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A Study of train track landslip early warning detection systems

by

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Project submitted as part of the requirements for the
award of

BEng (Hons) Electrical and Electronics Engineering

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DECLARATION

I Christopher Stonelake declare that I am the sole author of this Project; that all references cited have been consulted; that I have conducted all work of which this is a record, and that the finished work lies within the prescribed word limits.

This work has not previously been accepted as part of any other degree submission.

Date : 23.03.2021

FORM OF CONSENT

I Christopher Stonelake hereby consent that my Project, submitted in candidature for the *B.Sc.(Hons) Electrical & Electronic* degree, if successful, may be made available for inter-library loan or photocopying (subject to the law of copyright), and that the title and abstract may be made available to outside organisations.

Date : 23.03.2021

Abstract

Reduction in the fatalities on UK train networks due to landslips or foreign mass on track's!

The importance of live track monitoring upon the discovery of a geological or structural weakness situated around a section of train track is paramount, not only to have the ability of monitoring but to have rapidly deployable monitoring stations along within on site visually and auditable warning signals.

Currently at the industry's disposal are finite amount of systems which offer, targeted specific application monitoring, rapid deployment and installation and direct local warnings which can give invaluable warning time to encroaching trains and fright.

The initial goal set out to prove the design concept that a standalone grid/ off grid monitoring system utilising a wide assortment of field sensor applications can effectively monitor, detect and signal local as well as electronic warnings which will affect the speed or stop/start of train track traffic.

From study of existing monitoring systems, it is clear that the ability to interact or combine onto a common platform is missing, what my prototype shows is that there is an ability to combine industry available monitoring sensors and combine into a common system.

One distinct advantage of this documents proposed system is the direct on track light and audible warning devices, this gives local and encroaching trains immediate warning signals to correct speed or come to an immediate stop, this capability is not really seen within other local monitoring stations.

Another key suggestion but would require further research, is the utilisation of signal generators using train tracks as signal conductors to on-coming trains which would automatically alter the trains speed or bring to a controlled stop, the signal generator would be activated via the track monitoring system.

My Study thus far has concluded the feasibility of muliti-sensory monitoring system with the immediate light and sound track warning along with electronic notification systems. The system can also be pre-manufactured (off the shelf) which will be an advantageous factor in the timely manner these system's need to be implemented and working from the initial discovery in a weak or high risk geological area. My work to date has laid the foundation to proceed onto the trial next stage which would be real world track monitoring and deployment.

I hope the readers of this document enjoy the contents and insight to this topic matter and enjoy as much as I have done in creating and working on this wonderful and fascinating subject.

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Chapter 1

Project Background

My proposal for the forthcoming works and submissions for my major project, I have selected a industry within the U.K. which has a history dating back to 1825, and is the 17th largest train infrastructure in the world and one of Europe's most busiest with 20% more train services than France, 60% more than Italy, and more than (Spain, Switzerland, Netherlands, Portugal, Norway) combined. [1]

The rail system in the U.K. plays a vital role in the country's economy moving people, freight and other vital recourses in a safe, efficient and cost effective manner.

But due to large sections of Britain's rail network and the age of these sections are very sub-settable to sever weather impact, this has also been exacerbated in recent years with more unpredictable and violent weather events, which leaves track conditions subset able to (landslips, flooding , debris build up) to name a few.

Where's the problem?

It goes without saying that there are good extensive track monitoring trends in place but these are cited around the high risk track sections based on historic information, as new weather patterns emerge and more aggressive weather periods sections of track though previously not high risk to being susceptible to these kinds of environmental conditions are now at risk.

Following a recent tragedy in Aberdeenshire resulting a train derailment caused by a landslip, resulting in three people losing their life's.

As stated by Network Rail – ' A health and safety report warned about the "vulnerability" of Network Rail to landslips and severe weather just four weeks before the **train derailment in Aberdeenshire**.

The annual report by the Office of Rail and Road (ORR) said there were six times more flooding events on Britain's railways in 2019-20 than during the previous 12 months.

It also noted a spike in landslips, demonstrating the "vulnerability" of the network.

The ORR found Network Rail's plans to address climate change and extreme weather are "not keeping up with the frequency and severity of these events". [2]

Project Aim

The concept of my proposed major project will be based around the solution for avoiding these, but more important is the rapid deployment of remote track monitoring stations which can be deployed into rural areas or any other areas without having the need to rely on hard wired connections for power and communications and field monitoring devices to be retrofitted and installed within a reduced time, it should be noted that these rapid deployment units are not intended to be permanent but are for rapid deployment for vulnerable track sections which need accurate monitoring until more long term permanent solutions can be designed and installed **(any monitoring is better than no monitoring at all)**.

What should the (RDTMU) Rapid Deployment Track Monitoring Unit [™] be capable of doing and providing, without detailed technical overview is as follows;

- Durable casing and weather resistant & freestanding
- Self-power generation (wind/solar)
- Self-power containment (battery)
- Communication protocol (4G/5G areas with no signal satellite coms)
- CPU – (PLC based i.e. Siemens)
- Sensors as follows;
- 1 – Vibration sensor (placed below track and on embankments)
- 2 – Optical/laser sensor (placed along high risk embankments)
- 3 – Humidity sensor
- 4 – Wind Sensor
- 5 – Temperature Sensor
- 6 – Float sensor (to be placed on track or adjacent monitor water levels)
- 7 – IP Network Camera (if alarms triggered by sensor set points operators can dial in and remote look on camera)
- 8 – Warning Beacon Light (ideally mounted 50-100mtrs away from sensor monitoring point visual warning signal to drivers)

The above list is not extensive but gives an initial concept for the devices required but the system should be flexible so that sensors can be added and removed as required for each application.

For ease of installation all field mounted sensors, shall have IP rated plug and play connections and ports external to the main housing unit, this will remove the need for wiring or termination in the field and ensure correct devices going into the correct ports to avoid incorrect interconnections.

Objectives

Project Planning

In order to maintain a review of output performance to ensure KPI's are met, this will be monitored and tracked with the use of Microsoft project manager, using a project plan and corresponding Gantt chart.

Throughout the project at weekly intervals monitoring progress will be critical to ensuring a timely delivery on final project documents.

Upon weekly progress checking amendments shall be made every 2 two weeks in order to compensate for delays or works completed more sooner, this will allow the document to be as accurate as possible.

Program of Works & Gantt Chart

To ensure continuity in my work deliverable for this project I have set out an initial programme of works, which will aid to ensure time tracking and also high light forthcoming commitments and milestones.

I will be intending to periodically review the below gantt chart and programme to continually improve and monitor progress.

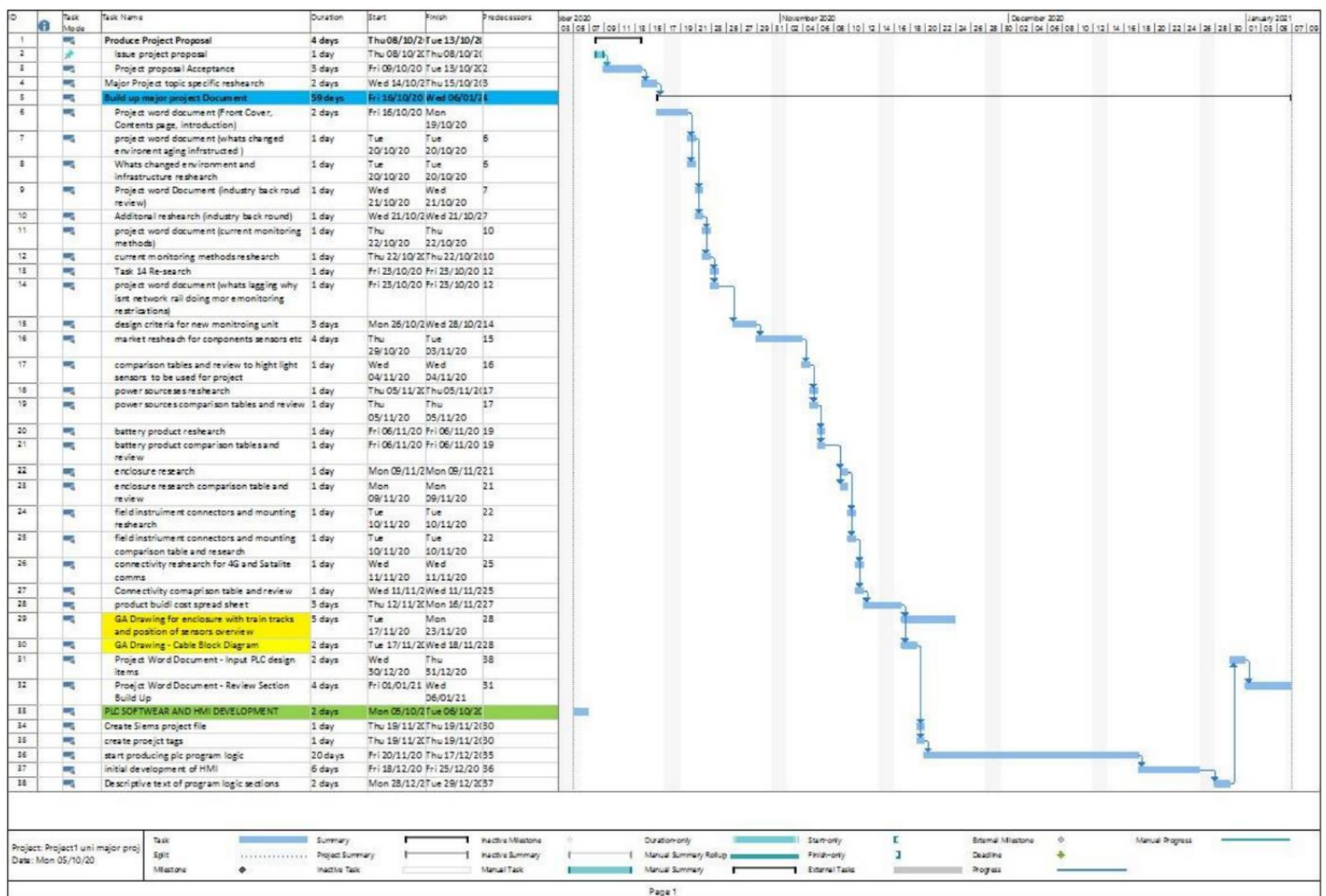


Figure 1

Chapter 2

Research & Review of Literature

Why rail monitoring is important

It goes without saying that monitoring around a service which transports hundreds of thousands of people every single day in the UK is quite essential for safety of all personnel but also to ensuring economically the UK is in top shape financially, on average per year train delays lose 14 minutes costing over 1 billion in lost time, as stated by the NAO (National Audit Office) [1].

The evidence is also mounting when we look into news articles for train delays directly as a consequence to landslips, below are a few brief links for landslips on track's in 2020;

- 12.Aug.2020 train derailment due to landslip - <https://metro.co.uk/2020/08/12/torrents-water-flood-railway-line-near-landslide-where-train-crashed-13119166/>
- 14.Sep.2020 train derailment due to landslip - <https://www.heraldscotland.com/news/18719676.west-highland-rail-line-closed-landslip-amid-climate-strategy-calls/>
- 13.Aug.2020 train stuck due to landslip - <https://www.expressandstar.com/news/uk-news/2020/08/13/passengers-evacuated-from-train-after-landslide-in-kent/>
- 11.March.2020 Major disruptions due to landslip - <https://www.getreading.co.uk/news/reading-berkshire-news/landslip-between-reading-guildford-causing-17908613>
- 5.Oct.2020 Lines closed to track block due to landslip - <https://www.manchestereveningnews.co.uk/news/greater-manchester-news/rail-lines-blocked-between-manchester-19054557>
- 29.feb.2020 Landslip 100t onto tracks - <https://www.walesonline.co.uk/news/wales-news/aberdare-mountain-ash-train-landslip-17839222>
- 12.Feb.2020 Major disruptions due to landslip - <https://www.express.co.uk/news/uk/1085809/barnehurst-station-travel-latest-landslide-southeastern-entire-line-closed-national-rail>

The above are just a few examples of landslips having caused serious issues, some did not involve trains and others did where injury or loss of life did occur.

where the incidents of trains running into the debris on the track caused by landslips, they had no early warning or indications that trouble was ahead, other incidents were either captured by monitoring systems or reported by other trains running on an unaffected part of the track.

What is clear is that where monitoring systems are in place they give vital time for drivers to respond to the hazard ahead.

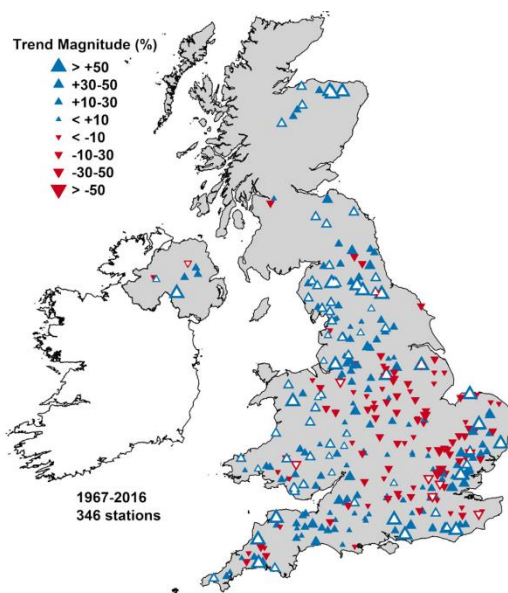
There are systems which give notifications but rely on emails being sent and someone miles away receiving the message and that message then being passed on vital minutes could pass before drivers are notified, it should be said now and early on that this document wants to embody the existing systems technologies to have multiple measuring facilities but also to have local outputs such as warning lights and sound beacons at distances down the track both ways this will give immediate on site warning of danger ahead. [3]

What's changed in recent years ?

What has changed or should we say what hasn't changed ? as stated 'network rails asset base comprises some 200,00 discrete earth works constructed primarily during the 19th century. With a typical age between 100-150years, they have been subject to many cycles of traffic and climatic degradation within a historically reactive maintenance regime'. [4]

So from the above statement and countless other resources its clear to see that things for the UK rail network are only going to get worse before they get better, this degradation in recent years has also been vastly accelerated due to more adverse weather conditions, this is suggested that saying an important driver to the increase loss of performance and stability is weather driven annual cycles or pore pressure, and anecdotal evidence suggest that extreme weather events contribute to the occurrence of failure. [5]

An increased rain fall is also echoed by the UK (NRFA) national river flow archive, which collects data from 1,500 gauging stations monitored by (environment agency, Scottish environment protection agency, natural resources wales, department for infrastructure), the below image shows that the flow of rivers is continually increasing represented by the blue triangles;



From the image we can see the significant increase in river flow rates, cause by increase of rain fall, even though there are decreases shown in red triangles these are not statically significant. [6]

Figure 2

How do rail networks monitor landslips & other abnormalize

at present once a area has been designated as high risk by network rail, they employ a number of solutions such as CCTV, Motion sensors & GIS sensors[3].

With solutions in deployment it seems a large amount of monitoring systems require good main connected power source or comms, and ultimately rely on signal alarm signal sent back, as stated before what we can is the local monitoring but with also the local and immediate alarm system to warn drivers while also sending digital signals back to a command centre.

as networks rail technical document , review table shows the types of monitoring techniques but also the failure category's for each in a proven real world trial and error, this will prove vital information when reflecting on instruments suitable for ground movements. [7]

Monitoring Technique	Description & Comments	*Failure Category		
		S	R	I
Surface deformation monitoring				
Global positioning system (GPS)	GPS system receives time signals from orbiting satellites and positioning is based on signal travel times. Limited reception in topographic depressions and accuracy issues in forested areas (signal scatter)	1		
Photogrammetry	3D reconstruction of surface topography from overlapping at least 2 photographs taken from different positions. Complex post processing of data. Application limited by high cost and time requirements.			
Remote Sensing (InSAR, LiDAR)	Terrestrial, aerial or satellite based recording of reflected electromagnetic energy from the Earth's surface, Positional reflectors required to overcome vegetation. Complex and expensive data processing	1		
Distributed acoustic sensing (DAS)	Optical fibres used as a sensing device to measure acoustic energy generated by noise and vibrations; identifying threat events from normal background activity (i.e. rock falls).			1
Accelerometer & Geophones	Recording of ground surface velocity or acceleration.in response to rapid movements and earthquakes. Limited detection capability of low velocity ductile movements. Post-processing is complex.		1	
Electrode tracking using ERT	Electrical resistivity tomography (ERT). Measured resistivity can be inverted to track electrode / slope movement. Readings sensitive to sensor spacing. Complex installation and post-processing.	1		
Surface mounted tiltmeters	Microelectronic sensors capable of detecting changes from the vertical. Typically installed on the end of a pole inserted with suitable embedment. Wireless network required to create an array across an asset.		1	
Subsurface deformation monitoring				
Time domain reflectometry (TDR)	Deployment of cables in boreholes, locating displacement faults by measurement of reflections along conductor. No direct measurement of deformation or deformation rate. Sold as commercial systems.			
Shape acceleration array (SAA)	Comprise a string of microelectronic sensors at regular intervals and installed inside boreholes. Measures 3D displacement. High costs of instrumentation and processing. SAA string recoverable from borehole.	1	1	
Acoustic emission monitoring	Deformation of angular backfill in a borehole, creates high energy acoustic emission on a steel conductor waveguide. Most applicable to slopes failing along a defined shear surface. Sensitive to slow rates.	1		
Electrical resistivity tomography (ERT)	Moisture content mapping in 4D of earth structure via electrodes placed below ground level, using soil resistivity. Complex installation and post-processing. Readings sensitive to sensor spacing.	1		
Porewater suction / soil moisture probes	Variety of probes available for detailed measurement of soil and water interaction and soil water retention. Does not directly detect deformation. Careful calibration required and specialist expertise.	1		
Ground penetrating radar (GPR)	Measurements based on the propagation of electromagnetic waves in the subsurface. Commonly used to establish ballast depth in railway formations. Requires complex post processing.	1	1	
In place inclinometers and extensometers	Tubing installed into boreholes to detect zones of disturbance and determine whether movement is constant, accelerating or responding to remedial intervention. Possible to automate but expensive.	1	1	
1 Technology that NR either use, have researched or plan to trial * Failure Categories; Slow (S), Rapid (R) and Instantaneous (I)				
Monitoring Technologies Table; Modified after Smethurst et al (2017).				

Monitoring Technologies Table; Modified after Smethurst et al (2017).

Figure 3

Research Review

As per the above table you can see that a large amount of sensors are still in the planning trails with network rail, this is also a sticking point with the research with existing systems and technologies there simply isn't a one solution fits all, and for what I'm proposing as a rapid deployment unit there isn't any comparable solutions available, yes I will use some technologies for certain monitoring applications but adopting them to my own design, this is why its importance for the use of a plc, a plc is versatile in the fact that it can run a wide range of sensors and instruments and the feedback from them and be relayed in a variety of different fashions.

It must be stressed again and I have mentioned this a few time thus far in this report, that the monitoring unit must be able to have immediate local warning activation (bacons, sound speaker, etc) as well as being able to send digital warning signals to monitoring stations. But this way the unit has multiple avenues to alert and warn the rail network and more fundamentally we are not relying on a control room operator to see the alarm signal and waste precious times in alerting train drivers on that section of track.

Equipment Research & Development

Within this section of the report I will start to look at offered solutions for materials and equipment to use within the final built design, as with any initial concept project the focus will be concentrated on good engineering practices with the aim of being economically cost effective as possible. But we should also embrace/understand that some solutions requiring rapid/ease of installation these items may need a higher level of detailed design and thus would be subject to initial higher cost margins.

I will detail each section going forward into individual component sections which will ultimately come together and make to the final product solutions, each section will research and evaluate 4 different sensory technologies, from this 2 sensory technologies will be chosen to progress based on merit award system on factors such as but not limited to – (Cost, accuracy, output signal, real world applications).

From the two technology groups that have been selected three pre-manufactured sensors for each technology bracket will be selected and evaluated to determine the best overall product for the design built with a balance of cost, quality, accuracy.

Based on the initial review section of this assignment the areas in which will give us the most value for monitoring are as follows;

- 1) Rail fall
- 2) Collecting water on tracks
- 3) Landslips (motion sensor / trip cord / laser) we would need 2 of any sensors to active to trigger an alarm
- 4) Vibration
- 5) Camera

Key Considerations for equipment selection that should be crossed check back to ensure compatibility

Environment

As this monitoring device solution is intended to be deployed anywhere within the UK Isle, we must ensure that the constructability is suitable to withstand a wide variant of weather variations to ensure reliable performance.

Power Source

The remoteness of locations where these monitoring systems will be deployed may not guarantee a lock source of mains power, the monitoring station there for will have to ensure self-powering and researching capability's to ensure effective monitoring and a minimal human intervention as possible. The unit will have to include a battery source and a form/forms of power generation as a base line each unit should have the capability of being fully self-reliant for 4months (allowances should be made for winter months).

Terrain

The rail networks crosses vast different terrains urban, country etc the units should be designed and capable of being free standing with a durable base, but at a minimum of 300mm from ground level to ensure installation is above any standing water levels.

Communications

Wireless communications are essential for this application dependant on geographical location the utilization of GSM, Mobile networks should be explored, the unit should also have the capability to have hardwired Ethernet, in the rare locations where access to telecommunication networks are viable.

Equipment Selection & Evaluation (RAIN SENSORS)

Purpose of the Technology – Rain Fall monitoring (Rain Volume)

Brief capture of technologies which can monitor rain fall –

	Technology 1	Technology 2	Technology 3
Technology Name	Rocker Systems (rain gauge)	Electrolytic impedance measurement	Infra-red light principle
Principle workings of technology	Rain collectors that capture rain in a small collection cup and measure the weight to a certain volume and the holder tips out the water and repeats to process the quicker it tips the higher the rain fall level	Flat surface device with conductive strips on surface, electrical impedance changes when in contact with moisture	Precipitation in the form of rain falls through a light band, induced by light diodes, and lead to showing effects on the receiving side. The sent light is pulse-modulated so that outside light effects cannot falsify the measurement results
Industry's/applications technology found in	Agricultural, environmental research	Weather stations, environmental	Weather stations, agricultural
Accuracy of technology for this application	Very high	Very good, but does not accurately measure rain volume	Very good
Financial cost of technology	Medium	low	Medium

Rain Sensor Technology Review

Based on the above table for technologies suitable for rain fall monitoring, the two technologies we will be looking into further are (Rain Gauge & infra-red light) the main reasons for this selection are based on the following;

For technology (Rain Gauge) – the rain gauge can detect and accurately measure rain volume and is a proven technology

&

For technology (Infra-red) – the infra-red can sense and measure rain fall and volume

In the next table this will look at more specific on the market available sensors, 3 sensors selected per technology concept. From these tables one sensor from each technology will be selected on the merit/point award based system, from this a final evaluation and review will be conducted on the remaining two sensors to ultimately determine a sensor selection going forward for the built prototype phase.

Rain Gauge (Bucket Type) Market Product Reviews

Technology 1 (Rain Gauge) Market available sensors comparison table

	Sensor 1 	Sensor 1 (score 1-5 , 5 being best)
Make & Model	TR-535 Rainfall Sensor	
Functionality	Bespoke design for rain monitoring	4
Out Put Signal	30VDC	4
Mounting applications	Direct pole or enclosure mounting	5
Cost	£628.41	1
Durability	Very good aluminium construction	4
Power Consumption	2A @ 30VDC	3
Negative Points	Cost/power consumption/ collection port could get blocked	4
Positive Points	Quality construction/High accuracy	4
Supplier Web Site	file:///C:/Users/cston/Downloads/6134.pdf	

	Sensor 2 	<u>Sensor 2</u> (score 1-5 , 5 being best)
Make & Model	CS700	
Functionality	Created for heavy rain fall areas	4
Out Put Signal	Sdi-12 INERFACE 7 BITS	2
Mounting applications	Direct to pole or enclose mounting	5
Cost	£1,342.89	1
Durability	Very good	3
Power Consumption	3.7a-5.8a @ 30VDC	3
Negative Points	High current demand due to internal heater	1
Positive Points	Good for large volume heavy rain	4
Supplier Web Site	https://www.campbellsci.co.uk/cs700	

	Sensor 3 	Sensor 3 (score 1-5 , 5 being best)
Make & Model	Meteo-Rain 200 Compact	
Functionality	Heavy rain fall and low rain fall applications	4
Out-Put Signal	15VDC	3
Mounting Applications	Enclosure mounting or pole mounting	5
Cost	£120.00	3
Durability	Very Good	4
Power Consumption	10mA	4
Negative Points	None	5
Positive Points	Cost/high accuracy/good for heavy rain/	5
Supplier Web-Site	https://static1.squarespace.com/static/597dc443914e6bed5fd30dcc/t/5f18133f5adebf195132bfab/1595413324598/MeteoRain+200+Compact+DataSheet.pdf	

Final Score Tally's

Sensor 1 = 29 out of 40

Sensor 2 = 23 out of 40

Sensor 3 = 33 out of 40

Bases on the above review tables and scoring criteria based on available data for each sensor the 'Meteorain 200' was a all-round capable unit with cost effectiveness.

Infra-Red Rain Sensor - Market Product Reviews

Technology 2 (Infra-red rain sensor) Market available sensors comparison table

	Sensor 1 	<u>Sensor 1</u> (score 1-5 , 5 being best)
Make & Model	OMC – 271 Precipitation Sensor	
Functionality	Rain sensor suitable for all rain applications	4
Out Put Signal	4-20Ma	5
Mounting applications	Very versatile	5
Cost	£845.89	1
Durability	Very Good	4
Power Consumption	90mA @ 24v DC	4
Negative Points	None	5
Positive Points	Low power consumption/accurate/no moving parts	5
Supplier Web Site	https://observator.com/wp-content/uploads/2019/11/Datasheet-OMC-271-V20191126.pdf	

	Sensor 2 	<u>Sensor 2</u> (score 1-5 , 5 being best)
Make & Model	OSi ORG Optical Rain Gauge	
Functionality	Rain sensor suitable for all rain applications	4

Out Put Signal	RS-232	2
Mounting applications	Pole mounted only	5
Cost	£653.98	1
Durability	Very good	3
Power Consumption	110Ma @ 12v dc	3
Negative Points	Pole mounted only /	1
Positive Points	Measures true rain rate / high accuracy	4
Supplier Web Site	https://geneq.com/environment/en/product/optical-scientific/optical-rain-gauge-6010	

	Sensor 3 	Sensor 3 (score 1-5 , 5 being best)
Make & Model	Thermo-Technik Rain Detector	
Functionality	Rain sensor	4
Out-Put Signal	4-20Ma	3
Mounting Applications	Direct mounted	5
Cost	£59.00	4
Durability	Very good	3
Power Consumption	870ma	4
Negative Points	Rain sensor only, does not measure volume	1
Positive Points	cheap	5
Supplier Web-Site	https://www.fruugo.co.ukwE	

Final Score Tally's

Sensor 1 = 33 out of 40

Sensor 2 = 23 out of 40

Sensor 3 = 29 out of 40

Based on the above review tables and scoring criteria based on available data for each sensor the 'OMC 271 Precipitation sensor' was a all-round capable unit with cost effectiveness.

Rain Sensor Equipment Review & Proposed Concept

Having reviewed the available technical devices available for rain monitoring, the choice for accuracy, reliability, cost and proven concept would be the collector and bucket especially the Meteo-rain 200 Compact.

Sensor Selection for Rain Fall Monitoring – Data Sheet



MeteoRain® 200 Compact

BARANIDESIGN

• AGRICULTURE
• COASTAL

• HYDROLOGY
• INDUSTRIAL & PLC

• METEOROLOGY
• SMART CITIES & IOT

• SOLAR POWER PLANTS
• WEATHER STATIONS

Ø 200 cm² self-balancing, self-emptying rain gauge

MeteoRain® 200 Compact uses a self-balancing measuring principle. It offers high resistance to error producing effects as found in most rain gauges. These include soiling of the internal measuring mechanism, mechanical friction, residual water remaining in the measuring spoon from previous rain event, and debris. Additionally, MeteoRain® offers high resistance to vibrations and non-level mounting.

Notable features include:

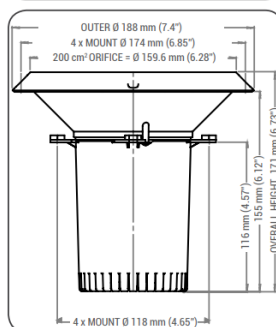
- Simplicity and reliability
- Multiple mounting options
- Easy to maintain and simple to clean with a removable funnel sieve/sift
- Robust and impact resistant funnel and housing
- Errors from non-level mounting are minimized with the self-balancing design
- Easy adjustment and recalibration of internal measuring mechanism
- Protection of measuring mechanism from contact during wire connections
- High-speed (0.13 s) self-emptying mechanism for high precipitation rate accuracy
- High-dynamic range up to 10 mm/minute (50 tips/minute) rain rates
- Bird-spikes are available. Leaf fence is not required due to self-cleaning funnel.
- Low-profile funnel for easy cleaning with a sharp edge for accuracy

Self-balancing, self-emptying magnetic tipping bucket technology to ensure uninterrupted measurement of precipitation regardless of amount and intensity.

It measures rain by means of a standardized orifice funnel which collects water into the precision measuring mechanism. The mechanism offers more **consistent long-term response** than any other standard tipping-bucket rain gauge.

Individually tested

Rain gauges are individually tested and use high quality sealed reed switches. Electronics are protected against salt spray, water, frost and heat by a weather-resistant coating.



Default
NO - Normally Open
reed switch in series
with a 470 Ω resistor

Special Order
NC - Normally Closed
reed switch in series
with a 470 Ω resistor

Pluviometer type	Accuracy	Stability	Resolution	Measuring range	Operating range	Starting threshold	Rain orifice area
Precipitation type: Liquid (Rain)	< ±1% for rain rates <100mm/hr	< 0.0125 mm per year	0.1, 0.2, 0.25 mm (0.01")	Up to 600 mm/hr in above freezing conditions	-40 °C...80 °C	Resolution + 0.07 mm (0.0027")	200 cm² (Ø 16.0 cm, 6.3")

* Rain gauge starting value is the amount of precipitation required to register a first reading. All funnel based rain gauges trap a small amount of precipitation on the funnel surface, which includes drops remaining on funnel surface (~1.4 ml), evaporation from the funnel surface, wetting of debris, dirt, and dust in the funnel catch sieve/sift and water opening (together an additional 1 ml). Rain gauge inspection interval should be determined by user experience and the environmental conditions.

Electrical interface	Electrical switching speed	Switching resistance	Max current	Max voltage	Surge protection	Tipping bucket speed	Shock resistance
Magnetic reed switch	0.25 ms	470 Ω	10 mA	15 VDC	Transient protection	0.13 seconds	15 g

For agricultural and IoT use where consistent measurement and long-term reliable maintenance-free operation are important



Weather resistant, robust and simple to maintain with reliable ultra-low power reed switch operation. ISO:9001 quality

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Equipment Selection & Evaluation (WATER LEVEL SENSORS)

Purpose of the Technology – Water level

Brief capture of technologies which can monitor track water levels –

	Technology 1	Technology 2	Technology 3
Technology Name	Ultrasonic	Capacitance	Float Switch
Principle workings of technology	Ultrasonic sensors measure levels by calculating the duration and strength of high frequency sound waves that are reflected off the surface of the liquid and back to the sensor.	Capacitance level sensors operate in the way that fluids have dielectric constants, significantly different to air, they measure the change in capacitance between two plates produced by changes in the level.	A float switch includes a magnet within a float and a magnetic reed switch contained within a secure housing, the float moves with the change in liquid and will cause the reed switch to either open or close.
Industry's/applications technology found in	Non-contact applications, good for monitoring highly viscous liquids	Tank water, levels, food treatment , power industry's	Tank levels for oil, water etc
Pro's	No moving parts, compact, reliable	Solid state, can be non-invasive, compact , accurate	Non-powered, direct induction, various outputs
Cons	Expensive, invasive	Can only be used in certain liquids	Moving parts, invasive

Water Level Technology Review

Based on the above table for technologies suitable for water level monitoring, the two technologies we will be looking into further are (float switch & capacitance sensors) the main reasons for this selection are based on the following;

For technology (float switch) – the float switch can give us accurate measurements, various output signal, and ease of installation.

&

For technology (capacitance sensor) – the capacitance sensor has no moving parts should prove ease of installation depending on mounting housing.

In the next table this will look at more specific on the market available sensors, 3 sensors selected per technology concept. From these tables one sensor from each technology will be selected on the

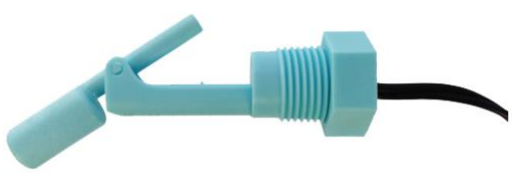
research and merit/point award based system, from this a final evaluation and review will be conducted on the remaining two sensors to ultimately determine a sensor selection going forward for the built prototype phase.

Water Level – Float Switch - Market Product Reviews

Technology 1 (Float Switch) Market available sensors comparison table

	Sensor 1 	<u>Sensor 1</u> (score 1-5 , 5 being best)
Make & Model	LR03-LO5M	
Functionality	Water Level float switch	4
Out Put Signal	24VDC	4
Mounting applications	Direct on floor	5
Cost	£27.66	1
Durability	Very Good	4
Power Consumption	80W	3
Negative Points	Accuracy levels, precise installation required	4
Positive Points	Low cost, durable	4
Supplier Web Site	http://www.farnell.com/datasheets/316999.pdf	

	Sensor 2 	<u>Sensor 2</u> (score 1-5 , 5 being best)
Make & Model	CSSF24 Series Float Switch	
Functionality	Miniature vertical side mount switch	4
Out Put Signal	24VDC	2
Mounting applications	Vertical mount will need frame made	5
Cost	£74.66	1
Durability	Very good	3
Power Consumption	30ma	3
Negative Points	Requires custom mounting frame	1
Positive Points	Accurate	4
Supplier Web Site	https://uk.rs-online.com/web/p/float-switches/2356204/	

	Sensor 3 	Sensor 3 (score 1-5 , 5 being best)
Make & Model	Low Level Bilge Float Switch	
Functionality	Float Switch	4
Out-Put Signal	24VDC	3
Mounting Applications	Direct Floor Mounting or onto a unit to determine minimum water level height	5
Cost	£16.00	3
Durability	Very Good	4
Power Consumption	None	4
Negative Points	Moving Parts	5
Positive Points	Cheap, easily installed	5
Supplier Web-Site	https://www.fluidswitch.com/wp-content/uploads/sites/2/2019/02/FH07-08-horizontal-plastic-fluid-switch.pdf	

Final Score Tally's

Sensor 1 = 29 out of 40

Sensor 2 = 23 out of 40

Sensor 3 = 33 out of 40

Based on the above review tables and scoring criteria based on available data for each sensor the 'Low Level Bilge Float Switch' was an all-round capable unit with cost effectiveness.

Water Level – Capacitance Sensor - Market Product Reviews

Technology 2 (Capacitance Sensor) Market available sensors comparison table

	Sensor 1 	Sensor 1 (score 1-5 , 5 being best)
Make & Model	Nivector FT126	
Functionality	Capacitive water level sensor	3

Out Put Signal	DC-PNP	2
Mounting applications	Will require mounting bracket	3
Cost	£245.21	2
Durability	Extremely Good	4
Power Consumption	20mA	4
Negative Points	Peotential accuracy on water levels, and mounting brackets	2
Positive Points	Robust, cost effect	3
Supplier Web Site	https://visaya.solutions/en/product/nivector-fti26	

	Sensor 2 	<u>Sensor 2</u> (score 1-5 , 5 being best)
Make & Model	Solicap FTI55	
Functionality	Capacitive fluid sensor	3
Out Put Signal	8-16Ma 2 Wire	2
Mounting applications	Will require a mounting bracket	3
Cost	496.43	1
Durability	Very good	3
Power Consumption	80ma	3
Negative Points	Difficult shape to get good mounting options available	2
Positive Points	Good durability	3
Supplier Web Site	https://visaya.solutions/en/product/solicap-fti55	

	Sensor 3 	Sensor 3 (score 1-5 , 5 being best)
Make & Model	PFT Level Sensor	
Functionality	Level fluid Sensor	3
Out-Put Signal	4-20Ma	4
Mounting Applications	Mounting bracket required	3
Cost	193.28	3
Durability	Extremely good	3
Power Consumption	30Ma	4
Negative Points	Mounting applications could be tricky	3
Positive Points	Compact, durable	4

Supplier Web-Site	https://docs.rs-online.com/33de/0900766b81654e05.pdf	
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Final Score Tally's

Sensor 1 = 23 out of 40

Sensor 2 = 20 out of 40

Sensor 3 = 27 out of 40

Based on the above review tables and scoring criteria based on available data for each sensor the 'PFT Level Sensor' was a all-round capable unit with cost effectiveness.

Water Level Sensor Equipment Review & Proposed Concept

Having reviewed the available technical devices available for water level monitoring, the choice for accuracy, reliability, cost and proven concept would be the Low Level Bigile Float Switch

Sensor Selection for Rain Fall Monitoring – Data Sheet

FH07 & FH08 – Plastic Horizontal Float Switch

Side-mounted float switches available in polypropylene and nylon, making them ideal for a variety of general use chemical applications. Easily mounted through a horizontal NPT fitting or internal through-hole, these liquid level sensors offer superior dependability and economy. Featuring a "pivot" style functionality: float switches provide point level sensing.

FH07



FH07-0000 - Polypropylene Side Mounted Switch with 1/2" NPT pipe threads

FH07-0001 - Polypropylene Side Mounted Switch with PF1/4 threads for Bulkhead mounting in 1/2" through-hole

FH07-0050 - Polypropylene Side Mounted Switch with 1/2" x 1/2" NPT Stub-In Mount

Part Number	Switch Type	Max Switching Current	Max Switching Voltage	Max Temp	Max Pressure	Specific Gravity
FH07 -0000	50 Watt	0.5 Amps	200 VDC	105° C	25 psig	0.70
FH07 -0001	50 Watt	0.5 Amps	200 VDC	105° C	25 psig	0.70
FH07 -0050	50 Watt	0.5 Amps	200 VDC	105° C	50 psig	0.70

FH08



FH08-0000 - Nylon-6 Side Mounted Switch with 1/2" NPT pipe threads

FH08-0001 - Nylon-6 Side Mounted Switch with PF1/4 threads for Bulkhead mounting in 1/2" through-hole

Part Number	Switch Type	Max Switching Current	Max Switching Voltage	Max Temp	Max Pressure	Specific Gravity
FH08 -0000	50 Watt	0.5 Amps	200 VDC	105° C	25 psig	0.70
FH08 -0001	50 Watt	0.5 Amps	200 VDC	105° C	25 psig	0.70

Rotate for normally open (NO) or normally closed (NC) operation, and combine two switches at different levels for high and low level sensing or pump control. Horizontal liquid level sensors are mounted through a hermetically sealed hole on the side of a tank. When the level of the tank's liquid rises or falls past the level of the float, the float will rise and fall with it, activating the switch. Wires then send an electric signal to the outside of the tank through the watertight seal, making these components essential for accurate monitoring or regulation of fluid levels in many contexts.

Because horizontal sensors come as standard parts or customized OEM, it can be used in a vast amount of applications in many markets at a reasonable prices.

USA
SMD Fluid Controls
55 Barnes Park North, Wallingford, CT 06492
solutions@fluidswitch.com | (203) 294-5800

Europe
Strain Measurement Devices
Bury Road, Chedburgh, Bury St Edmunds IP29 4UQ
fluidswitch@smdsensors.co.uk | +44 (0)1284 852 000

www.fluidswitch.com

Equipment Selection & Evaluation (Optical / Laser Sensors)

Purpose of the Technology – Embankment Movement

Brief capture of technologies which can monitor embankment movement –

	Technology 1	Technology 2	Technology 3
Technology Name	Optical	Laser	Ultrasonic
Principle workings of technology	An optical sensor converts light rays into electronic signals. It measures the physical quantity of light and then translates it into a form that is readable by an instrument.	A laser used for the purpose of a distance meter, sends out a finely focused pulse of light to the target and detects the reflection. The meter measures the time between those two events and	Ultrasonic distance sensors measure the distance to, or presence of target objects by sending a pulsed ultrasound wave at the object and then measuring the time for the sound echo to return, knowing the

		converts this to distance.	speed of the sound the sensor can determine the distance.
Industry's/applications technology found in	Manufacturing, defence, construction	Manufacturing , construction	Manufacturing, marine, construction
Pro's	Good accuracy over distance, robust construction, no moving parts	Good accuracy, robust, no moving parts, ability to measure long distance	Good accuracy, robust construction, no moving parts, does not get effected with debris build up on lenses
Cons	Optical section of the device could become covered with debris, making the device unreliable	Optical section of the device could become covered with debris, making the device unreliable, laser hazard issue for workers in area	none

Embankment Movement's Technology Review

Based om the above table for technologies suitable for embankment moving monitoring, the two technologies we will be looking into further are (Laser & Ultrasonic) the main reasons for this selection are based on the following;

For technology (Laser Sensor) – the laser sensor has vast similarity's with the optical sensor range, how ever the laser sensor has a much higher susceptibility to debris build up.

&

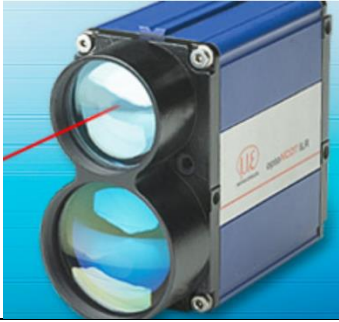
For technology (Ultrasonic Sensor) – the ultrasonic sensor has a vast back round with proven operations of measuring distance accurately within harsh environmental conditions.

In the next table this will look at more specific on the market available sensors, 3 sensors selected per technology concept. From these tables one sensor from each technology will be selected on the merit/point award based system, from this a final evaluation and review will be conducted on the remaining two sensors to ultimately determine a sensor selection going forward for the built prototype phase.

Embankment Movement Sensor's - Market Product Reviews

Technology 1 (Laser Sensors) Market available sensors comparison table

	Sensor 1 	<u>Sensor 1</u> (score 1-5 , 5 being best)
Make & Model	Type DAE-10-050	
Functionality	Measure Distance	4
Out Put Signal	4-20Ma (measures up to 50mtrs)	5
Mounting applications	Mounting bracket required	3
Cost	£345.87	2
Durability	Very Good	3
Power Consumption	0.5a at 24VDC	3
Negative Points	Possible build up of debris on lens	2
Positive Points	High accuracy measurement at long distances	4
Supplier Web Site	https://www.laser-distance-sensors.uk/product/dpe-10-050/	

	Sensor 2 	Sensor 2 (score 1-5 , 5 being best)
Make & Model	NCDT ILR 1191	
Functionality	Measure distance	4
Out Put Signal	4-20Ma (measure up to 3,000mtrs)	5
Mounting applications	Mounting bracket required	3
Cost	Dependant on measurement distance (£278-£8,000)	1
Durability	Very good	3
Power Consumption	Average 1a @ 24VDC	3
Negative Points	Possible build up of debris on lens	2
Positive Points	High accuracy measurement and large amount of distance sensor selection	4
Supplier Web Site	https://www.micro-epsilon.co.uk/displacement-position-sensors/laser-distance-sensor/optoNCDT_ILR_1191/	

	Sensor 3 	Sensor 3 (score 1-5 , 5 being best)
Make & Model	LDM4x Series	
Functionality	Measure Distance	4
Out-Put Signal	4-20Ma (Measures upto 150Mtrs)	5
Mounting Applications	Mounting bracket required	3
Cost	£486.89	2
Durability	Very good	3
Power Consumption	0.2A @ 24VDC	4
Negative Points	Possible build up of debris on lens	2
Positive Points	Eye safe class 2 laser	4
Supplier Web-Site	file:///C:/Users/cston/Downloads/lm-41-42-43-datasheet-de.pdf	

Final Score Tally's

Sensor 1 = 26 out of 40

Sensor 2 = 25 out of 40

Sensor 3 = 27 out of 40

Based on the above review tables and scoring criteria based on available data for each sensor the 'LDM4x Seris'_ was an all-round capable unit with cost effectiveness.

Embankment Movement - Market Product Reviews

Technology 2 (Ultrasonic Sensors) Market available sensors comparison table

	Sensor 1 	<u>Sensor 1</u> (score 1-5 , 5 being best)
Make & Model	XXS18S1VM12	
Functionality	Distance Sensor	4
Out Put Signal	0-10V Analogue (upto 25mtrs)	4
Mounting applications	Mounting Bracket Required	3
Cost	£297.61	2
Durability	Very Good	3
Power Consumption	30ma @ 24VDC	4
Negative Points	Limited on distance	2
Positive Points	Good constructability, good resilience to lens debris	3
Supplier Web Site	http://www.farnell.com/datasheets/2642640.pdf	

	Sensor 2 	<u>Sensor 2</u> (score 1-5 , 5 being best)
Make & Model	UM18-218161101	
Functionality	Distance Sensor	4
Out Put Signal	4-20Ma	4
Mounting applications	Mounting Bracket Required	3
Cost	£421.34	2
Durability	Very Good	3
Power Consumption	1.2A @24VDC	2
Negative Points	Power consumption	2
Positive Points	good resilience to lens debris	3
Supplier Web Site	https://www.tme.eu/Document/bf15ba4daaf5f9fc5b04e04f9b478176/SICK-ultrasonic-sensors.pdf	

	Sensor 3  TOUGHSONIC® 50	Sensor 3 (score 1-5 , 5 being best)
Make & Model	Touch Sonic 50	
Functionality	Distance Sensor	4
Out-Put Signal	4-20Ma or 0-10v	4
Mounting Applications	Mounting Bracket Required	3
Cost	£589.54	2
Durability	Very Good	3
Power Consumption	90Ma @ 24VDC	4
Negative Points	Cost and limitation on distance	2
Positive Points	Durable and accurate	4
Supplier Web-Site	file:///C:/Users/cston/Downloads/File-1453300340.pdf	

Final Score Tally's

Sensor 1 = 25 out of 40

Sensor 2 = 23 out of 40

Sensor 3 = 26 out of 40

Based on the above review tables and scoring criteria based on available data for each sensor the 'PFT Level Sensor' was a all-round capable unit with cost effectiveness.

Distance Measurement Sensor Equipment Review & Proposed Concept

Having reviewed the available technical devices available for the distance measurement technologies and market available sensors, my first thoughts was that I would be utilising a ultrasonic type sensor but after investigation to market available ultrasonic sensors and as you can see from the above tables that the limiting factor is the distance in which ultrasonic sensors can operate too, as we want to have a versatile system so that we have one common mounting pole for a number of sensors which can then monitor a wide distance of embankment locations or hot spots, given that the chosen technology for moving forward will be based on laser distance sensors.

Sensor Selection for Distance Measurement Sensor (Below Data Sheet)



For measuring distances within millimeter accuracy and precisely locating objects.
The LDM41/42/43 are proven workhorses for heavy-duty industrial applications.

Technical specifications	LDM41 series	LDM42 series	LDM43 series
Measurement capabilities			
Total range		From 0.1 m to 150 m	
Range on target board		From 25 m to 150 m	
Range on natural surface ¹		From 0.1 m to 30 m	
Accuracy		± 3 mm (from +15°C to +30°C) ± 5 mm (from -40°C to +50°C)	
Repeatability	n/a	n/a	n/a
Measured value resolution	0.1 mm	0.1 mm	0.1 mm
Measurement frequency, max.	10 Hz	50 Hz	50 Hz
Laser			
Wavelength		650 nm (red)	
Divergence		0.6 mrad	
Class		Laser Class 2, EN 60825-1:2014	
Connectivity and I/O options			
Interface options	RS-232, RS-422 (max. 38.4 Kbaud)	RS-232, RS-422 (max. 38.4 Kbaud)	Profibus (max. 12 Mbaud) SSI, 24-bit (max. 1 MHz)
Switching output	1x	1x	2x
Analog output	Yes	Yes	Yes
Trigger	Yes	Yes	Yes
Measurement operation modes	Single, continuous	Single, continuous	Single, continuous
Connectors	12-pole M16	12-pole M16	5-pole M12, 12-pole M16
Display / Controls	Status LED	Status LED	Status LED
Power			
Power supply		From 10 V DC to 30 V DC	
Power consumption, max.		Standard: 3.2 W Heating mode: 25.7 W	
Ambient conditions			
Operating temperature		Standard: from -10°C to +50°C Heating mode: from -40°C to +50°C	
Storage temperature		From -40°C to +70°C	
Humidity		From 10% to 90%, non-condensing	
Integrated heating		Optional	
Standards			
Shock / Vibration		DIN ISO 9022-3	
Protection class		IP 65	
EMC		EN 61326-1	
Physical			
Dimensions (L x W x H, incl. connectors)	205 mm x 96 mm x 50 mm	205 mm x 96 mm x 50 mm	210 mm x 96 mm x 50 mm
Weight	760 g	760 g	770 g

¹ Measurement range for naturally diffuse reflecting surfaces, depending on target reflectivity, stray light, and environmental conditions.

Equipment Selection & Evaluation (Control Hardware for System)

Purpose of the Technology – Main Operation Hardware

Brief capture of technologies which can control electronic component's –

	Technology 1	Technology 2	
Technology Name	PLC	PIC	
Principle workings of technology	A PLC program consist of a set of instructions either in textual or graphical form, which represents the logic to be implemented for specific industrial real-time applications	PIC microcontrollers (programmable interface controllers), are electronic circuits that can be programmed to carry out vast range of task, they can be used to connect the computer to the microcontroller circuit.	
Industry's/applications technology found in	Industrial automation applications	Automation, bespoke equipment	
Pro's	Proven technology, ease of device integration	Proven technology, precise control	
Cons	Size of components	Design is limited to certain devices	

Embankment Movement's Technology Review

Based om the above table for technologies suitable for embankment moving monitoring, the two technologies we will be looking into further are (PLC Only) the main reasons for this selection are based on the following;

For the PLC selection a few major factors to take into consideration are, ability of the PLC to integrate a full selection of inputs/outputs in both digital and analogue spectrums is greatly advantageous. The other point is for a personal reason that my own experience is more Intune with the interactions of PLC use so to ensure success within this project it is paramount.

In the next table this will look at more specific on the market available PLC systems, the tables will be looking at evaluating manufactures such as Siemens, ABB, Alan Bradely.

PLC Operation System - Market Product Reviews

Technology 1 (PLC) Market available sensors comparison table

	PLC 1 – Siemens	Sensor 1 (score 1-5 , 5 being best)
Make & Model	Siemens S7-1200 PLC	
Functionality	Programable logic controller	4
Out Put Signal	Analogue, digital, relay	4
Mounting applications	Din rail mounted	3
Cost	Free issue (University)	5
Durability	Very Good, needs enclosure	3
Power Consumption	180Ma @24VDC	3
Negative Points	Size of units and requires enclosure	2
Positive Points	Excellent selection of devices and usability	5
Supplier Web Site	https://docs.rs-online.com/7d6e/0900766b81639d60.pdf	

	PLC 2 - ABB	Sensor 3 (score 1-5 , 5 being best)
Make & Model	ABB AC500 PLC	
Functionality	Programable logic controller	4
Out-Put Signal	Analogue, digital, relay	4
Mounting Applications	Din rail mounted	3
Cost	£1,007.85	2
Durability	Very Good, needs enclosure	3
Power Consumption	340ma @24VDC	3
Negative Points	Size of units and requires enclosure	2
Positive Points	Excellent selection of devices and usability	5
Supplier Web-Site	https://search.abb.com/library/Download.aspx?DocumentID=3ADR010624&LanguageCode=en&DocumentPartId=&Action=Launch	

	PLC 3 – Alan Bradely	Sensor 3 (score 1-5 , 5 being best)
Make & Model	Compact Logix 5480 Control System	
Functionality	Programable logic controller	4
Out-Put Signal	Analogue, digital, relay	4
Mounting Applications	Din rail mounted	3
Cost	£1,596.89	1
Durability	Very good required enclosure	3
Power Consumption	298ma @24VDC	3
Negative Points	Size of units required enclosure	2
Positive Points	Excellent selection of devices and usability	5
Supplier Web-Site	https://www.rockwellautomation.com/en-no/products/hardware/allen-bradley/programmable-controllers/small-controllers/compactlog#specifications	

Final Score Tally's

Sensor 1 = 29 out of 40

Sensor 2 = 26 out of 40

Sensor 3 = 25 out of 40

Based on the above review tables and scoring criteria based on available data for each PLC the 'Siemens S7-1200 PLC' was an all-round capable unit with cost effectiveness.

As the PLC's ultimately offer the same level of technological advantages etc, the biggest factors to weigh in are that the siemens PLC has been free issued from the university which reduces cost hugely, also my own exposure to PLC systems is very limited with a soft wear programming stance. So it vital for me to use siemens systems based on familiarity.

SIEMENS

Data sheet

6ES7211-1BE40-0XB0

SIMATIC S7-1200, CPU 1211C, compact CPU, AC/DC/relay, onboard I/O: 6 DI 24 V DC; 4 DO relay 2A; 2 AI 0-10 V DC, Power supply: AC 85-264 V AC at 47-63 Hz, Program/data memory 50 KB



General information	
Product type designation	CPU 1211C AC/DC/relay
Firmware version	V4.2
Engineering with	
• Programming package	STEP 7 V14 or higher
Supply voltage	
Rated value (AC)	
• 120 V AC	Yes
• 230 V AC	Yes
permissible range, lower limit (AC)	85 V
permissible range, upper limit (AC)	264 V
Line frequency	
• permissible range, lower limit	47 Hz
• permissible range, upper limit	63 Hz
Input current	
Current consumption (rated value)	60 mA at 120 V AC; 30 mA at 240 V AC
Current consumption, max.	180 mA at 120 V AC; 90 mA at 240 V AC
Inrush current, max.	20 A; at 264 V

Equipment Selection & Evaluation (Early Warning Beacon Light)

Purpose of the Technology – To warn approaching trains of ahead danger

Beacon Light Technology Review

For the purpose of the selection for beacon lights, there is no technological reviews and we predominantly know that we need to utilise, a light beacon for this application.

In the next table's this will look at the available market products and determine their suitability.

PLC Operation System - Market Product Reviews

Technology 1 (PLC) Market available sensors comparison table

	Light Beacon 1 	<u>Sensor 1</u> (score 1-5 , 5 being best)
Make & Model	Moflash Industrial LED traffic light	
Functionality	Light Beacon	4
Out Put Signal	Red or Green light	4
Mounting applications	Mounting bracket required	3
Cost	£164.63	5
Durability	Very Good, IP65	3
Power Consumption	24Ma @ 24VDC	3
Negative Points	None	2
Positive Points	Led Light, IP rated, Excellent working voltage range	5
Supplier Web Site	https://docs.rs-online.com/b919/0900766b815022dc.pdf	

	Light Beacon 2 	Sensor 3 (score 1-5 , 5 being best)
Make & Model	Eaton LED Beacon Tower	
Functionality	2 Light LED tower	4
Out-Put Signal	Red or Green light	4
Mounting Applications	Bracket mounted	3
Cost	£141.90	2
Durability	Very Good, IP66	3
Power Consumption	238ma @24VDC	3
Negative Points	Possible light out put	2
Positive Points	LED light, IP Rated, 24VDC working voltage	5
Supplier Web-Site	https://docs.rs-online.com/15b8/0900766b813022bc.pdf	

	Light Beacon 3 	Sensor 3 (score 1-5 , 5 being best)
Make & Model	Werma 424 Horn Beacon 98dB	
Functionality	LED flashing beacon & Horn	4
Out-Put Signal	Flashing Beacon and horn	4
Mounting Applications	Bracket mounted	3
Cost	£129.58	1
Durability	Very good, IP 65	3
Power Consumption	800ma @24VDC	3
Negative Points	High power consumption	2
Positive Points	LED Xenon light, audible sound	5
Supplier Web-Site	https://docs.rs-online.com/dcaa/0900766b809d1cfe.pdf	

Final Score Tally's

Sensor 1 = 29 out of 40

Sensor 2 = 26 out of 40

Sensor 3 = 25 out of 40

For the above selection and benefits from each light option and the benefit of more than one unit to be utilised will be needed to go forward, this will ensure maximum benefits from 1 and more light beacons.

Equipment Selection & Evaluation (Siemens additional modular attachments)

As specified in the above PLC selection reviews, for this project the use of the Siemens Plc will be utilised. With this there is a requirement for a additional modular items to support the overall system.

Below area each components to compliment the Siemens PLC. As the products are brand specific it is not required to go through a scoring process.

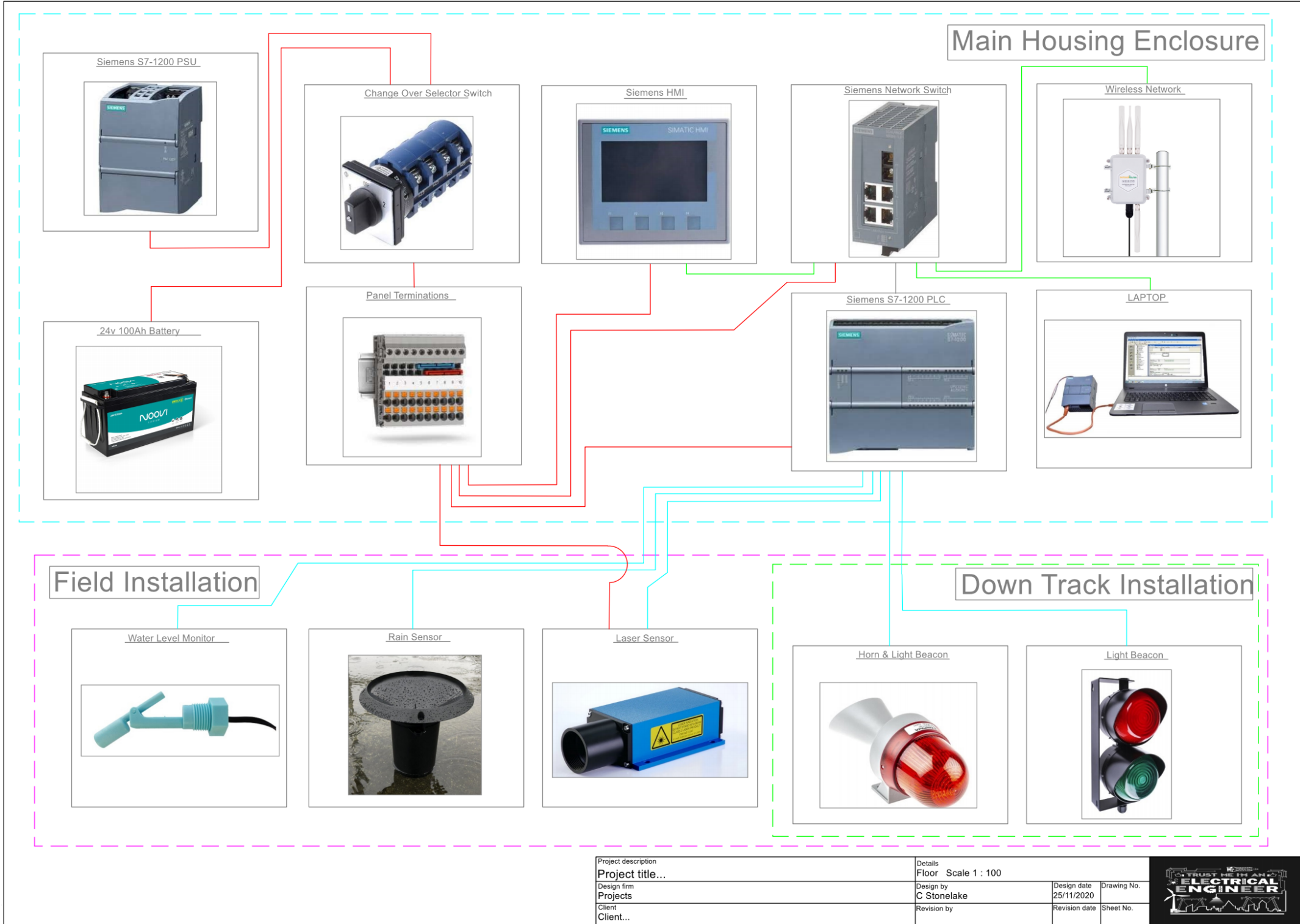
	Siemens Network Switch 	Sensor 3 (score 1-5 , 5 being best)
Make & Model	Siemens Ethernet Network Switch	
Functionality	Either net network switch	
Out-Put Signal	N/A	
Mounting Applications	Din rail mounted	
Cost	£152.00	
Durability	Very good, required IP rated enclosure	
Power Consumption	70Ma @ 24VDC	
Negative Points	N/A	
Positive Points	Enables the build to incorporate HIM and additional network applications	
Supplier Web-Site	https://docs.rs-online.com/2bfd/0900766b813eb15d.pdf	

	Siemens Power Supply Unit 	Sensor 3 (score 1-5 , 5 being best)
Make & Model	Siemens PSU (Power Supply Unit)	
Functionality	Power supllly unit	
Out-Put Signal	N/A	
Mounting Applications	Din rail mounted	
Cost	£71.93	
Durability	Very good, required IP rated enclosure	
Power Consumption	1A @ 230V	
Negative Points	N/A	
Positive Points	Enables power convershion down to 24VDC when using mains source power supplys.	
Supplier Web-Site	https://docs.rs-online.com/2bfd/0900766b813eb15d.pdf	

Notes – The PSU is intended for use only when connected to a mains 230v system, when using in remote applications the system will be connected to the battery supply system which will operate at a default 24VDC system.

System Block Diagram (Hardware Overview)

System block diagram is a hardware Visual representation of the proposed products specified to date, at this point in the project it is also tool to help identify additional component requirements. (Figure 4 Below)



Battery Calculation for main control centre

From the initial project build concept build as shown in the system block diagram, I can now start to build up what the power consumption rates are for the system, this will also help to ensure the PSU (Power Supply Unit) is also rated for the task.

Device	Quantity	Max Current Ma	Total mA
Siemens S-7 PLC	1	180Ma	180mA
Siemens Network Switch	1	70Ma	70mA
Siemens HMI	1	125Ma	125mA
Water Level Switch	1	N/A	N/A
Rain Sensor	1	10mA	10mA
Laser Sensor	1	200Ma	200mA
Wireless Network	1	500Ma	500mA

From the above table the total maximum current is calculated at (1.08A), from this we can work out the battery requirements as follows;

Battery Calculation Whole System

- Capacity (Amp Hour) = Total Current (Amps) x Time (Hours)
- Capacity = (with out the TBC) 1.08Amps x 24 (Hours) = 25.93mAh
- Capacity = 25.93mAh x 7 Days = 181Ah Required Battery

** 2 x 100Ah battery would suffice but this does draw a short fall or regular visits to remote location where these units are being installed, recommendation is to research power generation technologies such as wind, solar to recharge battery levels.

Battery Calculation for Beacon light centre

Device	Quantity	Max Current Ma	Total mA
Horn & Beacon	1	800mA	800mA
Light Beacon	1	24mA	24mA

From the above table the total maximum current is calculated at (0.82A), from this we can work out the battery requirements as follows;

Battery Calculation Whole System

- Capacity (Amp Hour) = Total Current (Amps) x Time (Hours)
- Capacity = (without the TBC) 0.82Amps x 24 (Hours) = 19.68mAh
- Capacity = 19.68mAh x 2 Days = 39.36Ah Required Battery

** Note that the battery capacity for the beacon light centre will only be required mainly when the warning beacons are activated, there still maybe small residual current been drawn be other comms devices, but the use of a 60Ah battery will more than cater for this.

Enclosure Selection

The enclosures selection for the build shall be durable metal or high impact PVC, at least IP66.

The size of enclosure will need to enclose the equipment in the main control centres. *it should also be noted that the enclosure for this section of the assignment will be based on 1 x control centre with all remote beacons operating directly out from this, this will allow to keep cost and simplify the proto-type build concept.

The below image shows a GA representation of the internal mounting arrangements of the ensure so that we can accurately size the required enclosure.

Based on the sizing GA above the enclosure will ned to be 400x400x200 (W,H,D).

- Based on the scaled GA below, the required enclosure size required is (400x400x200 – W,H,D)

Specification	
Brand	Schneider Telemecanique
Colour	Light Grey RAL7035
Depth	120mm
Dimensions	(H)400 mm x (W)400 mm x (D)120 mm
Finish	Epoxy Polyester Powder Coated
Guarantee	18 Months
Height	400mm
IP Rating	IP66
Lockable	Yes
Material	Sheet Steel
Mounting	Surface
Packaging Types	Each
Product Range	Spacial SBM
Size	400 mm x 400 mm x 120 mm
Standards	IEC 62208
Suitable Mounting Plate	NSYMM445B
Type	Industrial Box
Unspac	39121303
Weight	5.36400kg
Width	400mm

[Schneider Sarel 400mm x 400mm x 120mm Steel Enclosure IP66 \(NSYSBM404012\) | CEF](#)



MCG 400mm x 400mm x 200mm GRP Enclosure Grey IP66

Part Code: **HL44200**
Stock Code: **1448-7229**

- Glass reinforced polyester [GRP]
- Polyurethane gasket
- IP66 rated
- Hinged lockable lid
- Fixing kit included
- Complies to IEC 62208
- Mounting plates available [sold separately]

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£5.95 Delivery on orders under £50

-

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The Below Image shows the proposed proto-type
Internal layout and configuration

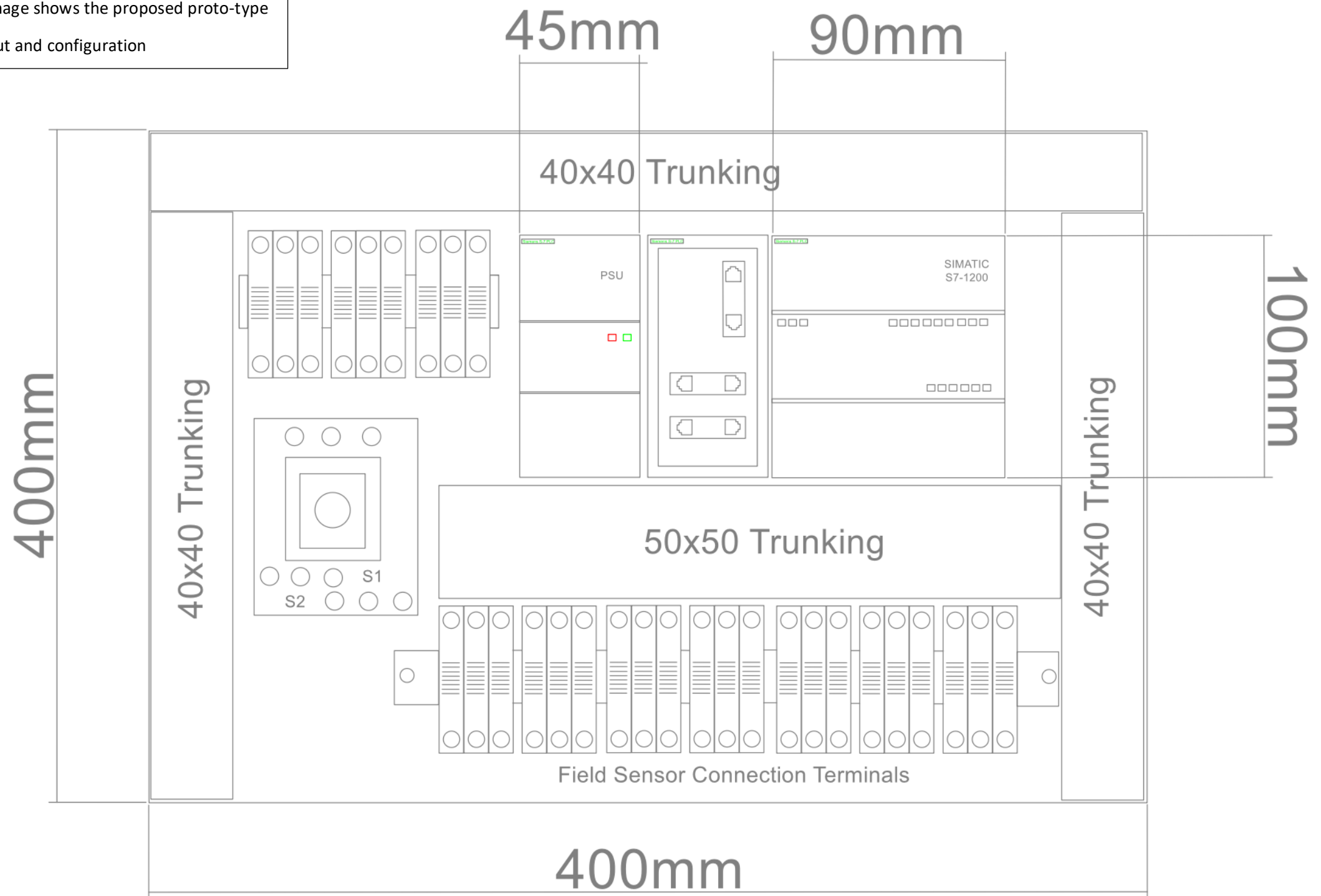


Figure 5

Project description		Details	
Project title...		Floor	
Design firm	Design by	Design date	Drawing No.
Projects	C Stonelake	25/11/2020	1
Client	Revision by	Revision date	Sheet No.
Client...			1

Bill of Materials

As the majority of the equipment has been pre-selected, it is now possible to accurately build the bill of material for the prototype build. As during the prototype build such hardware e.g. battery's, will not be sourced due to the availability of mains power.

Bill of material table;

Product Description	Supplier	Item Cost	Quantity	Line Total
Siemens PLC S7	N/A	Free Issue	1	N/A
Siemens PLC Network Switch	N/A	Free Issue	1	N/A
Siemens PSU	N/A	Free Issue	1	N/A
Laser Sensor	RS Components	£486.00	1	£486.00
Float Switch	Fluid Controls	£16.00	1	£16.00
Rain Sensor	Square Space	£120.00	1	£120.00
Light Beacon	RS Online	£164.00	1	£164.00
Light Beacon with sounder	RS Online	£129.00	1	£129.00
Enclosure	City Electrical	£60.00	1	£60.00

Total Build Cost	£975.00
-------------------------	----------------

As this is a prototype build it will be unreasonable to proceed with some of the higher end equipment selections made in the start of this report, the suggestion is to replace the below sensors with a counterpart equipment (this is shown in the below table).

The following equipment although also has a high unit value, has been given free issue for the duration for the build equipment supplied from the university and employer.

Existing Equipment	New Replacement Equipment	New Section Cost
Light Beacon	LED Panel Lights	£15.00
Light Beacon with Sounder	LED panel lights and sounder to be represented by LED light	£8.00
Laser Sensor	Beam reflector type sensor	£20.00
Enclosure	Steel IP65	£40.00
Rain Sensor	Rain Sensor	£10.00
Vibration Sensor	Additional sensor	£15.00

New Build Total Build Cost after changes	£108.00
---	----------------

PLC System Software Development

Operational Flow Chart

The below shows the initial system control operation flow chart (operation philosophy), this will help set the foundation for system operations when progressing further with PLC righting and generic outcomes from the system we would like to see.

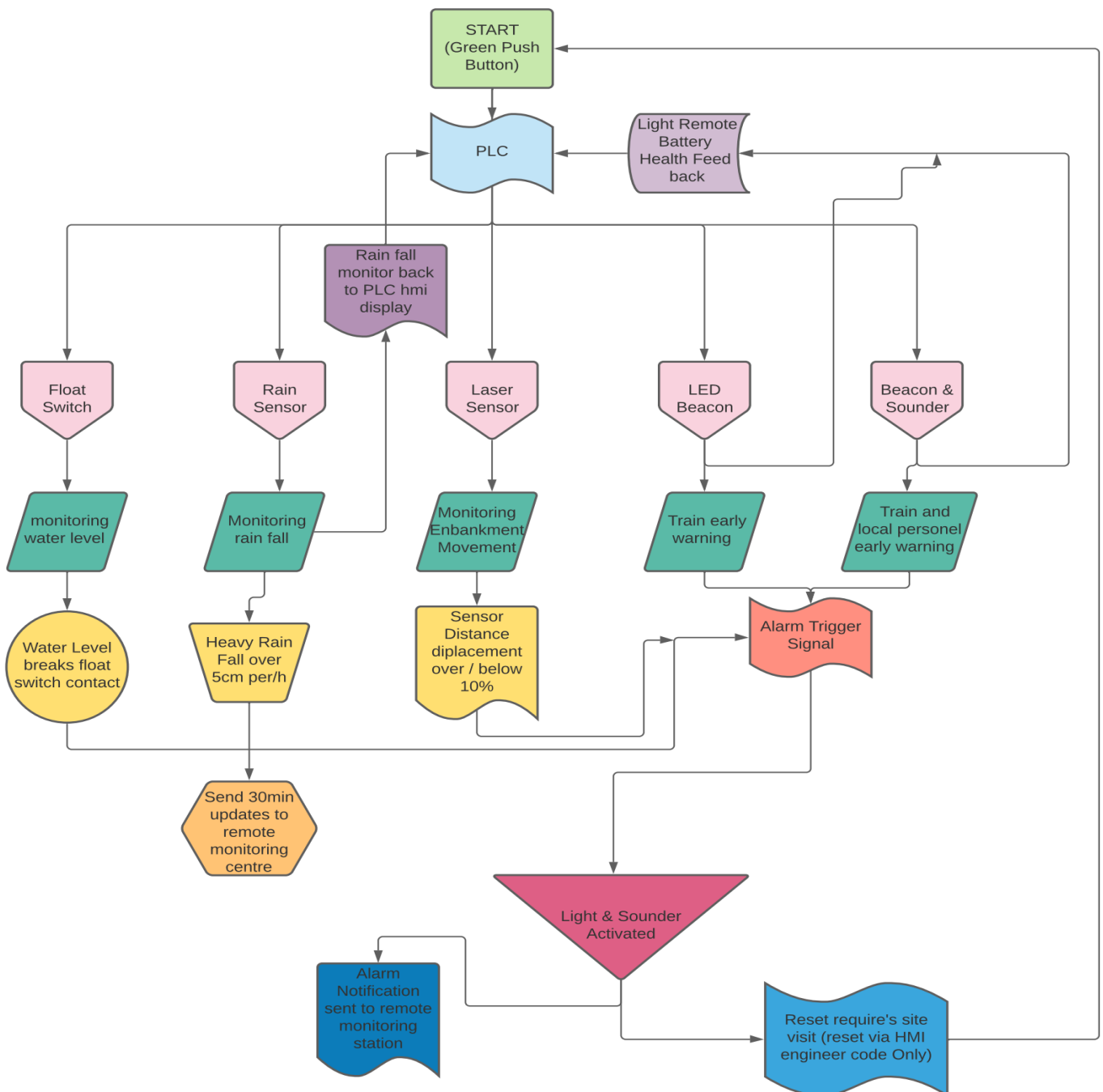


Figure 6

Sensor Prototype High Level Bench test

Sensor 1 Bench Test – Float Switch

Test overview –

Testing of the float switch is to confirm the correct workings of the instrument but also to ensure instrument suitability for the proposed application, as the float switch is a very basic construction electrically the switch is either NC (Normally Closed) or NO (Normally open).

Images –

Image 1 – (Float switch in closed position, circuit continuity)



Figure 7

Image 2 – (Float switch in open position, no circuit continuity)



Figure 8

Test results –

Instrument	Instrument Status	Instrument Out Put	Reason for output results
Float Switch	Instrument in open state	None, open circuit	This would be the normal status with low water levels
Float Switch	Instrument in closed state	3.1ohm, switched closed	When water levels are high (above set point) switch will close

Test Review –

The float switch operated as predicted it is a very simple device, once the sensor is installed in its field installation set point the device will only operate in the event water levels reach the flow switch set point.

Sensor 2 Bench Test – Vibration Sensor

Test overview -

Testing the vibration sensor is to test the correct workings of the instrument, but also to ensure instrument suitability for the proposed application, and get a sense of output values.

Images –

Image 1 – (Vibration sensor with no immediate local sources of vibration)



Figure 9

Image 2 – (Vibration sensor, with a local vibration source (hand tapping table) as source of vibration)



Figure 10

Test Results -

Instrument	Instrument Status	Instrument Out Put	Reason for output results
Vibration Sensor	Stationary, no local vibration sources	0.0mV	No source of vibration for sensor to give out any readings
Vibration Sensor	Stationary, local vibration source	6.1mV	Hand tapping close to sensor, as source of vibration

Test Results –

The initial bench test results show promising results that the instrument is suitable for the application, however I think further test should be carried out to get some clear definition of output readings so that we can pin point out put ranges when a land slip occurs

Next Objective

The next object proposed is to put the vibration sensor within a holding enclosure, in a fixed position and carry out to types of test. Test 1 will be of close by heavy traffic mimicked by walking close to sensor. Second test 2 would be to tip soil over the vibration sensor enclose .

The initial prediction which I hope to see is that we have much larger mV output spikes in the events of land slips and for passing traffic to see more level put constant mV output levels.

Sensor 2 Field Test – Vibration Sensor (Next Objectives tasks)

Test Overview –

As detailed and described in the vibration sensor next objectives section, this stage 2 testing required the prototype build for the field application of the vibration sensor and also modifications to the sensor to allow it to be more sensitive to vibration sources (this was achieved by adding a spring and weight added to the diaphragm of the vibration sensor, which is detailed in the following sections)

Images & Commentary –

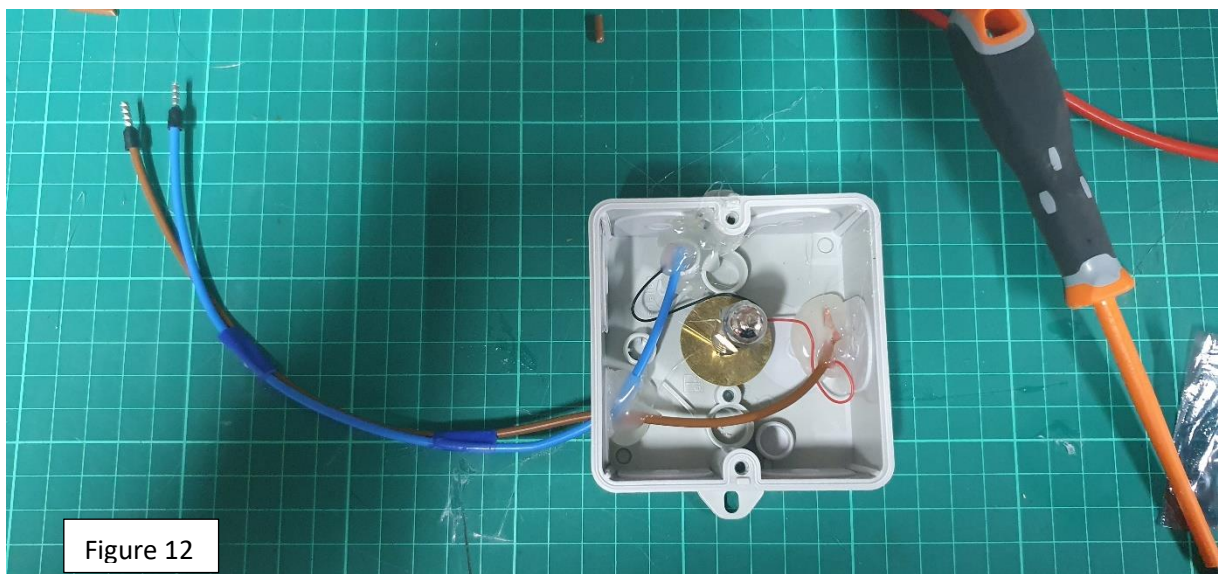
Vibration Image 1 –

In the below image the vibration sensor has been retro fitted to an IP rated enclosure and spring, weight added to the vibration sensor. Extended electrical connections added to make field testing more practicable.



Vibration Image 2 –

extended electrical connections shown below;



Vibration Image 3 –

In image 3, as below it was important after the retro fit to a field enclosure to ensure all connections still had continuity and the vibration sensor still active, a local vibration force was implemented and a out put reading was recorded @ 21.4mV.



Figure 13

Vibration Sensor Field Test

Vibration Image 4 –

image 4, shows the sensor lightly buried to replicate a more real world installation scenario for the next test.



Figure 14

Vibration Image 5 –

The below image5, show the mV output Max reading of 7.2mV. this reading was replicated by a constant vibration source in the idea to replicate a continuous low pitch vibration which would be caused by a passing train.

For more clarity, readers shall reference and view video – [Video Vibration Field Test 1](#)



Figure 15

Vibration Image 6 –

Image 7, show's how the replication of how we mimicked a land slip, a volume of soil was dropped onto the location of the vibration sensor at a height around 14inch drop.



Figure 17

Vibration Image 7 –

Image 7, shows the output from the vibration sensor from the soil debris dropped as discussed in image 6. The maximum output level recorded was 32.5mV which is a significant voltage difference recorded in the vibration test on 7.2Mv.

For more clarity, readers shall reference and view video – Video Vibration Field Test 2

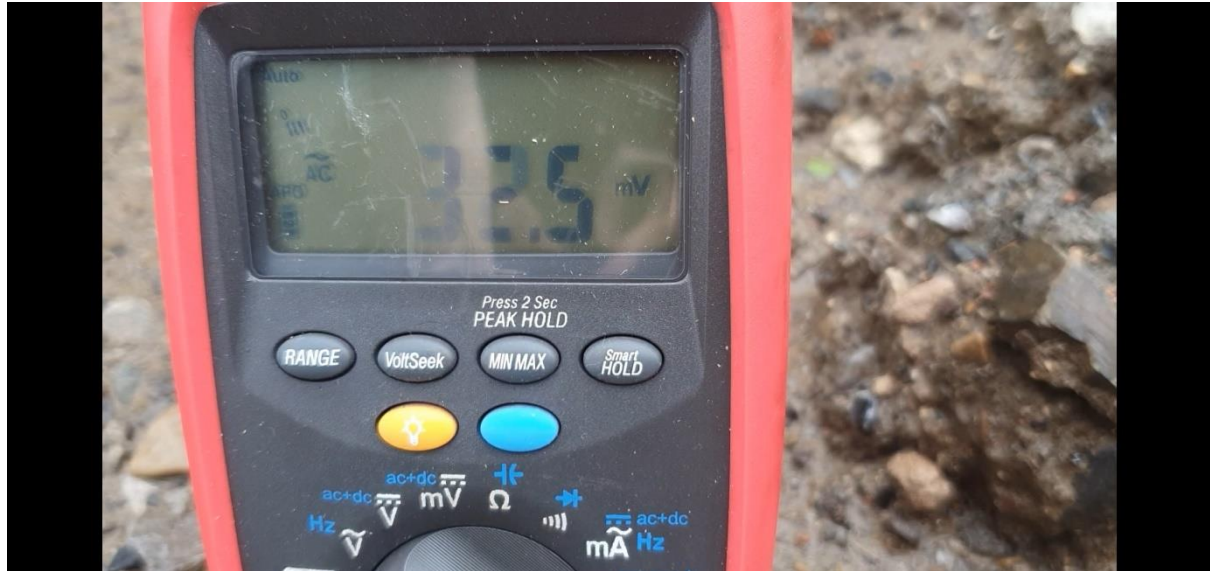


Figure 18

Vibration field test conclusion

Following a success field test of the vibration sensor prototype, I can take a lot of positives from the test which are summarised below;

- For PLC values we now have defined values in which we can stick a higher limit, before system triggers an alarm output. For clarification purposed the high value for an alarm to be triggered will be set at >15mV.
- Durability, even though the vibration sensor and modifications are a prototype after a clean and inspection the enclosure and instrument were still in good condition ready for more field test.
- This field test has clarified that the vibration sensor will be a critical piece of equipment in determining the event of a land slip.

Earth Work Failure's

The below table shows the types of earth failures and the resulting time frames, the below backs up the sections of optical sensor for the earth movement as this will react with rapid and slow movements once its out of alignment with the reflector strip it will trigger the warning, also the secondary sensor in the form of the vibration sensor will also be a very complimentary addition into detecting the below earth work failures.

Categorisation of earthwork failures by speed of failure		
Slow	Rapid	Instantaneous
		
Failure Mechanism		
<i>Rotational Burrowing</i>	<i>Earthflow, Washout & Translational</i>	<i>Toppling, Wedge, Planar & Ravelling</i>
Time to intervene / mitigate		
<i>Days to years</i>	<i>Minutes to hours</i>	<i>Seconds</i>

Figure 19

Sensor 3 Bench Test – Reflective Optical Sensor

Testing of the optic reflective sensor, within this bench test the optic sensor is working principle is a switch, if there is no reflective surface the switch opens circuit and when the reflective surface is there the switch stays in contact.

Optical Sensor Image 1 –

Optic sensor bench test set up, voltage source is at PSU with optic operational at 24VDC.



Figure 20

Optical Sensor Image 2 –

Functional test where sensor sees reflective surface and 0mV output recorded.

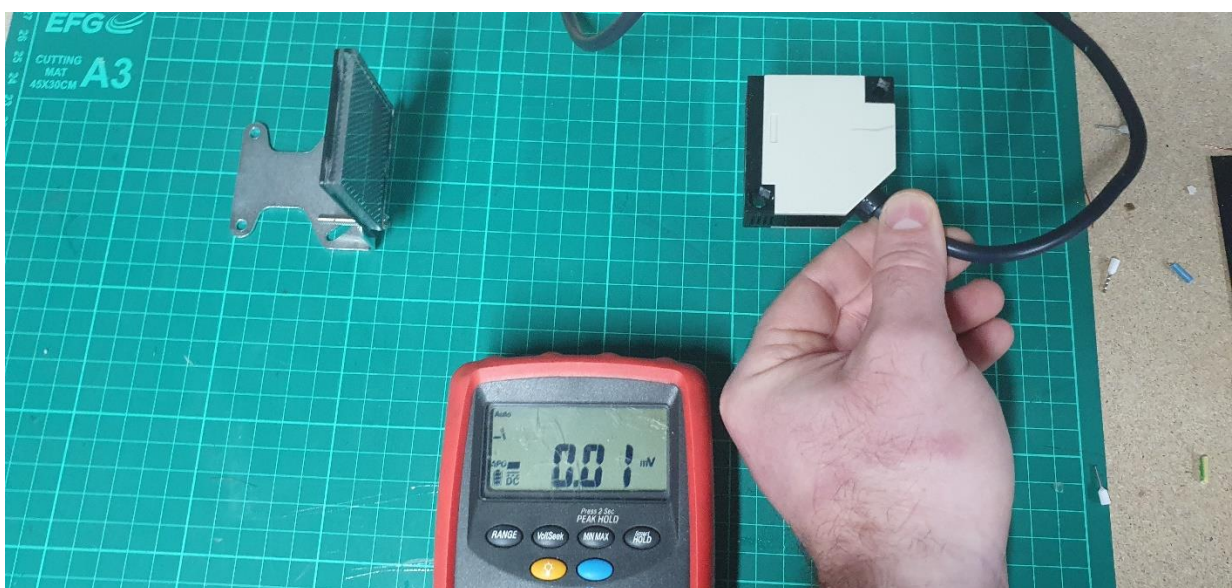


Figure 21

Optical Sensor Image 3 –

Functional Sensor test, sensor is repositioned out of the line of sight from reflective surface and 3.55mV output recorded.

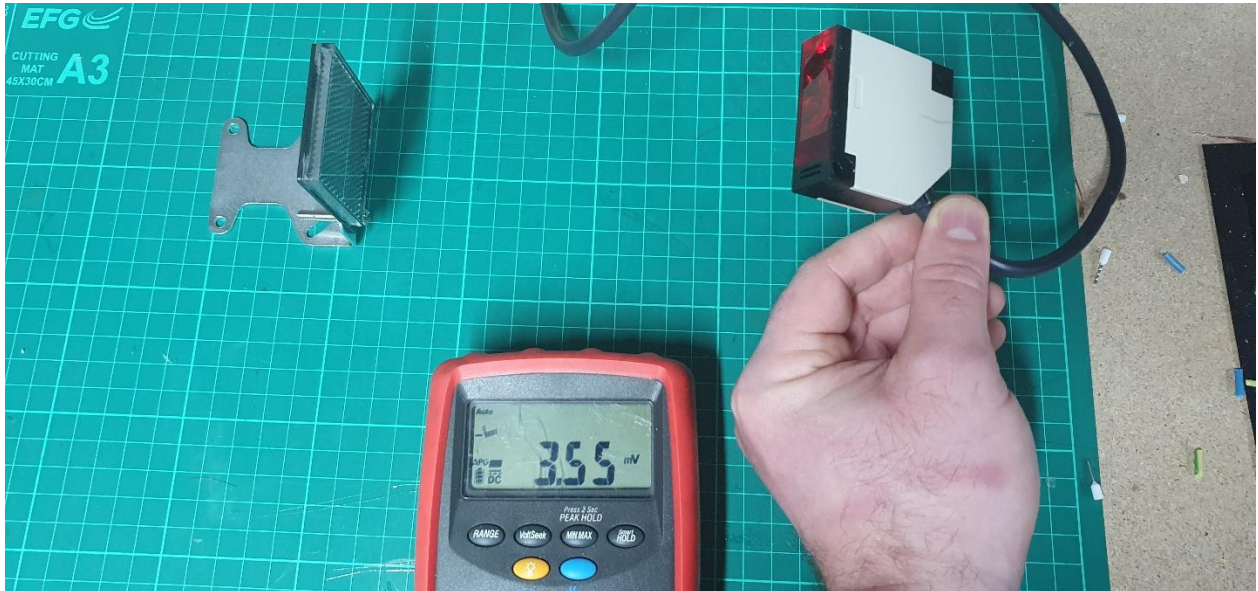


Figure 22

Test Results -

Instrument	Instrument Status	Instrument Out Put	Reason for output results
Optical Sensor	Stationary, in line with reflective sensor	0.0mV	Optic sensor is in line with reflective surface
Optical Sensor	Stationary, out of line with reflective sensor	3.55mV	Optic sensor is not inline with reflective surface

Test Result review -

From the bench test, which was very straight forward and predictable results.

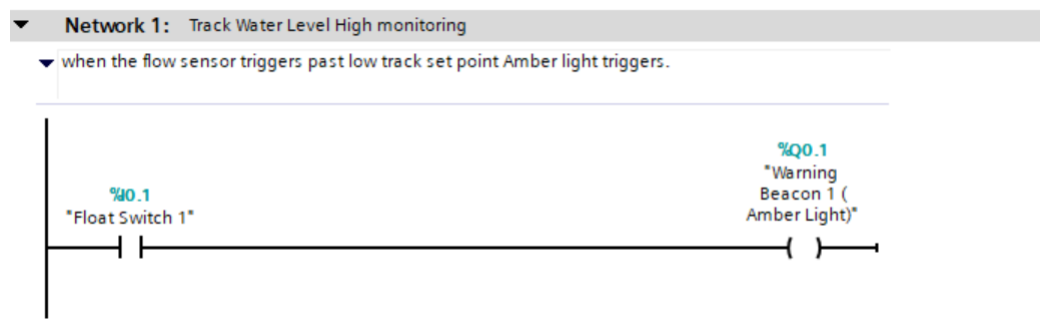
PLC software and programme

PLC software programme, within this section its one of the most important as with all the hardware and field sensors connected the working programme (the brains) are in the PLC block logic process which will pull together all systems and ensure we have the desirable out puts.

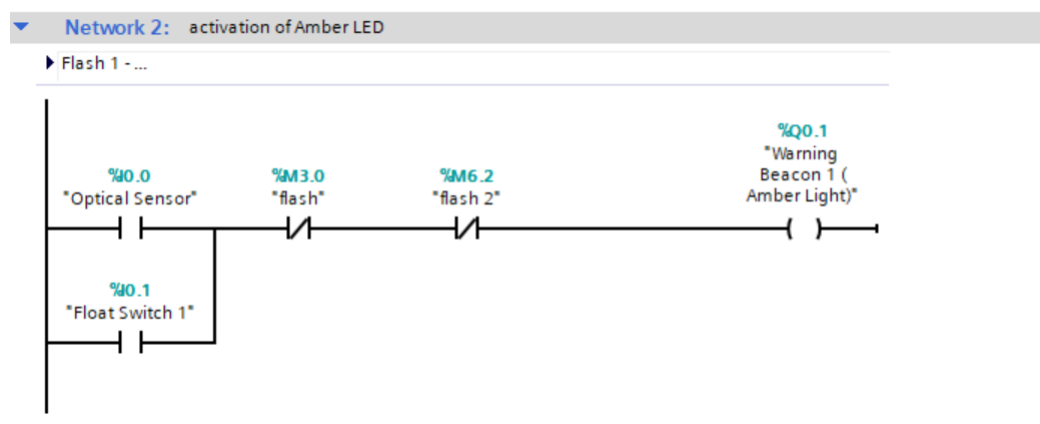
Below section is the of the 1st draft of issue of the siemens PLC block logic;

Draft 1 Siemens PLC Logic;

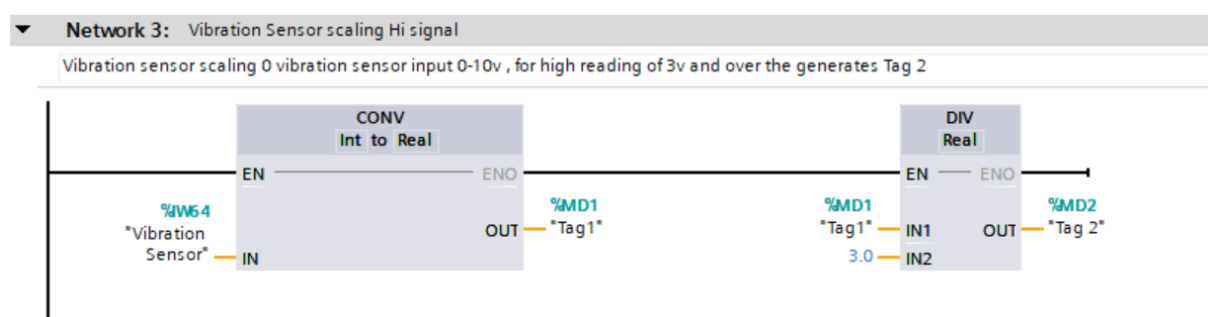
Network 1



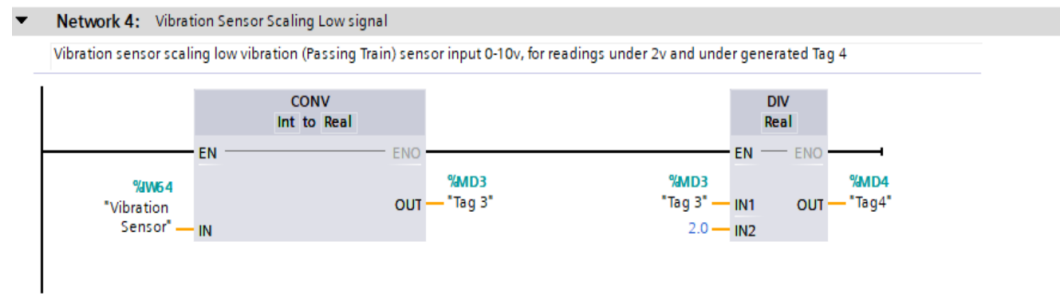
Network 2



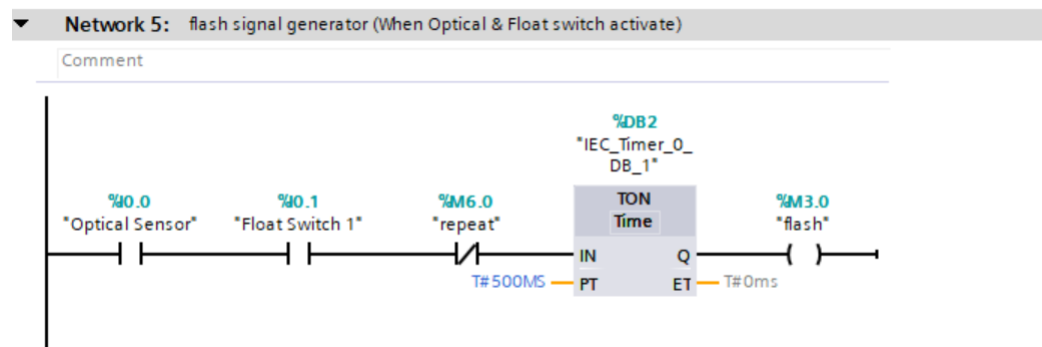
Network 3



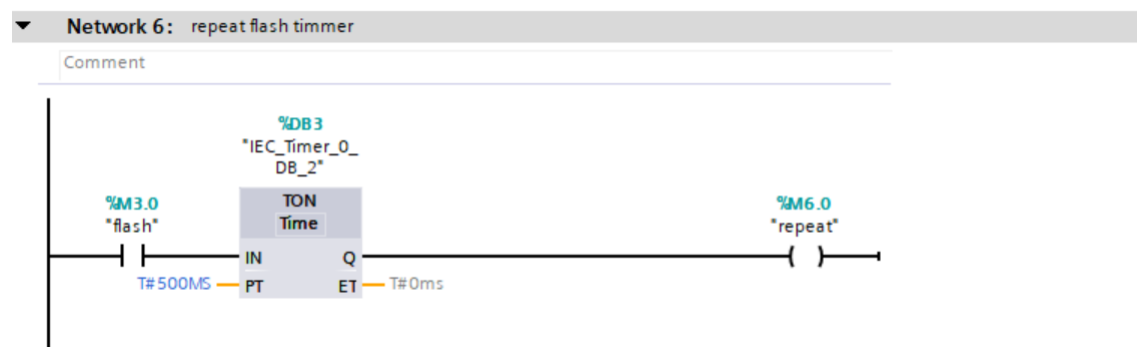
Network 4



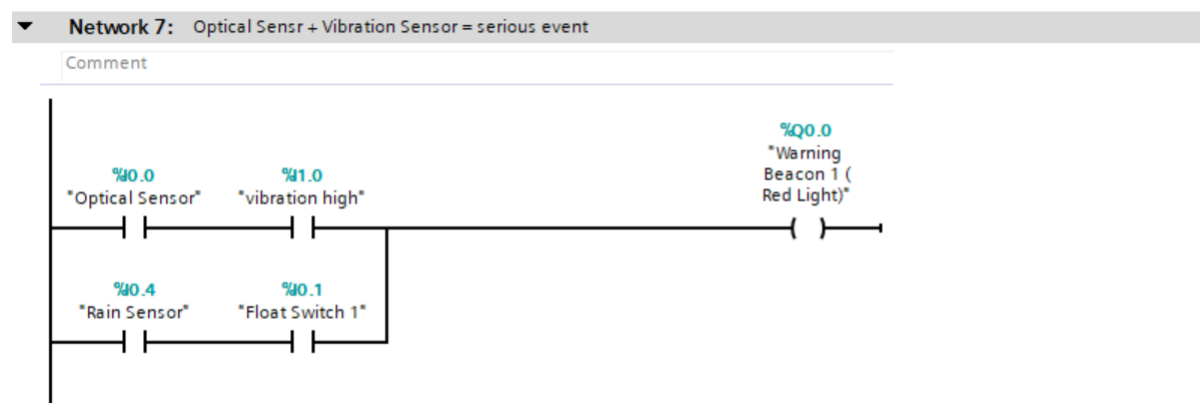
Network 5



Network 6



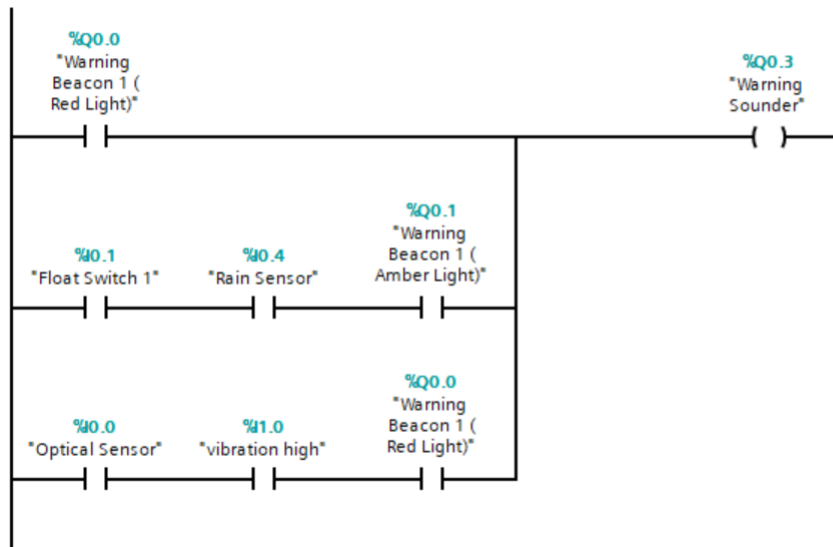
Network 7



Network 8

▼ **Network 8:** Red light activated in serious events, when red light is activated audible sounder is also activated.

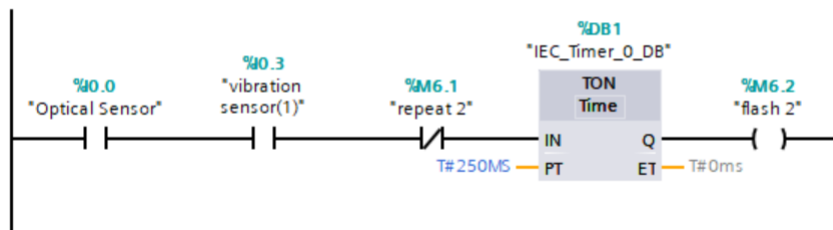
Comment



Network 9

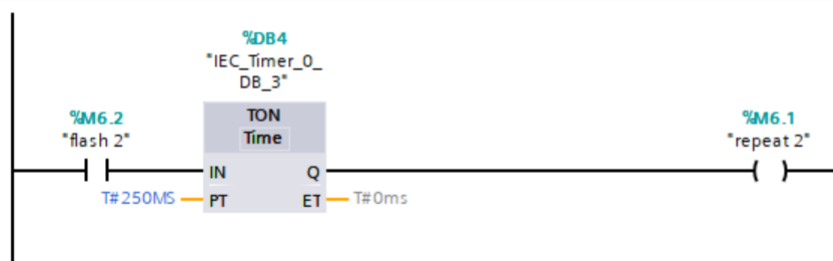
▼ **Network 9:** Generation of signal to make LED light flash

Comment



Network 10

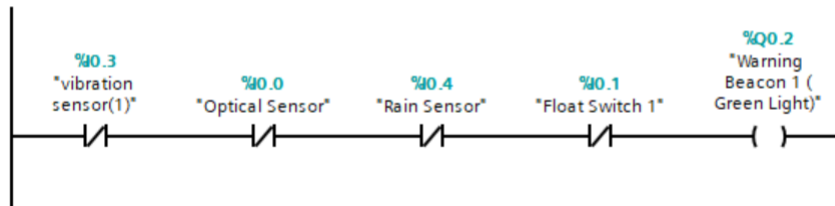
▼ **Network 10:** repeat signal used in network 9, for the LED Flash signal



Network 11

Network 11: Track Conditions Good

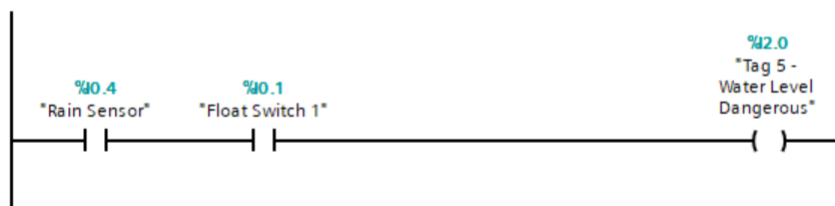
- Green Light is a constant when the track conditions are good, no breaks in signals or high valve inputs



Network 12

Network 12: Creation of Tag 5

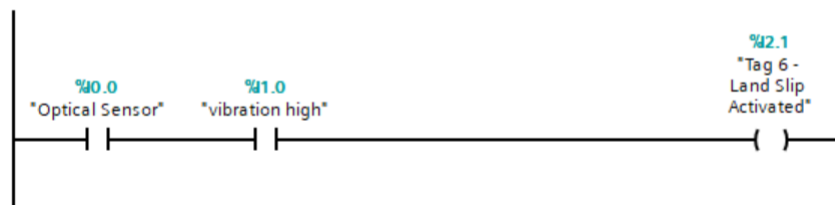
Tag 5 Water Level high for HMI use



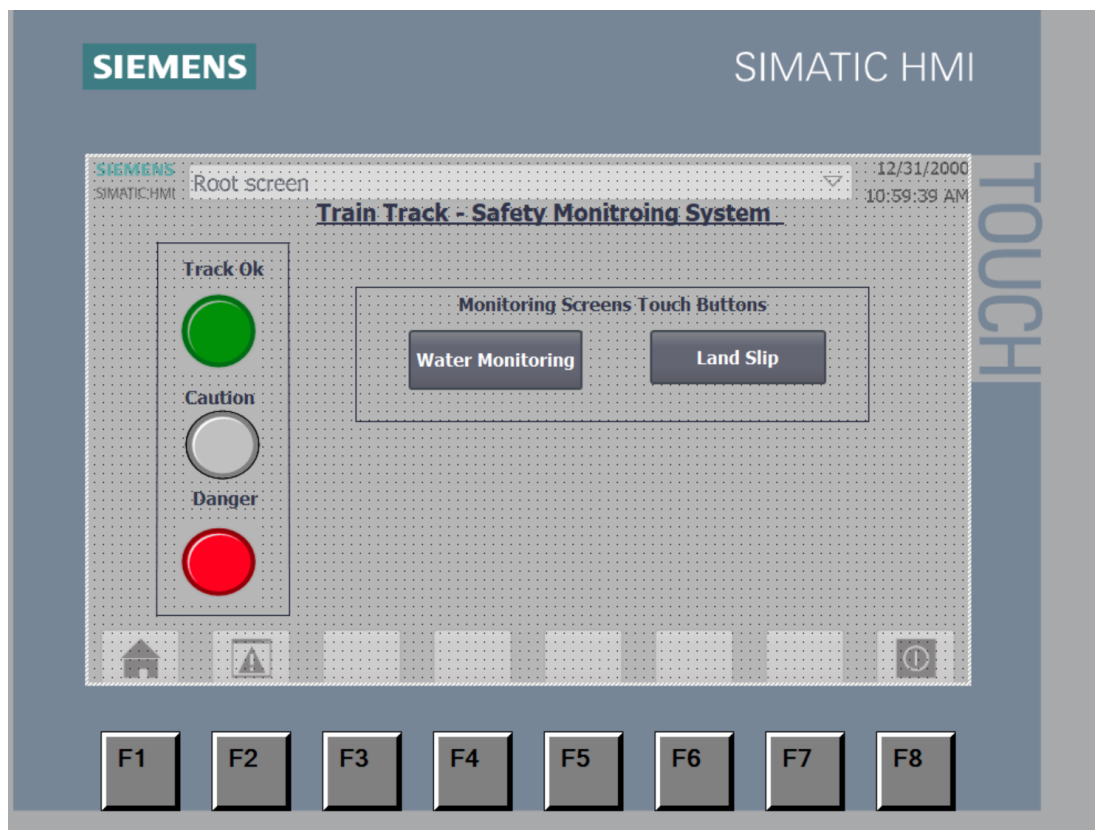
Network 13

Network 13: Creation of Tag 6

Tag 6 landslip confirmed for HMI use



PLC HMI Screens



Home Screen Layout

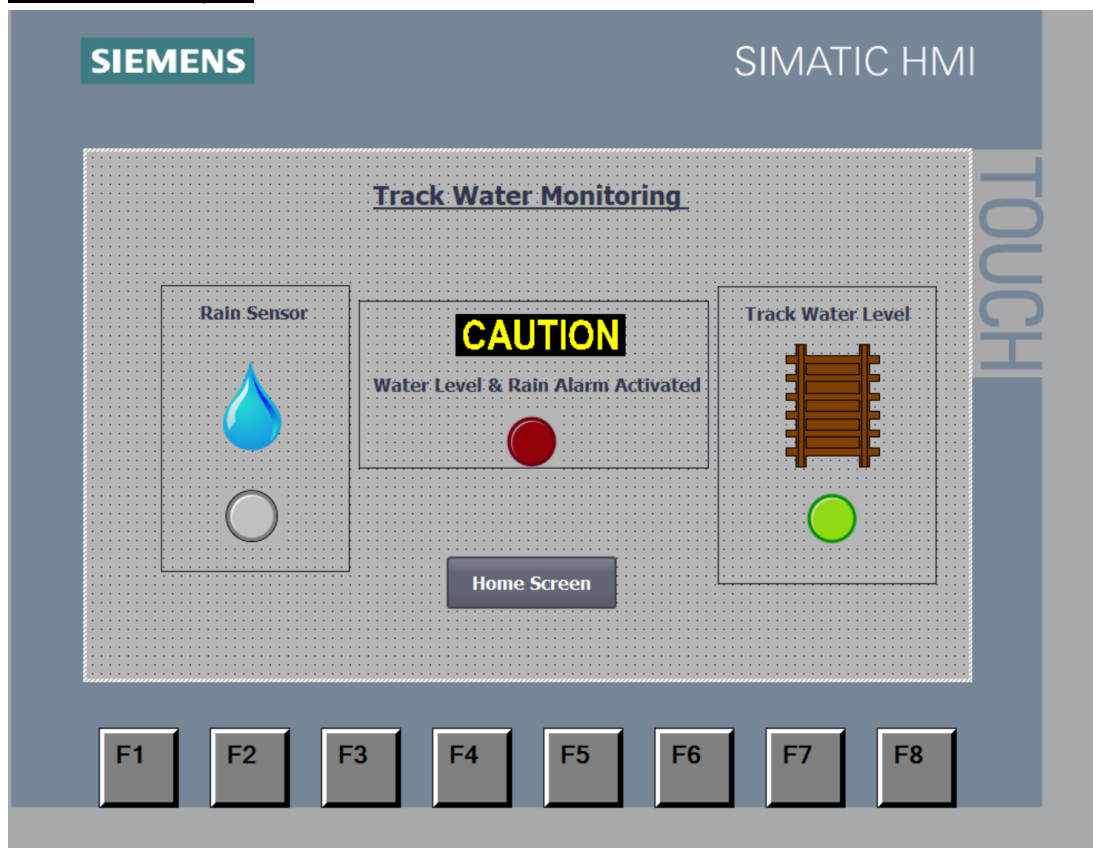


Figure 22

Water Monitoring Screen

Lanslip Monitoring Screen

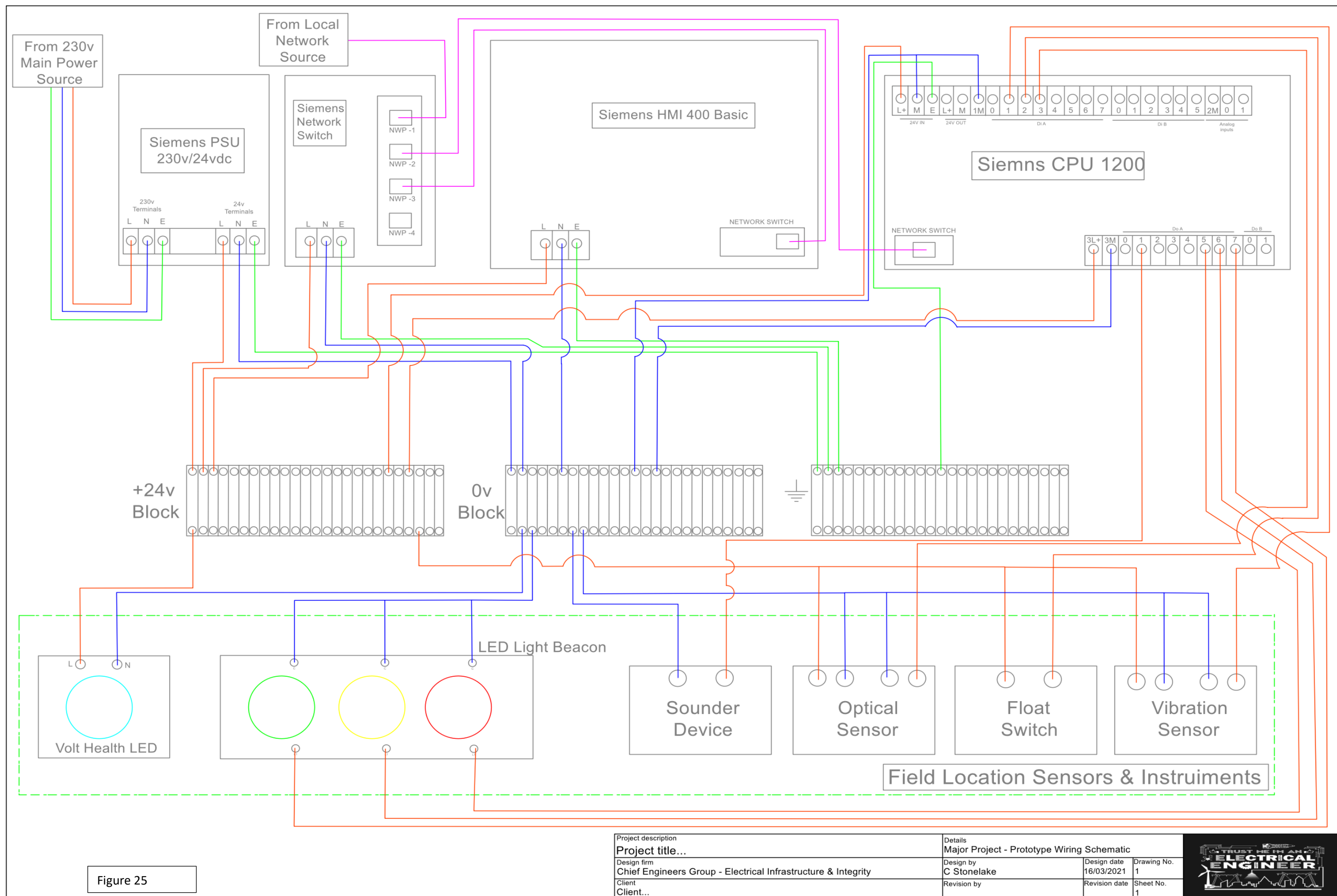


Figure 24

Prototype Build Wiring Schematic

The next drawing (Figure 25) shows the detailed wiring diagram for the build of the prototype landslip monitoring unit.

This was a helpful tool not only as a reference point during the construction but also to limit wiring mistakes.



Bench Testing Complete Build & Working PLC Software

Photos and videos of each section and what happen as a result

Need to do a traffic light sheet and show the different states with sounder etc



Figure 26



Figure 27

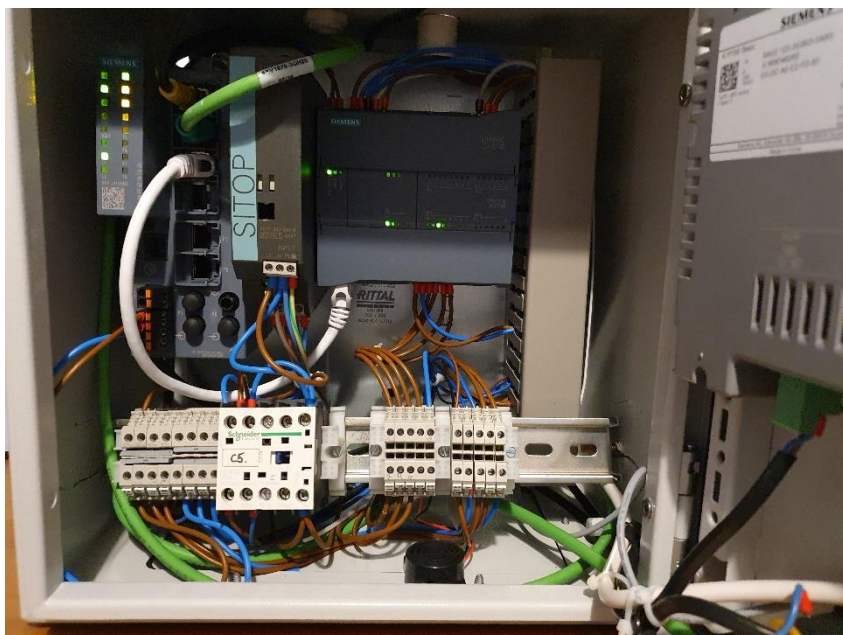
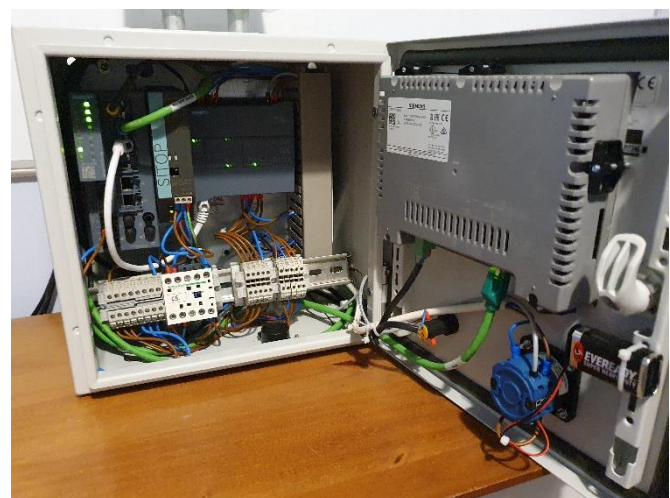


Figure 28



Testing – Float Sensor



Figure 29



Figure 30

Testing – Optical Sensor



Figure 31



Figure 32

Testing Rain Sensor



Figure 33



Figure 34

Testing Vibration Sensor



Figure 35

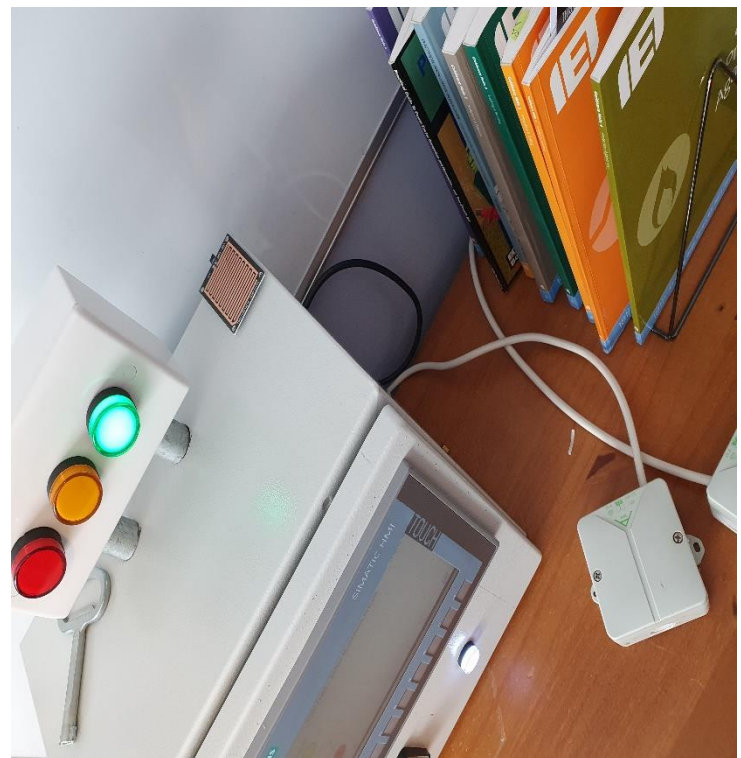


Figure 36

Train Track Landslip & Obstruction Monitoring Rig

Enclosure

Due to the location of installations in open environments robust structure is required.

Steel enclosure IP 66 rated

Power Supply Change Over Switch

option to change power from mains to 24dc battery system

Optical Sensor

Monitoring embankment movement at areas deemed to be high risk

Reflector

this will be position on the embankment and the optical sensor is focused on its position if the reflector moves out of focus this will signify embankment movement

Vibration Sensor

Monitoring vibration/impact from the result of a land slip.

Beacon Light (Red, Amber, Red)

This is representing the beacon light system that would be deployed 200Mtrs from the area of track being monitored.

Green = Conditions Good
Amber = Caution / Reduce Speed
Red = Danger Immediate Stop

Rain Sensor

Monitoring rain fall

HMI Display, this gives service engineers or end users a more friendly user interface to see how the system conditions are

24v Power health

LED indicates 24v Health is good.

Float Sensor

Monitoring track water level



Figure 37



You Tube Video Links

Due to the limitations created by the current pandemic and limited ability to show case the working model, the below videos have been made to help display some of the final projects working functionalities.

Certain field test the videos are also a great way to obtain data and as a review tool in order to determine better testing methods.

1) Testing Vibration & Optical Sensor Combined

Video Link – [vibration and optical sensor activation - YouTube](#)

2) Testing Float Switch & Rain Sensor Combined

Video Link – [rain sensor and float switch operation - YouTube](#)

3) Field Testing Vibration Sensor Test 1

Video Link - <https://www.youtube.com/watch?v=7r6PWTAHedc>

4) Field Testing Vibration Sensor Test 2

Video Link - <https://www.youtube.com/watch?v=BMX54BI1BjA>

5) Testing Float Switch Field Test

Video Link -

Track LED Light Beacon (Warning Notifications)

Due to the number of different sensors that could be monitoring the track section, inputs into the monitoring system from the field sensors could be from mild (non-serious) conditions too hazardous (life threatening) conditions.

Below is listed the possible light beacon status which could be present and for train drivers to act accordingly.



Activated Light	Flashing/Solid	Sounder Active	Status
Green	Solid	No	No Warnings, track Okay
Amber	Solid	No	Proceed with caution
Amber	Flashing	Yes	Reduced speed and proceed with caution
Red	Solid	Yes	Stop immediately



Project Build Review

Project initial specification and changes to physical build, what changes? And why?:

From the initial project specification to the final prototype build a few material and parts specifications were changed, some of these changes are minor and small and others are significant.

The main driving force for changes within the project were simply due to financial cost, as this is a prototype build it would be unrealistic to outlay high financial cost to simply to the concept of an application.

The initial sensors and materials selected were based on what would be ideally used within a real track monitoring proto type build, so for the next stages of the track monitoring system which would involve live track monitoring the original instruments specified would need to be utilised and the measurement distances and tolerances will be required.

The prototype at the stage of this document being issued, was simply to establish the working theory's and principles around what's is to be monitors and how the different monitoring sensors can interact with a PLC system and compliment of type of devises to give a more robust and accurate monitoring system.

Continued Development future recommendations

What other equipment would be required for the real track monitoring:

In order for the track monitoring system to be developed for a real world application we must include the accessory's such as battery back up or sole battery power and wireless telecommunications.

The battery system should be able to function in two way, the first being that the system has access to 230v main power and the battery pack can be utilised as an emergency back in the event of mains power loss, for the benefit of this report we will assume the system has to be fully run off battery system for a period of no longer than 14 days.

The calculations for the battery system are shown on the following pages.

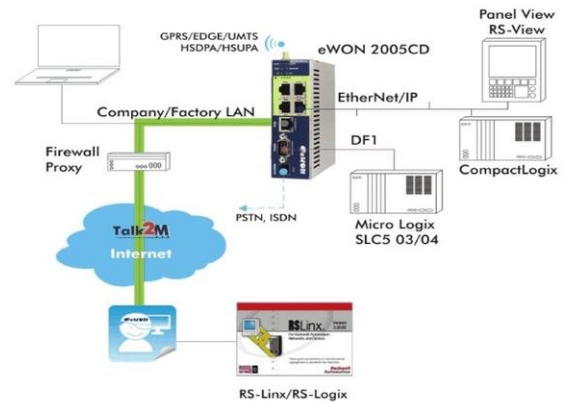
As with the battery system requirements the principle is that mains power or communications a=may not be available. To ensure that system can get out put signal notifications to remote monitoring stations wireless communication protocol is required which is provided in detail in the following pages.

Recommendation for remote off grid communications

The prototype develops into future field trials, the need for wireless communication protocol is required, this can be in the form for 4G/5G networks.

One industrial VPN router this section will concentrate on is the Ewon router units.

Set up and installation are simple and this can permanently replace the current situated Siemens network switch as part of the current proto-type build. For network provider reference this will be based on EE Network.



EE is now recognised as the UK's largest 4G/5G network provider, in 2016 EE 4G network already covered 97% of the population and about two thirds of the UK geographically. EE are aiming to cover just under 100% of the population and 95% of the UK's land mass by 2020 (some delays due to covid).



As the two corresponding tables show EE constantly out ranks all other service providers for coverage and signal strength, and this trend is only set to grow until EE can confidently state UK 100% geographical coverage.

Combined 2G and 3G coverage		Combined 3G and 4G coverage	
Premises	Geographic	Premises	Geographic
	95%	78%	95%
	98%	84%	97%
	95%	78%	89%
	97%	86%	96%

Region	Coverage (best to worst)
East Midlands	EE, O2, Vodafone, Three
East of England	EE, Three, O2, Vodafone
London	EE, Vodafone, O2, Three
North East	EE, O2, Three, Vodafone
North West	EE, Vodafone, O2, Three
Northern Ireland	EE, O2, Three, Vodafone
Scotland	EE, O2, Vodafone, Three
South East	EE, Vodafone, O2, Three
South West	EE, Vodafone, O2, Three
Wales	EE, Vodafone, O2, Three
West Midlands	EE, Vodafone, O2, Three
Yorkshire and the Humber	O2, EE, Vodafone, Three

Based on the findings, it would be hard to argue now to select EE as the chosen network provider for the remote, monitoring unit. However it cannot be ruled out that certain black spots which still exist can cause issues, in the event of this scenario either the use of 4G network booster generators will be deployed or the utilisation of satellite communications on more extreme circumstances.

Recommendation for remote off grid Battery Storage

Calculation of system power usage

Hardware / Instrument	Working Voltage	Current Usage	Total System mA	mA to Watt	Watt usage per 24hrs	Watt usage per 7 days	Watt to I(Amps)
S7 1200 PLC	24 Vdc	500mA	1,405mA /1.4A	1.4Ax24v = 33.6W	33.6Wx24 = 806.4Wh Per Day	806.4 x 7 Days = 5644.8Wh	5644.8Wh / 24Vdc = 235.2Ah
HMI	24 Vdc	230mA					
Network Switch	24 Vdc	500mA					
LED Bacon Lights	24 Vdc	60mA					
Sounder	24 Vdc	40mA					
Optical Sensor	24 Vdc	55mA					
Float Sensor	24 Vdc	N/A					
Vibration Sensor	24 Vdc	20mA					

Battery sizing from the above table figures (based on 24Vdc 230Ah deep cycle Battery's) = 235.2Ah / 230Ah x 2 = 2.045 Rounded up = 2x 230Ah Battery's Required

Note reasoning for (x 2) is that battery's generally don't want to be discharged greater than 50%, plus in the event of regeneration failure system can have almost 2weeks power supply before maintenance intervention.



Capacity (Ah)	Warranty (Years)	Terminal Layout	Terminal Type
230	2		
H: 240mm x W: 270mm x L: 513mm			
~~£219.99~~ £199.99 Including VAT & Standard Delivery Express Delivery Available			
1		Add to Basket	

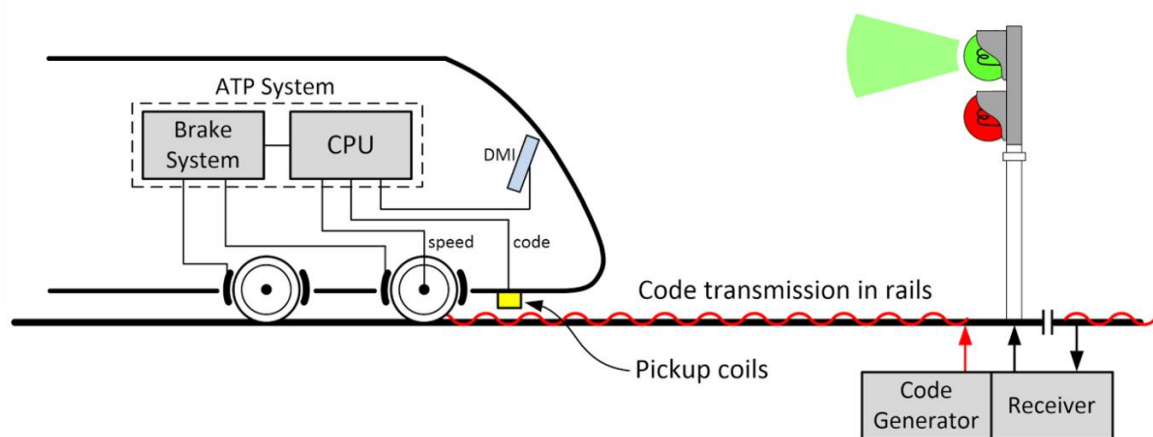
Height (mm)	240
Length (mm)	513
Width (mm)	270
100 Hour	230
20 Hour	215
Brand	Xplorer™
Capacity (Ah)	230
Construction	Lead Acid
Maintenance Free	Yes
Product Type	Battery
Suitable for use with motor mover?	Yes
Terminal Layout	Terminals at One End (Layout 2)
Terminal Type	Standard Round (Type 1)
Voltage	12V
Warranty (Years)	2
Weight (kg)	50

Further Development of prototype and inclusion of other technologies

Within the section of the project review and further recommendations, a look into the benefit of other technologies which may increase the effectiveness of the monitoring and improve the system all round.

Signal/Code Generators

For the first recommendation technology and for me the one with the more promise of system improvements and applications is the use of sign/code generators, the unique feature around the signal generator technology is the ability to transmit its data along the pre-existing tracks using the steel track as it conductor.



Where the signal generator would be a addition to the current proto-type build, it would reduce the need for hard wires cabling from the main control box to the remote down line light beacon. But the real advantages are that a train fitted with the appropriate receiver box can then at the driver desk have alert notification of any hazards down the line at a much greater distance than any of the local warning light systems.

IMPORTANT – the CPU receiver units on the train depending on distance to the incident location, and in the event of a driver error the automated systems can take control and bring the train to a stop, this is a huge advantage in that we can eliminate human intervention by 100% so the system safety factor greatly increases. This type of auto mated system can also prove beneficial when in the possible even a solo driver has a potential serious health incident while driving the train can come to a controlled stop.

Renewable Technologies For Power Source (Solar)

To compliment the battery recommendation for the use in isolated locations, the need to re-charge the battery comes to light as a big factor in having remote systems operate for longer durations thus keeping maintenance visits to a minimum.

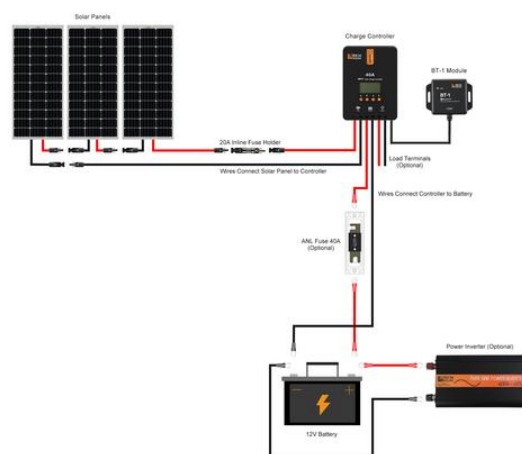
Based on the battery calculation sizing section the system will deplete the batteries of 34Ah per day.

The below table shows the required solar panels for maintaining the system charged to optimal levels.

Calculation Type		Value
Estimated Watt demand		
3	Total Watts Per Hour (DC) DC Amps x System Voltage	36.6 Watts
Hours per day		
6	Hours Equip is expected to run (24hr) as per application	24 Hrs d ⁻¹
Watt-Hours per day		
9	Total daily usage Watts x Hours	878.40 Watt-Hrs d ⁻¹
Amp-hour calculation		
10	Total watts Daily requirements	878.40 Watt-Hrs d ⁻¹
11	Corrected for battery losses Assumes static average loss	895.968 Watt-Hrs d ⁻¹
12	System voltage DC voltage only	24 Volts
13	Amp-hours per day Watts divided by Volts	37.332 Amp-Hrs d ⁻¹
Battery bank calculation		
14	# of days backup power required Average 24 hour periods	7 days
15	Amp-hour storage Raw capacity you need	261.3240 Amp-Hrs
16	Depth of discharge Assumes 50%	0.5 fraction (enter decimal)
17	Required amp backup Prevents excessive discharge	522.6480 Amp-Hrs
18	Battery Amp Rating (20 hr) Battery Capacity in Amps	230 fraction
19	Actual # batteries wired in parallel Raw number	2.27
20	Batteries wired in series Relates to system voltage	2.00
21	Rounded number of Batteries Always rounded up	1
Solar Panel Array calculation		
22	Sun hours per day (Direct only) Be realistic!	5 Hrs
23	Worst-weather multiplier* 1.55 default	1.55 fraction
24	Total sun hours per day Assumes average sun	3.226 Amp-Hrs
25	Select panel size (Watt rating) Watt hour rating	190 Watts
26	Nominal Panel Voltage Approximate Solar output	16 Volts
27	Amps required from solar panels Total daily consumption	37 Amps
28	Peak amperage of solar panel Watts divided by Volts	11.875 Amps
29	Number of solar panels in parallel Raw Number	0.975
30	Number of panels in series (12 V) It is 1 for 12v, 2 for 24v, etc	2
31	Rounded number of solar panels Always rounded up	2

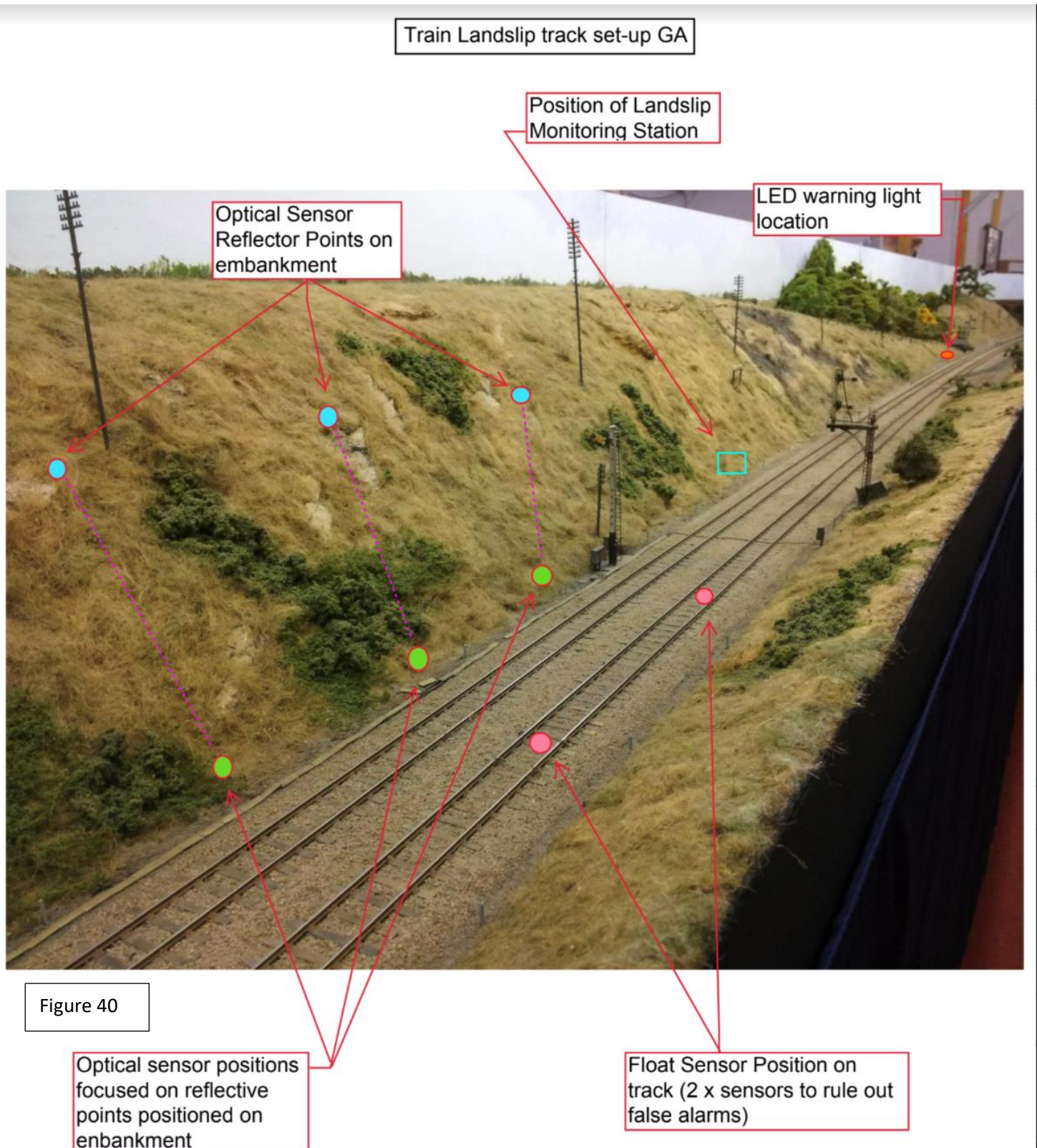
From the above the system will require 2 x 190watt 24v solar panels and 1 charge controller.

To incorporate this into the monitoring system is fairly straight forward as it would just replace the inputs from the PSU 230/24v unit currently installed. The real test would be to get the system in a real world scenario and monitor battery life expectancy etc in winter conditions to get the more extreme conditions.



Train Track Monitoring Equipment and Sensors location set up GA

The below GA shows the initial concept of positions for field sensor devices, however this is the initial recommendation and that the continued development into field testing will determine by trial and error the best positions to ensure optimal performance.



Chapter 7

Project Reflection

When looking at what to do for my major project, I wanted to explore an area of engineering that I am not exposed to in my current day to day working, an industry such as train networks which has a wide variety and diverse range of electrical engineering applications. It was clear very early on into my research of the train transport system in the UK what specific area of interest I was going to base my assignment on this was of course the monitoring of landslips and foreign matter on train tracks (flooding etc).

One of the main reasons this specific area grabbed my attention is that although there is a vast amount of monitoring and development in this field, it is also still a major weak link for operators such as network rail to manage this mainly due to the historical age of the network.

Throughout the project research, development and prototype build I have found the specific work elements fascinating, but also realised at an early stage due to the complexity of the type of monitoring required I could only ever get to a stage to prove the concept works, as the further developments require much more accurate/sophisticated monitoring sensors along with more track side testing, this was reflected in the change of scope in the bill of materials when sensors were changed for more cost effective instruments.

Due to the choice of using a Siemens PLC for the main CPU, the choice on low end sensors to give a measurable 24v or analogue 4-20ma was very limited, without increasing the capital spend it was difficult to find sensors to fit the bill so some minor compromises were made, but the sensors proved the concept.

Time keeping, I found the utilisation of the project plan which was broken down into bite sized steps to be extremely useful in tracking progress along with implementation of next goals, I also found the weekly project mentor meetings hugely motivational as it was always keen to show developments for me the mentor meetings were crucial in the delivery, and I would liken them to weekly progress meetings within day to day working environments it's always a good challenge to show weekly progress moving forward.

The build, I was overall very happy with the build and the results that came from it, I just wish I had a bigger budget to build what I had originally intended but this is what the further development recommendations are for.

Overall I'm very pleased with how the project ended up, I could also look for improvements but with the resource and time I had I am proud of what I have submitted. One of the biggest pros for me is the development of my ability and understanding of PLC software righting which has given great insight into my day to day working environment. However that was the automated mail notifications network feature I was unable to get working, but this is something I am still working on as a personal goal I would like to get this feature in place as an ongoing personal development into PLC's.

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