impact-resistant PVC pipe product was selected for durability during the construction period. Once the temporary water system was commissioned and connected to the plumbing at each home, the existing buried water system was depressurized and abandoned. However, sanitary servicing still had to be secured so as not to cause a sewage spill during excavation. A sewage management plan was developed to allow continuous sewage servicing during construction, enabled by the use of SDGS with interceptor tanks. Thirty (30) 4000 litre interceptor tanks were installed, one adjacent to each home or shared between two homes. Lateral drainage piping was installed from the home to the interceptor tank inlet. Existing sanitary connections were cut and abandoned, and the new drainage pipe was connected to the home plumbing, allowing sewage to flow into the interceptor tanks which were capped at their outlet to act as sewage holding tanks (refer to Figure 1). Sewage level floats were installed in the tanks to monitor when they needed to be pumped out by vacuum truck.

Once the temporary drinking water system and sewage holding tanks were operational, full excavation could begin. Approximately one kilometre each of 75 mm HDPE small diameter sanitary sewer and 31 mm HDPE watermain pipe were installed below the frost penetration depth in a common trench beside the roadways (refer to Figure 2). The HDPE pipe was thermally fused at joints to eliminate infiltration and exfiltration, allowing for a narrower common trench with water and sewer services. Water and sewer appurtenances were installed, including valves and valve boxes, draining curb stop valves, and sanitary sewer maintenance cleanouts. Installation was slow because of restricted working space to allow continued traffic and pedestrian access on roadways and to the homes. Water and sewer service laterals were installed but not connected until after commissioning of the new systems. The new drinking water distribution system was chlorinated and pressure-tested, while the sanitary sewer system was tested for leakage. The old water and sewer services were abandoned, and the septic systems were decommissioned.

While installation of the water and sewer services was underway, the treatment plant supplier manufactured the package MBR plant. All of the equipment, components and electrical were installed inside of a modified 40-foot shipping container at the supplier's workshop. On-site installation included excavation and delivery of two large precast concrete tanks—one for the flow equalization lift station, the other for waste sludge holding. Buried piping and ducts were installed under a granular pad that was designed to support the weight of the containerized plant. After the plant was assembled and pre-tested at the workshop, it was delivered to site on a flatbed truck and lowered precisely by crane onto the granular pad over buried vertical pipe stubs for the plant inlet and outlet (refer to Figure 3). A short pipe outfall with rip-rap treatment was installed to the nearby drainage ditch. The plant supplier made the connections and commissioned the plant. Once sewage was flowing through the sanitary sewer network to the lift station tank, the plant was seeded with waste activated sludge from a nearby operating wastewater treatment facility. Within several days of start-up, the new MBR plant was processing sewage and meeting its discharge quality limits. The operator can fine-tune the operation manually or remotely through a custom integrated control panel.



Figures 1, 2 & 3: Installation of an interceptor tank, small diameter gravity sewer and membrane bioreactor in Ontario

2.4 Lessons Learned

The Fetherston project was successfully completed after over a year of planning, design and approvals, and five (5) months of construction. A review of the project identified several key success factors: a strong team focused on overcoming obstacles, a clearly defined scope and achievable milestones, the support and patience of stakeholders, and cooperative weather during construction.

The following are the main lessons learned during the Fetherston project:

Private financing can unlock the successful delivery of infrastructure projects. Public funding may not be available or appropriate for all water and sewage infrastructure projects; however, private funding arrangements can be successfully developed to serve both public and private interests. Open discussion and cooperation among stakeholders is critical to implementing the project on a tight timeline.

Communication between stakeholders keeps the project moving forward. There were many parties actively involved in the project, namely the residents, review agencies (Municipality and MOE), and the implementation team (technology/service provider, contractors, and operator). Open communication between stakeholders allowed for quick responses, problem solving and implementation so that the interests of all parties were satisfied. Positive support for the project was maintained from planning through to commissioning.

Living sites have complex safety and implementation considerations. Because residents continued to live in their homes during construction, there were several considerations that complicated the project implementation. Construction phasing had to be closely planned to ensure continued water and sewage servicing and access throughout the site. Installation took longer than expected because of limited work space and consideration for residents. Vigilance was required at every work area to ensure the safety of workers and residents.

3. JAMBUDIYAPURA, GUJARAT STATE, INDIA

3.1 Project Context

Jambudiyapura is a small village located in a rural agricultural area northeast of the city of Vadodara, Gujarat. The village has a population of approximately 250 people living in 56 family homes, with a daycare and a small elementary school. The village is facing potential economic growth because of the recent completion of a nearby new local highway and expected construction of a new cricket stadium on vacant lands adjacent to the village. Although there is a pressurized drinking water supply from a communal water tower to overhead tanks in the homes, more than 90% of households do not have access to toilets and bathing rooms. Open defecation and bathing water

accumulate in low-lying areas, creating non-point source pollution and contaminating crops and the nearby creek and small lagoon. The area is generally flat and gets flooded almost every year during the monsoon season. The lack of dedicated sanitation facilities is threatening public health and economic development in the village. Hence, there is need for a low-cost low-maintenance sanitation system that includes toilet and bathing facilities, wastewater collection and treatment.

The Swachh Bharat Abhiyan, or Clean India Mission, was announced by the Indian government in 2014. The five-year campaign promotes a massive change towards sustained sanitation, from cleaning streets to establishing open defecation free practices across the country. In addition to government and NGO programs, the government has called on corporations to contribute to the open defecation free movement by directing corporate social responsibility funds towards new sanitation infrastructure in schools and villages.

3.2 Delivery Model

In India, corporations are required by regulation to fund corporate social responsibility (CSR) programs to encourage a community-based approach to enhance public awareness of health and security issues related to sustainable development. The developer for the nearby local highway decided to use its CSR funding to implement open defecation free sanitation for the village. The key objectives for the project are to have safe access for all households to a private toilet and bathing facility, and for the villagers to be trained to take over operation and maintenance of the new sanitation system.

The developer selected a partner to design and build a fully functional and cost-effective sanitation system to meet the project objectives and budget. Although the developer's CSR program would fund most of the project capital cost, residents were asked to contribute a nominal amount upfront as a commitment to the project. A cost sharing agreement was developed to ensure affordability and participation of all residents, whereby each household could pay up to a maximum amount or to contribute in kind, for example, by providing labour for construction. Operation and maintenance costs are covered for the first two years by the developer, while longer term responsibility will be negotiated between the developer and the village.

3.3 Implementation

At the design planning stage, the major focus was the evaluation of different wastewater collection and treatment technologies, and of toilet and bathing facility features. Detailed discussions on toilet and bathing facility designs were held with the developer, villagers, the design-build partner, and a local architect and engineering consultant hired by the developer. The resulting design of side-by-side enclosed squat toilet and bathing rooms was considered most appropriate to meet the villagers' preferences, while providing a facility in each household backyard ensures safe private access for residents. Site visits to the village and surrounding areas were undertaken to collect information and get an understanding of site conditions and constraints. The collected field information included household survey data, land uses, water supply data, power supply status, and topographic characteristics. It was reported that the per capita water supply in Jampudiyapura is 70 litres/capita/day for both domestic and agricultural (cattle) uses. With such a low flow rate and high solids concentration in the wastewater, it was determined that a conventional sewer system would be difficult to maintain because of solids accumulation; therefore, a SDGS collection system was selected for solids-free wastewater conveyance. Various on-site wastewater treatment technologies were considered; however, a constructed wetland was chosen by the developer and its engineering consultant because of low-cost construction, easy operation, minimal maintenance, and low power requirement.

The final design package for the village sanitation system was reviewed and approved by the village and the developer's engineering consultant. The system is an end-to-end solution consisting of a toilet and bathing facility at each home connected to an underground interceptor tank in the backyard of each household lot, flowing to a shallow buried SDGS network, and to a constructed wetland for wastewater treatment discharging to the nearby creek and lagoon. The toilet facilities are designed with a small rooftop water storage tank over separate toilet and bathroom stalls each with lockable doors, high windows and lighting for privacy and safety. An elevated floor prevents flooding during monsoon and a sheltered outdoor washbasin, or mori, is provided for dish washing and laundry. Wastewater generated from the mori, toilet and bathroom is collected in PVC drain pipes connected to a 2000 litre interceptor tank. The interceptor tanks are constructed in-place with top and bottom concrete slabs and hand-laid brick walls lined with cement. The tanks are connected to 75 mm HDPE small diameter sanitary sewers that convey

effluent wastewater to the constructed wetland for final treatment. The constructed wetland is a proven design by an Indian supplier that can achieve the effluent standards set by the Ministry of Environment and Forest (MOEF) and Central Public Health and Environmental Engineering Organisation (CPHEEO). The wetland is described as a soil biotechnology treatment process utilizing vertical flow through a proprietary media.

Construction started in late November 2015 after the monsoon season. Some challenges were encountered early on, largely due to the lack of skilled field workers, inflexible schedule, and tight budget. Under the contract agreement, the design-build partner was retained for carrying out all aspects of the project such as preparing tender documents and construction specifications, finding and evaluating local contractors, conducting quality control and site supervision, risk mitigation, monitoring construction progress and reporting to the developer and the villagers. To address these challenges, the construction activities were carefully planned in four stages. In the first stage, the constructed wetland was installed by the supplier at the downstream end of the system near the discharge creek. Meanwhile, the final design of the toilet and bathing facilities was completed. In the second stage, the household toilet and bathing facilities were constructed by an experienced contractor who carried out the labour-intensive field work of casting in-place each toilet and bathing facility and completing the plumbing, tiling and other finishing work (refer to Figure 4). A communication plan was developed to guide the interactions with residents to inform them of construction activities on their properties and enabling them to contribute to construction decision making and risk mitigation. A site engineer was present to oversee construction management and quality control by checking material samples and coordinating with the design engineers for field adjustments due to commonly encountered terrain conditions such as waterlogged ground and black cotton soil. The third stage of construction started after 50% completion of the toilet and bathing facilities. The SDGS and sanitary connections were installed along the rear household lots (refer to Figure 5), across the roadway towards the school and daycare, and connecting to a lift station near the constructed wetland (refer to Figure 6). The final stage before operation was testing and commissioning of the sewage system components including leakage testing of the interceptor tanks and sewers, and hydraulic testing of the constructed wetland.



Figures 4, 5 & 6: Construction of toilet and bathing facilities, interceptor tanks and constructed wetland in India

3.4 Lessons Learned

The Jambudiyapura village servicing project was successfully completed after 6 months of construction. Construction of the toilet and bathing facilities for each household accounted for most of the work during that period; however, these private facilities are the critical aspect of delivering a safe and usable wastewater solution. Long-term success of the open defecation free village model will depend on the effectiveness of the final implementation, particularly whether the design of the toilet and bathing facilities meets the daily needs of the villagers. User buy-in will be tied to the residents' sense of ownership and pride for the new wastewater system, and to the perceived health and economic benefits of maintaining sanitation servicing in their village. A review of the project identified several key success factors: well-defined project objectives, the support of residents and stakeholders, and a well-organized local workforce for delivering the project.

The following are the main lessons learned during the project:

Technologies must be adapted to suit local preferences and conditions. Canadian expertise in technology should be paired with local experience in project delivery. It is also critical to be engaged with local professionals and residents to establish preferences and expectations that will make a project successful or not. For example, the most important local considerations—design of the toilet and bathing facilities, toilet and interceptor tank locations on each lot—were not well-understood by the Canadian team members; but working closely with the residents enabled successful implementation and user buy-in.

Corporate social responsibility programs are an important delivery mechanism for community infrastructure projects in rural India. Through CSR, Indian companies are incentivised to engage with local communities to target appropriate servicing solutions. Technology providers can benefit from a CSR partnership to participate in manageably-sized projects with clear delivery objectives. Working directly with an Indian company is an effective way for Canadian companies to import technology while respecting local customs and business practices.

4. DISCUSSION

These case studies highlight how innovative funding and unconventional technology enabled the implementation of decentralized wastewater solutions in two small communities in Ontario and India. In both cases, residents were unable to afford the initial capital cost of constructing a new wastewater system; however, creative funding models—corporate social responsibility in India, and a private design-build-operate-finance arrangement in Ontario—were applied to make these projects viable. Additionally, the choice of wastewater technology—specifically, small diameter gravity sewers with interceptor tanks—was critical to the success of these projects, but for different reasons. In India, SDGS was suited to conveying the low flow of wastewater where conventional whole sewage sewers have failed. In Ontario, the risk of causing sewage spills from the existing system was eliminated by using SDGS interceptor tanks for sewage holding during construction. Wastewater treatment technologies were thoughtfully selected to match the requirements for each project. While final treated effluent quality was a main consideration, the sustainability of operation and maintenance for the treatment technology was also important. In India, a locally-designed low cost constructed wetland provided adequate treatment with easy operation and maintenance, and low power requirement. In Ontario, a membrane bioreactor process was selected to meet the strict nutrient limits and to reduce the footprint of the treatment plant. The success of both projects was attributed to having well-defined objectives, the support of stakeholders and local resources, and strong communication to allow collaborative planning and effective problem solving.