Senceive

Harnessing intelligent monitoring technology to keep people and infrastructure safe

Rail Projects

Senceive wireless solutions are in use on hundreds of rail tracks, structures and earthworks worldwide.
Engineers, surveyors and owners are relying on them for real-time insights and automated alerts to inform data-driven decision making.

More than 10,000 railroad sensors were installed in 2020 alone.

This document highlights just a few of the rail sites where users have applied Senceive technology.

If you can measure it, you can manage it.

Prevent bridge failures through structural health monitoring

Get early warning of landslides to prevent accidents and delays

Manage your liabilities to third parties using sensors that are discreet and non-disruptive

Measure changes in track geometry to optimize your maintenance program

Monitor ground behavior to build and manage tunnels effectively

Monitoring at Sandpoint, Idaho

United States

Construction of a second rail bridge over Lake Pend Oreille will alleviate pressure on a longstanding bottleneck restricting capacity in the region. The second crossing will allow train movements in and out of the busy Spokane-Sandpoint "Funnel" with little or no delay.

The project team was tasked with monitoring the impact of the excavation and pile driving for the new structure, which is adjacent to the existing bridge. Conditions at Sandpoint are challenging for any monitoring solution; snow falls on an average of 80 days each year, December temperatures average 18.5°F (-7.5°C), and the existing bridge is typically used 60 times every day – mostly by very heavy freight trains. The team implemented a wireless monitoring solution comprising 536 Senceive tilt nodes (FM3N-IXH) installed on track ties every 10 ft to monitor:

- Cross-level
- Twist
- Dip

Thanks to the FlatMesh™ wireless platform, all sensors remain connected across the bridge and are providing continuous data without the need for cabling and post-installation track access.

The Senceive team worked hand-in-hand with the engineering crew to integrate all raw data, geometry calculations and alerts on their visualisation platform through an API.

The system will be in use for three years and will provide critical information - whatever the weather.

United Kingdom

Box Tunnel Electrification - Structural Monitoring

CLIENT: AECOM / NETWORK RAIL

How a wireless monitoring solution supported major structural changes to a historic rail tunnel as part of Great Western Main Line electrification

Challenge

Network Rail's Great Western Mainline electrification project started in 2014 to improve capacity and reliability. The route passes through the 3 km Box Tunnel, designed by Isambard Kingdom Brunel and completed in 1841. It was bored through four distinct strata and two fault zones and comprises 2 km of brick lined, 350 m of unlined and 450 m of brick arch construction.

In order to achieve clearance for overhead line installation in 2015, there was a need to lower the track by 350 mm. To safeguard the integrity of the tunnel and minimize disruption to train operations there was a need to monitor and control movement.

The challenge was to implement an economical, resilient and precise monitoring solution within a fully operational and congested construction site over the full length of the tunnel. Due to the live network, the system had to be wireless and mains power free.

Solution

Conventional systems were considered impractical due to obstructed lines of sight, absence of power supply, long installation times and risk of damage.

Monitoring experts at AECOM chose to use a Senceive solution to provide near real-time data relating to tunnel distortion that was wireless and did not need AC power.

The AECOM team installed 250 Senceive tilt sensor nodes on a FlatMesh™ platform – providing sufficient coverage to monitor the full length of the tunnel. Data was collected through internal battery powered gateways and sent to users inside and outside the tunnel every 20 minutes to help verify predicted structural movements throughout the works. Additional innovations were made to allow for automatic switch-over to backup gateways in the event of damage or failure.

Outcome

The FlatMesh™ wireless solution met the very challenging requirements of this site, providing a solution where there was really no viable alternative.

The system was delivered and installed in extremely tight timescales, necessitated by the fixed date of the line closure for the works. Additionally, safety was enhanced through the fast and simple installation.

As the system was entirely wireless and AC power free, it was swiftly decommissioned at the end of the project, and the sensors reused, minimizing waste, environmental impact, and whole life cost.

Senceive

Spain

Costa Blanca - Martorell Tunnels

DRAGADOS

INSTOP
Su especialista en productos Leica

CLIENT: INSTOP / DRAGADOS - TECSA

Innovative use of combined optical displacement sensors and tilt sensors to safeguard Spanish tunnels during major engineering program

Challenge

As part of Spain's ambitious Mediterranean Corridor, a number of disused tunnels were being refurbished. Spanish rail infrastructure operator ADIF appointed main contractor Dragados to upgrade three tunnels including the 810 m track tunnel between Martorell and Castellbisbal. The masonry structure had been disused since the 1980s and required relining with 4,500 cubic metres of sprayed concrete, the construction of overhead line electrification and track lowering.

In order to safeguard the structure and the workforce during the construction work, there was a need for a reliable and accurate monitoring programme, but a conventional approach using optical survey methods was not an option due to the nature of the site:

- No AC power in the tunnel which is at a remote location
- Ongoing construction activity and use of heavy machinery
- Conventional monitoring using automated total station was not possible due to no line of sight

Solution

The construction team required real-time 24/7 movement monitoring. They appointed survey and monitoring experts Instop to provide a Senceive wireless remote monitoring solution.

This comprised of a combination of tilt sensors and optical displacement sensors (ODS) to detect rotational movement and convergence.

The ODS method was novel in this application and provides a number of advantages over laser or optical techniques.

Data from the various sensors were transferred from the site via a GeoWAN™ gateway located outside the tunnel. With no AC electricity available, an advantage over alternative technologies was the ability to power the system using solar panels.

Easily installed by non-specialists, robust enough to last many years without maintenance and with no cables to interfere with other infrastructure, Senceive wireless remote monitoring has proved to be an effective solution.

Outcome

All stakeholders were able to see changes in tunnel cross section from a real-time 24/7 data feed. Construction of the sprayed concrete lining and lowering of the track could therefore continue safely and efficiently with the reassurance provided.

The solution proved highly cost-effective to the client as it was provided on a four month hire basis.

Installations were done in record time at a speed of 4 sections per hour (3 nodes per section) or 100 m/hour, a complete tunnel in a working day.

Senceive regional distributor Instop supervised the installation of the monitoring system, which comprised of:

- **Martorell: 87 ODS sensors, 35 triaxial tilt beam sensors & 9 4-channel VW nodes to extensometers**
- **Costablanca: 99 ODS sensors and 96 triaxial tilt beam sensors**
- **Castelbisbal: 105 ODS sensors**

Norway

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Trackbed Monitoring - Follobanen

CLIENT: CAUTUS GEO/BANE NOR

Monitoring high speed rail and train station construction on Norway's largest transportation project

Challenge

The Follobanen project started in 2015 and is a planned 22.5 km high speed railway between Oslo, Norway's capital, and the public transport centre at Ski. The project will involve the realignment of tracks for the existing Østfold Line on the approach to Oslo Central Station and between the tunnel and the new Ski Station, as well as the construction of a new double railway track.

As part of the project, a completely new station is being built at Ski for both local and passing high speed trains. Oslo's Central Station will also receive an extensive renovation.

Due to the extensive construction works, Cautus Geo was called on to monitor rail conditions on the Oslo side of the project, as well as monitoring both rails and construction activity near the new Ski station. They needed a wireless monitoring solution for both ease of installation and the abiilty to monitor site condtions remotely. Cautus Geo worked with Senceive's Norwegian distributor Measure It to select Senceive's high precision tilt sensors because of their robustness and suitability for tough conditions at sites where construction activity is taking place.

Solution

Cautus Geo installed 300 triaxial tilt sensors on railway sleepers at critical areas on the Oslo side of the project to monitor deformation. An additional 13 sensors were installed in an existing building near Ski Station to ensure the building foundation was not adversely affected by the construction work.

The mesh network formed by the wireless sensors was set up to relay data from the sensors to Senceive servers via a solar powered gateway and on to Cautus Geo's own visualization software 'Cautus Web'. Any discrepancies or movements beyond the established threshold values trigger an alarm that is sent to nominated stakeholders. "We have had several alarms, but train traffic and construction work have not been disrupted. The alarms provide an opportunity to check the cause and assess potential mitigating measures. The goal is to ensure safety throughout the entire project period" says Cautus Geo CTO Lars Krangnes.

Outcome

The installed system has minimized the need for site visits and enabled a targeted decision making response during this lengthy project. The sensors are housed in robust enclosures with protective antenna caps, making them ideal for the harsh conditions.

"The sensors from Senceive have proved to be of very good quality. They can withstand 'Norwegian conditions' with periods of heavy precipitation and large temperature changes. They have a long battery life, are very robust and very accurate," says Krangnes.

"There are demanding ground conditions in the station area where construction pits will be established near the current track and the station building. It is therefore important to have sensors we can trust and near real-time data that gives an alarm if something happens in the ground," says CEO Atle Gerhardsen in Cautus Geo.

Senceive's sensors allow partners like Cautus Geo to integrate a higher level of risk mitigation and safety into their monitoring projects. Senceive's technology is helping them to protect people and assets in the world's most complex and dangerous environments.

Senceive

United Kingdom

Monitoring Assets Affected by London Power Grid Tunneling

CLIENT: COSTAIN / BT TUNNELS

How wireless remote monitoring helped to safeguard critical assets affected by tunnelling activity and supported efficient progress of tunnel boring machines

Challenge

In February 2011 National Grid embarked on a seven-year project to upgrade London's electricity grid. This involved construction of a series of tunnels to house 400 kV power cables, boosting capacity and access to renewable energy. Main contractor Costain was responsible for the civil engineering work.

Tunnel routes connected Willesden in the west to Kensal Green and Hackney in the east. A north-south route extended from Kensal Green to Wimbledon. Two tunnel boring machines (TBMs) were used to build the 32 km of tunnels. Costain was also responsible for monitoring assets along the route that may have been affected by the tunneling.

They used Senceive technology at several sites where there was concern about the risk of settlement affecting critical assets, including British Telecom (BT) communications tunnels, the River Thames embankment wall and London Underground railway tunnels.

Solution

Costain engineers worked closely with Senceive experts to devise appropriate and cost-effective solutions.

In Camden, for example, a series of interconnected aluminum beams, each with a high-precision dual axis tilt sensor measured longitudinal settlement along a 100 m section of BT tunnel. With no wires, the installation was quick and easy. The movement sensors were connected via a gateway and BT's own lines. Stakeholders could see and interact with the feed of monitoring data which was updated four times an hour.

At the Thames embankment site, tilt nodes were installed on beams on the river side of the wall. Data was relayed wirelessly to the WebMonitor cloud server via solar-powered GPRS gateway.

Outcome

Each of these projects lasted several months and was effective in reassuring owners of third-party assets that movement levels were generally well within acceptable tolerances. As a result, a number of other sites affected by the London Power Tunnels project chose to use Senceive technology to safeguard at-risk infrastructure.

KEY POINTS

- **Complex tunneling operations took place in close proximity to other critical infrastructure**
- **Wireless monitoring solutions were quick to deploy and were adapted to work in varying conditions above and below ground**
- **Monitoring data reassured asset owners and allowed tunneling to go ahead with confidence**

Senceive

United Kingdom

Slope Monitoring: Barnehurst

CLIENT: NETWORK RAIL / COSTAIN

How an intelligent earthworks solution provided early warning of slope failure to prevent a major incident

Challenge

Network Rail manages nearly 200,000 earthworks assets, most of which are more than 150 years old. Victorian engineers left a highly variable range of earth structures that includes many steep embankments and cuttings with questionable drainage and few records.
Increasingly frequent severe storms have caused unprecedented numbers of failures, with February 2020 seeing close to 100 failures alone – the worst month since reliable records began. Despite this, the number of derailments attributable to earthworks failure has consistently fallen in recent years, with proactive, data-driven decision making at the heart of this achievement. Analysis of various types of information, ranging from weather data to frequent visual inspection of high risk sites has helped asset managers detect problems, prioritize resources and manage train movements to reduce the risks. Wireless remote monitoring has proved to be a particularly valuable means of detecting the early stages of ground movement before any material has encroached on the track.

Solution

The value of wireless monitoring was demonstrated at Barnehurst on Network Rail's Bexleyheath line in 2019. Around 200 Senceive triaxial tilt sensors and seven cellular cameras were installed on the slope above the track. In the early hours of Monday February 11th some of the nodes detected slow and gradual ground movement.

The system automatically requested further data samples from nearby nodes to see if the initial small movements were widespread. It also "told" the gateway to stay open in order to transmit data and minimize any lag in decision making. These smart characteristics combined to provide a picture of the situation at any point in time. With alerts and alarms from sensors and images from the cameras being automatically sent to the route engineers as trigger points were breached, it provided an early indication of the potential for failure.

Outcome

By the time it finally collapsed a few hours later it left a tree and a heap of debris on the track, but everyone was ready and the line was closed to traffic.

Repairs were completed and the line was re-opened a week later.

KEY POINTS

- **Network Rail manages 200,000 earthworks assets**
- **Frequent inspection of all sites is not practical**
- **Wireless remote monitoring can detect early signs of slope failure, preventing disruption and potentially saving lives**

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Track Monitoring: Victoria Station

CLIENT: LONDON UNDERGROUND / TWBN

How the flexibility and mobility of FlatMesh™ enabled a grouting team to stabilize ground below London Underground tunnel at Victoria Station without damage to track

Challenge

The upgrade to London's Victoria Railway Station was a large and complex undertaking. As part of the project, an underpass had to be tunneled directly beneath a shallow brick-lined tunnel carrying the District and Circle Line.

In order to stabilize the permeable ground before the tunneling took place it was treated using the TAM grouting process. The work had to be conducted during short Engineering Hours access windows. In order to manage the risk of ground heave damaging the tracks, the client required a real-time, high-precision monitoring solution that could be quickly deployed during each shift. Optical methods were rejected because lines of sight could not be guaranteed. Wired monitoring systems were also rejected because they would have been prone to damage and would have been slow to deploy. A wireless monitoring solution using the Senceive FlatMesh™ platform was selected.

Solution

During grouting, movement could occur in any part of the 30 metre zone across two separate tracks.

TWBN employed Senceive's patented and specially upgraded magnetic mountings to secure the 20 wireless sensors directly onto the surface of the rail. Using the highly responsive FlatMesh™ wireless communications platform the system was operational within a few minutes of installation at the start of each shift. It was able to report any movement in excess of 0.009 degrees of angular tilt. Reporting frequency was set at no more than one minute. All this was carried out without signal or power cables.

KEY FEATURES

- **Installed and removed for every night shift**
- **Operated by non-specialists**
- **Sub-minute reporting intervals**
- **Reliable, precise measurement of movement enabled ground stabilization team to operate with confidence**

Outcome

The sensors communicated in real-time to a gateway attached to a laptop computer on the site. For this project, functionality was added to ensure that clear visual alerts and audible alarms would be triggered by any movement above pre-set trigger levels. This meant that the computer did not have to be permanently manned, allowing the engineer responsible for monitoring to complete other tasks.

The data were characterized by a high level of stability throughout the grouting program. The small levels of movement that were identified were corroborated by levelling surveys. No false alarms were raised.

This unique use of Senceive's award-winning tunnel and rail-focused technology was installed on site within three weeks of the initial proposal. Senceive specialists worked alongside shift engineers for the first two nights, to ensure all was well and the system was fully understood. After that, the monitoring was exclusively carried out by TWBN engineers who were extremely pleased with its overall performance and benefits.

United Kingdom

Large Scale Trackbed Monitoring at Crossrail PML

CLIENT: MORGAN SINDALL / NR / DLR / CROSSRAIL

How an extensive two-year wireless monitoring scheme helped avoid disruption during major London rail upgrade project

Challenge

A strategic programme of works was undertaken to improve transport links to the site that had hosted the London 2012 Olympics Games. This included demolition and replacement of the Pudding Mill Lane Docklands Light Railway (DLR) station in order to make space for a new Crossrail tunnel portal.

Contractor Morgan Sindall was responsible for the works. They were required to monitor the numerous Network Rail and DLR tracks to ensure that there was no significant movement or disruption for a period of some two years. Concerns had been raised about the effectiveness of optical monitoring at the site so they looked for other ways to measure track cant and twist with high precision, reliability and stability.

Solution

Working in close cooperation with the Morgan Sindall team, Senceive supported the installation of more than 700 high precision wireless tilt meters. These were attached directly to railway ties on five DLR and Network Rail lines. All the sensors communicated via a mesh network, transmitting data from the site through a solar-powered GPRS gateway. Working in this way, there were no need for power or communications cables, making the system far less likely to suffer damage or impede others during the extended construction period.

Track cant and twist measurements were accessible to stakeholders in realtime using Senceive WebMonitor software. The data showed high levels of stability and accuracy at below 0.1 mm on a 1.435 m track beam length (see Figure 1). There were no spikes or false alerts or alarms.

Outcome

The system provide capable of detecting very small movements, whilst providing stable and repeatable data. It picked up real movement at a very early stage and allowed the surveying team to respond rapidly.

When compared to more traditional approaches based on optical survey instruments the wireless solution compares favorably. Installation time and disruption to the railways was minimal. Following installation, there was no need to re-visit the site to maintain or clean the wireless system – which would have been necessary if an optical system using reflector prisms was used. This brought significant safety and cost benefits to the project.

Germany

Senceive

DB NETZE

DB

Hamm Railway - Embankment Monitoring

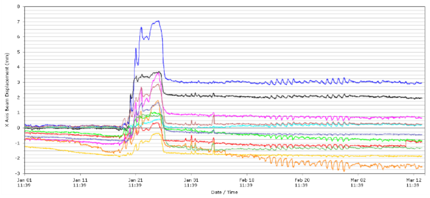
CLIENT: DEUTSCHE BAHN / DB NETZ AG

Rapid response monitoring of slope failure to safeguard German railway

Challenge

The Dortmund to Münster railway line is one of Germany's strategic rail routes. In late 2018 a major fissure appeared along a 100 m stretch of embankment, which ran parallel to the track. This raised concern about the risk of further ground movement and a decision was made to install an emergency monitoring system to mitigate the risk of damage to the railway.

Senceive remote monitoring technology has been proven in rail applications around the world. Railway infrastructure owner Deutsche Bahn chose to install a Senceive FlatMesh™ system to monitor the at-risk area following treatment of the fissured ground. This smart wireless system can be easily deployed in a matter of hours and allows stakeholders to see the relationship between slope and track.



Solution

Senceive provided an emergency track monitoring kit which could be deployed in a few hours if required. This comprised 34 triaxial tilt sensors capable of detecting movement of less than a millimetre, with a cellular gateway.

For the main investigation, a 3 km length of embankment was monitored using a total of 233 stake-mounted triaxial tilt nodes, arranged in two offset rows at approx. 25 m intervals. A FlatMesh™ camera was also deployed to provide around-the-clock photographic images of the defective area. The camera was set up to be automatically triggered in the event of significant ground movement.

The wireless sensors communicated with seven solar powered gateways, which transmitted data securely to the WebMonitor online visualization software. This was accessible to all registered users.

Outcome

During a period of harsh winter conditions, up to 9 mm of movement was detected by multiple sensor nodes in the at-risk area during a one-week period, before returning back to the baseline. The FlatMesh™ camera images could easily be accessed remotely and clearly showed that the area experienced heavy snow during this time, which indicates that the movement was caused by extreme variations in temperature causing the ground to contract/expand.

This precise data and accompanying visuals supported the view that the fissure, and the original movement that caused it, was caused by changes in soil moisture due to de-vegetation of the adjacent field. This was exacerbated by seasonal changes such as the cold winter conditions.

The exceptional battery life of the nodes, of 12 to 15 years, offers the flexibility for the monitoring duration to be extended to further investigate the seasonal impact on the slope movement. The emergency track bed monitoring kit remained on hand in case of further slope failure that might affect the railway.

Netherlands

Senceive

Botlek Railway Tunnel - Deformation Monitoring

CLIENT: IV-INFRA B.V. / A-LANES A15

How Senceive technology supported construction and 25-year structural health monitoring

Challenge

The Botlek railway tunnel was the first bored railway tunnel to be built in the Netherlands. It is located near Rotterdam under the Oude Maas river and next to the existing Botlek railway bridge. Designers were concerned about possible ground movement and deformation associated with ongoing infrastructure projects in the area. A robust monitoring program was therefore required during and after tunnel construction.

A monitoring system was required starting from mid-2017. The system had to be easy to install, as well as accurate, discreet and reliable. The 8.65 m diameter concrete segmental lining tunnel is 1.8 km long. No cellular phone signal or internet access was available. The design team predicted ground movement of up to ±3 mm.

Dutch survey and monitoring experts Iv-Infra were engaged by the construction team and contacted Senceive to find a solution.

Solution

Iv-Infra installed a total of 434 FlatMesh™ triaxial tilt sensors. These were located at points every 30 m through the tunnel, with nodes fixed to six of the seven segments in each ring. These were set to take readings every 30 minutes. The tilt node triaxial capability meant they could be positioned at any orientation, with no need for time-consuming levelling surveys.

To overcome the lack of internet/cellular connectivity, Iv Infra used Senceive monitoring hubs positioned 800 m from each portal to receive data from the wireless nodes. The hubs were setup to utilize the tunnel's 220 V power supply and relay data via a 2 km telecommunications cable to a telemetry hub located outside the tunnel. This transmits data through a mobile network to visualization software.

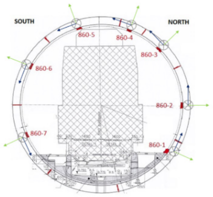


Fig.1 Cross section showing monitoring arrays on tunnel ring segments

Outcome

Iv-Infra opted to use their own software to read and process the data, however Senceive's WebMonitor software also allowed the support team to remotely check system health.

FlatMesh™ triaxial tilt nodes were the ideal choice, as they could be installed quickly and easily. This reduced man-power requirements, accelerated program and saved money. Senceive customer support team provided training and advice throughout the project. The extremely reliable and robust system also eliminated the need for any further maintenance or visual checks. For example, when construction works above ground commenced, Iv-Infra requested the reporting rate of the nodes to be increased to 7.5 minutes in certain areas. The system allowed this to be done remotely with no physical intervention.

Monitoring is due to continue for the full 15 year battery life of the nodes. Batteries will be replaced at that point and monitoring will continue for a further 10 years.

Senceive

MicroGeo ETS

Italy

Masonry Arch Bridge Monitoring - Formia Rail Line

CLIENT: ETS / MICROGEO S.R.L.

Wireless remote condition monitoring to support Italian bridge strengthening works

Challenge

Concern had arisen regarding the condition of a multi-span masonry arch bridge located on the Roma – Formia railway line in Italy. As part of the process of designing a strengthening solution there was a need to understand the behavior of the structure, particularly with regards to movement or settlement of the arches.

A strengthening scheme was designed based on stitching cracks and reinforcing the arch barrels with a concrete shell secured to the masonry with steel bars. In order to validate the retrofit design, a precise and reliable monitoring system was required. Rail engineering experts ETS Srl and Microgeo Srl considered options and selected a wireless monitoring solution using Senceive technology.

Over all other instrumental solutions, a wireless one was selected to assess two of the arches on a trial basis (Fig.1). This offered a high cost savings, allowed control of thresholds safe values of monitored parameters and provided automated alerts in case of excessive movement.

Solution

Senceive proposed deployment of four triaxial tilt sensors on each barrel, positioned at the top of the piers and on the arch haunches in order to measure rotation. An optical displacement sensor (ODS) was mounted at the crown to detect vertical movement based on change in measured distance to the ground. The ODS nodes were fitted to one-meter beams using swivel mounts, with the beams simply installed using self-tapping screws.

The wireless mesh network formed by these sensors transmitted data to a solar powered 3G gateway. The mobile cellular network relayed this data to a secure cloud server, which could be viewed and analysed by registered users of Senceive's WebMonitor software.

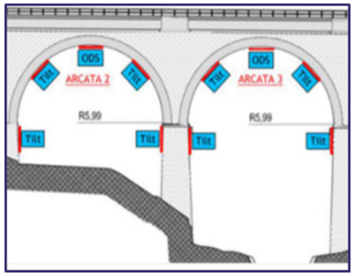


Fig. 1 Layout of monitoring system

Outcome

The sensors are extremely precise and the accuracy of ODS distance measurements showed a repeatability of ±0.15 mm – enough to detect the natural "breathing" of the bridge to sub-millimetre precision (See Fig.2).

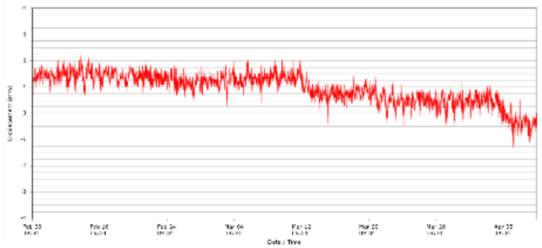


Fig. 2 Showing sub-mm precision of ODS

The scalability of the FlatMesh™ system allows it to be expanded easily and allows the user to control reporting rates, text alert trigger levels and gives the option of real-time monitoring. With a battery life of up to 15 years, the nodes are completely autonomous and monitoring duration can be increased if required. Eliminating any kind of intervention or maintenance also reduces the risk to site workers.