RedZone® ROBOTICS

SAMPLE SPECIFICATION

MULTIPLE SENSOR INSPECTION (MSI) FOR LARGE DIAMETER MUNICIPAL PIPELINES

This sample specification document is intended to encompass minimum requirements for a condition assessment utilizing state-of-the-art inspection technologies to enable condition based asset management of large diameter municipal pipelines, interceptors, outfalls and intakes.

Section A: Platform/Transport of Inspection Technologies

1.0 General:

The provision of a stable platform capable carrying a payload of a minimum three inspection sensors allowing for simultaneous, synchronized data collection in order to accurately determine existing conditions within a pipe of 36" (90 cm) minimum diameter for Video/Sonar/Gas and 48"(120 cm) minimum diameter for any combination of sensors that includes Laser. Comprehensive digital assessments in a variety of pipe environments are obtainable with onboard analog to digital data conversions that allow for extended inspection runs initiated through a single access location. The ability of upstream and downstream movement within a pipeline in empty, full, or partial flow conditions enables cost savings because reductions to pipe flow are not necessary in order to facilitate an inspection. However differences in flows, pipe configuration, or platform type could affect the number of usable sensors and the availability and quality of data from those sensors. Eliminating the risk of becoming lodged or lost in a pipeline is critical to the success of the inspection. Increased weight and ruggedness has been known to improve data quality by providing stability and increased control during data collection.

2.0 Tracked Platform/Transport Detailed Minimum Capabilities:

It is required that the platform be capable of insertion through (at a minimum) a circular standard 23" (58 cm) opening with minimum modifications to the access structure. The platform must be rated to a depth of 150' (45 m) and capable of deployments of a minimum 5,000' (1500 m) either with or against the flow. The platform shall be capable of complete operability in no flow conditions, and operable in flow of up to 8 ft/sec (2.5 m/sec) in partially and/or fully submerged conditions. Maneuverability must ensure that the unit is capable of zero degree turning radius.

The platform shall be equipped with an Inertial Measurement Unit (IMU) to enable real-time monitoring of its position and orientation. The IMU shall measure three axis of rotation and three axis of acceleration. The platform shall provide real-time measurement of pitch and roll measurements with respect to gravity that are accurate to +/- 1 degree. The platform shall be equipped with a standard CPU with RS-232, RS-485, USB, and Ethernet interfaces in order to facilitate simultaneous collection of multiple sensor data which provide pipe condition assessment data.

Certain pipe conditions may prohibit the use of a tracked Platform/Transport due to sediment, pipe shape, etc…. If the specified tracked platform has attempted and is unable to pass through a portion of the intended inspection area, the owner and contractor may mutually agree to the use of a floating platform. The use of a floating platform would be decided on a case by case basis.

Minimum Transport and Tether System Equipment Specifications:

ON BOARD POWER:	Electro-hydraulic, 4 hp (3 kW) power unit minimum
ON BOARD LIGHTING:	Supports up to 8 auxiliary lights with 1,300 lumens max. output per light
DRIVE:	Hydraulic –330 ft-lb (446 Nm) torque

STEERING:	Independent track control with powered forward, reverse, and skid-steer
TETHER:	7,500 lbf (33,361 N) break strength, copper power transmission, fiber optic
PAYLOAD CAPACITY:	Minimum 250 lbs (113 kg)
CONSTRUCTION:	Stainless steel body and rubber treads
SPEED:	0-40 ft/min (0-12 m/min)
TURRET:	180 º range of motion
YOKE:	90 º range of motion
MAX. DRAWBAR PULL:	2000 lbf (8896 N)

3.0 Floating Platform/Transport Detailed Minimum Capabilities:

It is required that the platform be capable of insertion through a standard 24” (61 cm) opening with minimum modifications to the access structure. The platform must have the ability to inspect continuous lengths of pipe up to 4,000 ft (1,200 m). Speed controlled reels/winches shall be used to pull the platform in both upstream and downstream directions. The platform shall support simultaneous use of multiple sensors weighing as much as 65 pounds. The platform must be stable in high-velocity flows of up to 5 ft/sec (1.5 m/sec). The platform shall support up to 8 auxiliary high intensity solid state lights with 1,300 lumens of maximum output per light capable of illuminating pipes as large as 12’ (3.6 m) diameter. The platform shall be capable of skid-based operations where the platform is pulled through the pipe while riding along the pipe surface or sediment so that low flow conditions do not prevent inspection.

The platform shall be equipped with onboard computing supporting RS-232, RS-485, USB, and Ethernet interfaces in order to facilitate the simultaneous collection of multiple sensor data.

Minimum Transport and Tether System Equipment Specifications:

ON BOARD POWER:	Battery Operated
ON BOARD LIGHTING:	Supports up to 8 auxiliary lights with 1,300 lumens max. output per light
DRIVE:	Speed Controlled Winch/Reel with 600lbf (2668 N) pulling force
TETHER:	4,000’ (1219 m) Optical cable
PAYLOAD CAPACITY:	65 lb (29 kg) of Sensors
CONSTRUCTION:	HDPE Hull and Aluminum Enclosures
SPEED:	0-40 ft/min (0-12 m/min)

Section B: CCTV Inspection

1.0 General Objective:
The purpose of a CCTV inspection component in a Multi-Sensor Inspection is to visualize pipeline defects and features. CCTV inspections gather digital images of the complete end-to-end and overhead arc of pipe coverage above the fluid level. The CCTV component must provide off-line viewing capabilities that can be imported into PACP / WRc compliant pipe annotation tools. This tool ensures that digital images are easily shared, viewed, stored and retrievable for comparative analyses, historical reference, and subsequent prediction of future pipe condition. The inspection is intended to identify operational or structural issues which require attention. The work shall include a CCTV inspection of the pipeline and the preparation of all video, digital, and written reports. If a blockage or obstruction is encountered and conditions allow, the survey shall be attempted from the opposite end of the pipeline and continued back towards the blockage or obstruction in order to ensure maximum data collection of the pipeline segment.

2.0 CCTV Video Signal Transmission:
The CCTV video system must be capable of transmitting from the underground pipe environment to a surface control center with zero loss of clarity. It is therefore required that the CCTV service provider utilize a fiber optic cable for signal transmission. The cable must support multiplexing of numerous signals from numerous sensors over the one fiber. CCTV signal transmission must take into account and prevent or compensate for high frequency roll-off in order to maintain image detail.

3.0 CCTV Operator Certification:
At all times during the inspection, a certified CCTV operator shall be used to operate the inspection equipment and code the inspection. NASSCO/PACP or WRc certification is required to ensure inspection and defect coding is done in a consistent manner. A copy of the CCTV operator's certificate stating certification or re-certification within the previous five years must be submitted prior to start of CCTV inspection operations.

4.0 CCTV Camera System Specifications:
The pan tilt zoom (PTZ) camera shall be waterproof and corrosion resistant with a minimum depth rating of 30m/100 feet and able to operate in temperatures between 0-50 degrees C (32-122F). The sensor shall be ¼" color CCD with a minimum 1.5 lux sensitivity for resolution of minimum 460 NTSC TV lines. A full 360-degree axial pan is required with a variable pan speed not to exceed 25 degrees/second. The camera shall have a minimum 40:1 zoom lens capable of 10X optical and 4 X digital, with auto or remote manual focuses. The adjustment of focus and iris shall allow optimum picture quality to be achieved and shall be remotely operated. The illumination shall be such as to allow an even distribution of the light around the pipeline perimeter without the loss of contrast or flare out of picture shadowing.

5.0 Distance Measurement:
A suitable distance-reading device which uses cable length to accurately measure the location of the camera in the pipe shall be provided. This device shall be accurate to ±1% of the length of the inspection. In order to obtain a full record of the pipe length, the distance shall be recorded as zero from the beginning of the pipeline segment (usually the intersection of the start of the pipeline and the inside face of access chamber) to the end point of the inspection (usually the intersection of the endpoint of the pipeline and the inside face of the terminal access chamber).

6.0 CCTV Video Capture and Data Recording:
Video capture equipment shall be capable of continuously capturing digital video from first generation recordings with no frame loss, regardless of the progression of the inspection. Software must be NASSCO or WRc certified and integrate seamlessly with other third-party NASSCO or WRc certified data management software.

Section C: 3D LASER Inspection

1.0 General Objective:
The provision of 3D laser scanning provides an accurate determination of pipe geometry above the fluid level. Internal Diameter and Deflection graphs will be used in conjunction with the integrated and detailed views to precisely quantify internal pipe wall material loss/gain or deformation at a given payout location and clocking angle. Pipe cross-sections obtained from precision high resolution scans will be used to provide quantitative information regarding internal pipe diameter, including ovality. Precision Scans are produced

with multi-color indication depicting deviations from as-built conditions as well as localized material gain and/or loss.

2.0 3D Laser Inspection Detailed Description of Work:
Laser scanning shall be conducted continuously and simultaneously with other inspection technology for the entire length of the pipeline as identified in the detailed Scope of Work. Laser equipment shall be moved through the pipeline on a transport vehicle capable of supporting the laser inspection equipment above the water level. Tracked platforms must be capable of forward/stop/reverse mobility for detailed high resolution scans to be collected at a specified interval.

3.0 Minimum Equipment Standard Requirements:
Laser scanning equipment shall be capable of measuring the distances to objects and surfaces in pipes, and shall be capable of imaging pipes from 48” (120cm) to 250” (635 cm) in diameter when used on a tracked platform and 80” (203 cm) to 250” (635 cm) in diameter when on a floating platform. The laser shall support 75 Hz scan rates or higher and be Class 1; eye-safe for operator safety. The laser sensor resolution shall be at least 1mm.

4.0 Laser Scan Results (Included in Multi-Sensor-Inspection report):
An overview of data is to be presented in a color coded format as 2D cross sections conveying pipe condition above the laser’s centerline over the length of the inspection segment. Measured pipe ID that coincides with expected values must be coded green. Outward deformations, as measured by increasing pipe ID, must be colored on a yellow/red color scale, advanced deformation. Material gain (buildup) or inward deformation, as measured by decreasing pipe ID, must be on a blue color scale. To support identified radial localization of defects, individual ID measurements as computed from the axis of the inspected pipe must be presented in an illustrated ovality and deflection graphs covering the length of the inspection segment.

Laser scan results identifying ovality and deflection must be presented in 2D cross-sections. The color coding is to be identical to the aforementioned requirements. Where the presence of fluids in the pipe necessitates interpolation and estimation, calculations to fill gaps and complete the full circumference view will be performed. The method and calculations used to support these assumptions must be presented. Sonar or as-built data, if used for these calculations, must be identified in the report. Areas revealing deflection greater then 2% ovality and 5% defection must be identified in the report.

Any high resolution scans obtained during the inspection are to be provided along with the report in a 3D point cloud (VRML) format including software for viewing on a PC.

5.0 Error Tolerance
Precision Ovality Scans including but not limited to Sensor Error, Axis Alignment Error, and Processing Errors must be accurate to +/- 1 %

Section D: SONAR Inspection

1.0 General Objective:
The provision of Sonar scanning provides an accurate determination of pipe conditions below the fluid level during an in-pipe inspection. Sediment depths must be measured at regular intervals and averaged over the payout length in order to show the average depth at each interval. Average Sediment Accumulation must be determined by calculating the cross-sectional area of the pipe obstructed by sediment and presented as a percentage of the total cross section area of the ideal pipe. The Available System Capacity will be calculated from the Cumulative Sediment Volume, which is derived by integrating the sonar profile scans which measure sediment cross sections. The pipe is to be divided into sections based on sediment volume. One of four cleaning levels must be recommended for each section, based on the Sediment Accumulation for that section of the pipe.

2.0 Minimum Equipment Standard Requirements:
Sonar equipment must be specifically adapted using multi-frequency sound waves to locate and map irregularities by creating continuous sonar images recorded in “real time” mode. Sonar equipment shall be digital, capable of operating in pipelines with diameters from 36” (90 cm) to 240” (600 cm). The equipment shall be programmable multi-frequency profiling sonar which supports a range of frequencies from 600 kHz to 1.0 MHz.

The Sonar equipment must utilize digital, multi-frequency profiling sonar in order to model the pipe under submerged and partially submerged conditions. Using a rotating transducer, the sonar unit shall transmit an acoustic signal toward the pipe walls in a radial fashion. The time delay between transmission and reception of reflected pulse echo is used to determine the distance from the transducer to the surface that reflected the pulse. Determination of the acoustic frequency to be used is influenced by two competing factors: background noise (which decreases as pulse frequency increases), and signal loss (which increases as frequency increases).

The Sonar equipment's unique architecture shall allow for the incorporation of positional sensors which provide accurate information on the location of sediment. In addition, the unique mobility system shall allow for the collection of high resolution data by slowing the robotic system and thereby facilitating the collection of more sonar data. A profiling sonar image is a 2D snapshot of the cross section of a pipe. The tracked platform shall have the ability to adjust the sonar's axis and consequently get additional representations of an area of interest within the pipe.

The quality of data is dependent upon obtaining accurate distance measurements from the sonar sensor. The amount of range error is a factor of the distance from the sonar unit to the feature (pipe wall) being measured. The range resolution measurement error shall be no greater than 0.08" (2 mm) from a distance of 3-12' (1-4 m) and no greater than 0.4" (10 mm) from distances of beyond 15' (5 m). The minimum detectable range for the sonar unit shall be minimum 6" (150 mm).

3.0 Sonar Scan Results (Included in Multi Sensor Inspection report):
Final reports must include graphical display of sediment volume and location, sediment levels, and pipe capacity depicting actual vs. ideal storage capacity. The data shall be compiled in a format that can be used for calculating changes in sediment depth, sediment volume, and sediment accumulation, when compared to past or future condition assessments.

4.0 Error Tolerances for Sediment Quantification:
Where sediment/debris volume estimates are given, the volume calculation accuracy shall be a minimum 92% for pipelines between 36" (900 mm) to 54" (1350 mm) diameter inclusive, and a minimum of 95% accuracy for pipelines equal to or greater than 60" (1800 mm) diameter.

Section E: H_2S GAS and TEMPERATURE Inspection

1.0 General Objective:
The presence of H_2S can prove devastating to waste treatment infrastructure. The potential for the presence of gases is greater in large diameter pipes because flow rates tend to be lower and the area above the flow level is greater than in smaller pipes.

H_2S in sewer pipes is produced by a combination of anaerobic bacteria and aerobic bacteria. Anaerobic bacteria (chemoorganotrophs) living below the water line transform sulphate into sulphide. The sulphide combines with hydrogen from the water to form H_2S gas, and this process is accelerated in higher temperature environments. Chemolithotrophs are bacteria that can process inorganic molecules such as hydrogen sulphide. Thiobacillus, a chemolithotroph, is a species of aerobic bacteria that thrives on surfaces above the waterline, such as the walls and crowns of sewer pipes. Thiobacillus converts the H_2S gas into sulphuric acid, H_2SO_4) which corrodes interceptors and can cause the collapse of other concrete waste treatment structures.

Normal average concentration of H_2S in clean air is about 0.0001-0.0002 parts per million (ppm). In order to produce sulphuric acid, the Thiobacillus bacteria require H_2S in amounts above 2.0 ppm.

Significant increases in the levels of H_2S gas facilitate the increased production of sulphuric acid. Increases in sulphuric acid accelerate the deterioration of concrete pipes. H_2S levels should be monitored over time to insure that the concentration remains below the threshold required to produce sulphuric acid (less than 2.0 ppm).

2.0 Scope of Work:
The gas and temperature inspection shall capture H_2S concentrations and air temperature measurements continuously along the pipe length using an electrochemical hydrogen sulphide sensor. H_2S concentrations measured and displayed relative to pipe location may indicate potential problem areas for further

investigation. High H_2S concentrations can be correlated to pipe corrosion and accelerated losses of pipe thickness. The atmospheric temperature inside the pipeline shall be recorded during the inspection.

3.0 Technical Sensor Specifications:
The H_2S sensor shall operate in a temperature range of -50F (-10C) to 104F (+40C) at pressures that vary from atmospheric by +/- 10%. The sensor will perform in 15-90 % non-condensing humidity with a 90% response time of less than sixty seconds. The Sensor Dynamic Range shall be from 0 ppm to 200 ppm with a maximum theoretical range from 0 ppm to 999.9 ppm. Sensor Measurement Resolution shall be 0.1 ppm. The Sensor Measurement Accuracy shall be +/- 1.0 ppm at standard temperature and pressure.

4.0 H_2S Gas and Temperature Results (Included in Multi Sensor Inspection report):
The final report, provided the inspection is a repeated inspection capable of comparison to previous gas inspections, shall compare the levels of H_2S gas over time. This report is not required if this is an initial inspection as this time-based calculation requires a baseline for reference. It will be possible to calculate changes in H_2S Concentration using H_2S concentration data from this initial report as a baseline by comparing this data to H_2S concentration data obtained during subsequent inspections.

The final report shall provide the locations where the inspected pipe contains average concentrations of H_2S above the 2.0 ppm level necessary for the production of sulphuric acid (H_2SO_4). In addition, the overall average of the concentration of H_2S gas in this section of pipe in ppm must be illustrated in graph and table format. The average temperature over the distance of the inspection along the pipeline must be graphically illustrated. The final report shall present the temperature levels over distance in a line graph.

Section F: Bid Line Items, Scope, & Schedule

1.0 Lump Sum Submittal:
It is recommended that the description of a lump sum proposal price specifically enumerate the tasks identified in the Scope of Work in order to ensure that no additional costs will be incurred for the completion of the inspection. This will ensure complete and accurate comparison of total costs required to perform the inspection.

2.0 Bid Line Items:
The chart below indicates a more accurate method of breaking out various tasks which have related costs that may affect the overall Bid price of the project. It is intended that all matters required to conduct the inspection, whether supplied by the owner, subcontractors, or the submitter, be addressed and considered in the overall reward of the contract. The line items reflect on-site and off-site activities for clarity.

SCOPE OF WORK					
Item	Description	Qty	Unit	Unit Price	Total Price
Phase 1: On-Site Robotics					
2.1	Project Recon / Logistics Management	1	LS	**$**	$
2.2	Mobilization / De-Mobilization to Project Site		EA	**$**	$
2.3	Line Stringing and Winch Setup		EA	**$**	$
2.4	Access and Insertion Set-up/Deployment		EA	**$**	$
2.5	Access Requiring Confined Space Entry		EA	**$**	$
2.6	Traffic Control (Cones without/police)		Day	**$**	$
2.7	Deployment of Robotic Transport Tracked		LF	**$**	$
2.8	Deployment of Robotic Transport Winched		LF	**$**	$
Phase 2: Off-Site Data Management					
2.9	CCTV: Data Collection/Processing/Analysis		LF	**$**	$
2.10	Sonar: Data Collection/Processing/Analysis		LF	**$**	$
2.11	H_2S: Data Collection/Processing/Analysis		LF	**$**	$
2.12	Laser: Data Collection/Processing/Analysis		LF	**$**	$
2.13	Final Report Submittal & Software Viewer	1	LS	**$**	$
				Total Projected Price	**$**

3.0 Scope and Schedule of Site Work:
This Multiple Sensor Inspection (MSI) may require variations in technology combinations to be synchronized in order to complete inspections. The below chart describes the approximate scope of work, minimum MSI sensors required to be used during the inspection, and estimated schedule for completion. The schedule for submission of final reports should be identified elsewhere in the proposal documents.

Item	Location	Pipe Size (inches)	Length of Pipe (LF)	Pipe Mtl.	Sensors to be used**	Site Time (hrs)	Inspection Day/Date
3.1	Example pipe from MH# to MH#	ANY	ANY	ANY	ANY	TBD	TBD
3.2	Example pipe from MH# to MH#	ANY	ANY	ANY	ANY	TBD	TBD
	Totals						

** Sensor Notes – “TV”=CCTV, “S”=Sonar, “L”=Laser, “G”=Gas

Section G: Cooperative Procurement of Services

1.0 General:
Preparation of these MSI specifications is intended to secure and procure an inspection service provider for this project which will be based upon proven accurate condition assessment inspection data. Rather than spending long periods of time developing a very narrow scope of work to allow line-item comparisons between “bids”, pipeline owners can focus on identifying qualified contractors in a fraction of the time through this qualifications-based selection process, and then jointly develop a suitable scope of services and estimated fees. This method for the procurement of professional inspection services not only ensures that the most qualified contractor is selected for each project, but is also cost-competitive and has the best potential to reduce long-term project costs. This specification will result in revealing the most qualified contractor to provide inspection services as specified in this document. The client wishes to allow pipeline owners to take advantage of this competitive selection process.

2.0 Scope of Additional Work:
The successful contractor agrees to honor the prices as stated on the Form of Bid for this project to any municipal agency or utility that has the need for MSI.

3.0 Conditions:
Each participating municipality or agency will be responsible to issue their own purchase order and/or agreement with the successful contractor. Insurance certificates, WSIB Clearance Certificates, Performance and Labor & Materials bonding, and/or any other supporting documentation as deemed necessary, will be provided as per each participating agency’s requirements. The client of this proposal assumes no authority, liability, or obligation, on behalf of any other public or non-public entity that may use any contract resulting from this bid. All purchases and payment transactions will be made directly between the contractor and the requesting agency.

Section H: Additional Submittal Requirements

1.0 References:
With consideration of the specific type of work required by this project, it is requested that the contractor provide at least three references where the contractor or the subcontractor has performed similar type of work using the equipment that is proposed for use on this project. The references must include a brief summary of the scope of work, in addition to name, position, email and phone number.

2.0 Sample Documentation:
Provide a sample final report of each type of inspection. (e.g. Sonar. Laser, CCTV, and Gas) with your submission.