SLOPE INDICATOR

GeoFlex
In-Place Inclinometer

DGSI
Durham Geo Slope Indicator

NOVA METRIX

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CHAPTER 1

GeoFlex Introduction

Introduction

The GeoFlex system consists of a vertically installed casing and a string of GeoFlex in-place inclinometer MEMS sensors. The casing provides access for the subsurface measurements and moves with the surrounding ground. The casing is installed in a borehole that passes through a suspected zone of movement into stable ground below. The GeoFlex sensors are installed in the casing and measure inclination from vertical. As ground movement occurs, the casing moves with it, changing the inclination of the sensors inside the casing.

The inclination measurements are then processed to provide displacement readings in millimeters or inches. In most applications, the sensors are connected to a data acquisition system and data processing is completed by a computer program.

System Components

- Casing
  - 2.75 in (70mm) ABS Inclinometer Casing, or
  - 1.5 in (38mm) Schedule 40 PVC Pipe
- GeoFlex Suspension Kit (specific to type of casing)
- GeoFlex Segments (10 ft, 8 ft, 6 ft, 4 ft or 2 ft)
- GeoFlex Jumper Cable
- GeoFlex Bottom Plug

Advantages

Real Time Monitoring:
The GeoFlex system is ideal for continuous, unattended monitoring and can deliver readings in near-real time.

Convenient Shipping and Transport:
GeoFlex systems have joints capable of bending to 90°, allowing for a compact shipping option. Five segments, each 10 feet long, can be shipped in a carton measuring approximately 26 x 26 x 26 in (64 x 64 x 64 cm) and which weighs less than 50 pounds (22 kilograms). This allows for the system to be shipped via common overnight carrier as well as fit in most standard vehicles.

Figure 1: GeoFlex segment folded for transport

Flexible Configurations:
GeoFlex systems have standard segment lengths of 10 feet. but can be custom ordered in lengths of 2, 4, 6 or 8 feet in order to instrument the precise length required.
The GeoFlex system can also be installed with sensorless nodes at the top of the system, allowing the designer to economize by only monitoring the zone of interest and bypassing the upper layers.

Durable Components:
Nodes, cables, connectors and gage rods are exceptionally durable, making it practical to remove the systems at the end of the project and redeploy them on other projects.

Data Reduction:
The GeoFlex system outputs the displacement as engineering units, requiring less computing power and a lighter load on your data acquisition system. The nodes are preloaded with the calibration information, allowing the segments to be installed in any order.

CHAPTER 2

GeoFlex Installation

Preparation

Verify that all system components have been received and are ready for installation.

Suspension Kit: One suspension kit is used for each string.

Figure 2: GeoFlex suspension kit for PVC pipe

GeoFlex segments or chains

Standard Segments: Each standard GeoFlex segment is 10 ft in length and has a male connector at the upper end and a female connector at the lower end. The segment consists of 5 nodes and each node has a 2 ft gage length. The upper end can also be identified by its lack of joint on the node. The lower end has a universal joint, as can be seen in the images below.

Custom Segments: The GeoFlex segments can also be manufactured in shorter lengths of 2, 4, 6 or 8 ft in length (with 1, 2, 3 or 4 nodes, respectively). Each of these segments also has a male connector at the upper end and a female connector at the lower end. The upper end can also be identified by its lack of joint on the node. The lower end has a universal joint, as can be seen in the images below.

Figure 3: GeoFlex top node (male connector and no joint)

Figure 4: GeoFlex bottom node (female connector and universal joint)

GeoFlex Jumper Cable: One jumper cable is used for each string. The jumper cable has a female connector on one end and exposed inner conductor wires on the other for connection to the data logger.

GeoFlex Bottom Plug: One bottom plug is used for each standard configuration string. The bottom plug has a male connector on one end and is used to protect the last node from water ingress via the connector.

Installation

Attach the Bottom Plug to the female connector on the first segment to be placed in the casing.

Insert the bottom end of the first segment into the casing.

> If inclinometer casing is being used, verify that the centralizer standoffs are placed in the grooves orthogonal to the direction of movement. The X-axis direction is marked on the sensor and should point towards the direction of anticipated movement.
>
> If PVC pipe is being used, roughly align the X-axis direction marking on the sensor with the direction of anticipated movement. Adjustments may be made once the entire string has been installed.

Continue to lower the segment into the casing until four nodes have been inserted. Fold the fifth node over the top edge of the casing. For deeper installations, a clamp (e.g. vise grips) may be attached to the upper node to protect it from accidentally dropping into the casing.

While lowering the nodes, the signal cable should be placed in the notch of the centralizer to avoid pinching it between the segment and the casing.

Connect the signal cables of the installed segment and the next segment to be installed. Note - it does not matter in which order the segments are installed, as the data logger will query the sensors and number them at startup.

Remove the pin from the universal joint of the installed segment and insert the top node's gage rod, pinning it in place. Verify that the alignment of the sensors is the same for both segments.

Lower the nodes into the casing, repeating the above steps until all but one segment has been installed in the casing.

Attach the suspension kit to the top of the last segment.

Connect the last segment to the installed segments, as per above.

Lower the last segment into the casing, aligning the suspension kit so that it is firmly seated on the top of the casing. The male connector should extend out of the casing.

Attach the jumper cable to the male connector and to the data logger.

CHAPTER 3

Data Reduction

Data Format

1. The Campbell Data Logger outputs a *.dat file. This file contains the readings in a comma-separated format, which can be imported into a spreadsheet program, such as Microsoft Excel™.

2. Once imported, the data will appear as below:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	TIMESTAMP	RECORD	Batt_volt	PTemp	X_(1)	Y_(1)	Volt(1)	Temp(1)	X_(2)	Y_(2)	Volt(2)	Temp(2)	X_(3)	Y_(3)	Volt(3)	Temp(3)	X_(4)	Y_(4)	Volt(4)	Temp(4)	X_(5)	Y_(5)	Volt(5)	Temp(5)
2	6/25/2018 18:30	6132	13.12	24.45	-25.41509	15.96104	12.62276	23.63629	-53.11737	35.18684	12.76975	25.26657	-29.16236	-10.1446	12.62276	24.21918	-31.57721	36.82491	12.62276	22.28995	-24.71881	2.042661	12.76975	20.21606
3	6/25/2018 18:35	6133	13.13	24.26	-25.38844	15.95506	12.76975	22.76672	-53.17498	35.06727	12.76975	25.14713	-29.10887	-10.15871	12.62276	24.21227	-31.6962	36.63987	12.76975	22.21091	-24.85069	1.8814	12.76975	20.01596
4	6/25/2018 18:40	6134	13.14	24.13	-25.15001	15.99873	12.76975	22.70087	-53.11404	35.26652	12.76975	25.3595	-29.18621	-9.978203	12.76975	24.1015	-31.81725	36.74278	12.76975	22.26161	-24.9009	2.025181	12.76975	20.45621
5	6/25/2018 18:45	6135	13.14	24.01	-25.43585	15.94726	12.76975	22.60864	-53.02817	35.23344	12.76975	25.3595	-29.17641	-10.10246	12.76975	24.21918	-31.73335	36.71712	12.76975	22.28995	-24.78923	2.024333	12.76975	20.18939
6	6/25/2018 18:50	6136	13.14	23.87	-25.47583	16.06767	12.76975	22.19786	-53.13278	35.09396	12.76975	25.29312	-29.1939	-10.13824	12.76975	24.15581	-31.83185	36.71041	12.76975	22.15817	-24.8	2.027444	12.76975	20.29611
7	6/25/2018 18:55	6137	13.14	23.72	-25.46988	15.99638	12.76975	22.29245	-53.14171	35.26204	12.76975	25.18692	-28.9816	-10.11191	12.76975	24.07512	-31.71008	36.77461	12.76975	22.25061	-24.75964	2.109595	12.76975	20.08264
8	6/25/2018 19:00	6138	13.15	23.61	-25.44954	15.96796	12.76975	22.12119	-53.10346	35.09436	12.76975	25.1604	-29.17996	-10.11326	12.76975	24.07512	-31.61276	36.70624	12.76975	22.3822	-24.87637	1.977941	12.76975	20.17606
9	6/25/2018 20:00	6139	13.17	22.9	-25.21228	15.76681	12.76975	21.3175	-53.08345	35.12051	12.91674	24.88162	-29.05379	-10.14719	12.76975	24.14072	-31.69661	36.7724	12.76975	22.17136	-24.92956	2.022574	12.76975	19.90921
10	6/25/2018 21:00	6140	13.17	22.73	-25.17925	15.72347	12.76975	20.97498	-53.01663	35.24311	12.91674	24.80197	-29.22868	-10.14828	12.76975	24.17996	-31.53552	36.80014	12.76975	22.3295	-24.87981	1.915247	12.76975	19.89587
11	6/25/2018 22:00	6141	13.17	22.7	-25.57894	15.50137	12.76975	20.76416	-53.07822	35.22713	12.91674	24.56302	-29.08897	-10.11514	12.76975	24.00995	-31.66167	36.7502	12.76975	22.18454	-24.89609	2.063257	12.76975	20.03197
12	6/25/2018 23:00	6142	13.17	22.87	-25.61125	15.66672	12.76975	20.8432	-53.04002	35.13475	12.91674	24.45685	-29.13253	-10.15229	12.76975	24.15581	-31.6308	36.64246	12.76975	22.13184	-24.85298	2.016898	12.76975	20.00259
13	6/26/2018 0:00	6143	13.17	22.75	-25.66415	15.59787	12.76975	20.61923	-53.20204	34.98492	12.91674	24.271	-29.27766	-10.21539	12.76975	24.04916	-31.4716	36.82603	12.76975	22.30313	-24.86719	2.119423	12.76975	20.40283
14	6/26/2018 1:00	6144	13.17	22.67	-25.7208	15.58302	12.76975	20.43478	-53.02592	35.1684	12.91674	24.3241	-29.17831	-10.09005	12.76975	24.08841	-31.57091	36.81695	12.76975	22.52716	-24.908	1.960134	12.76975	20.06931
15	6/26/2018 2:00	6145	13.17	22.73	-25.73293	15.42154	12.76975	20.23718	-52.96874	35.20765	12.91674	24.271	-29.33514	-10.00175	12.76975	24.31073	-31.53248	36.82796	12.76975	22.3822	-24.82204	1.827177	12.76975	19.78915
16	6/26/2018 3:00	6146	13.17	22.53	-25.9866	15.15701	12.76975	19.88144	-53.15527	35.09901	12.91674	23.84622	-29.41597	-10.04173	12.76975	24.57227	-31.62171	36.83503	12.76975	22.40857	-24.91397	1.968321	12.76975	20.17606
17	6/26/2018 4:00	6147	13.18	22.22	-25.81741	15.42362	12.76975	19.93414	-53.05482	35.11893	12.91674	24.00549	-29.18802	-10.18109	12.76975	23.9707	-31.55902	36.82271	12.76975	22.21091	-24.95663	2.068547	12.76975	20.17616
18	6/26/2018 5:00	6148	13.18	22.14	-25.89179	15.38386	12.76975	19.74969	-53.07444	35.01955	12.91674	23.79312	-29.19854	-10.09816	12.76975	24.21227	-31.5202	36.861	12.76975	22.3295	-24.92749	2.172043	12.76975	20.32278
19	6/26/2018 6:00	6149	13.19	22.06	-26.01517	15.30545	12.76975	19.65747	-53.19392	35.0756	12.91674	23.63382	-29.17479	-10.14585	12.76975	24.27148	-31.4164	36.94572	12.76975	22.55353	-24.8672	2.005538	12.76975	20.20271
20	6/26/2018 7:00	6150	13.18	22.19	-26.07291	15.43572	12.76975	20.18448	-53.12697	35.05213	12.91674	23.71347	-29.17314	-10.08538	12.76975	24.28458	-31.53749	36.85274	12.76975	22.34268	-24.96626	2.145589	12.76975	20.20271
21	6/26/2018 7:05	6151	13.18	22.19	-25.90891	15.52159	12.76975	20.09225	-53.14169	35.03426	12.91674	23.62054	-29.20765	-10.08603	12.76975	24.31073	-31.5278	36.85155	12.76975	22.3822	-24.93555	2.231705	12.76975	20.3895
22	6/26/2018 7:10	6152	13.18	22.19	-25.91525	15.5396	12.76975	20.25034	-52.9977	35.05701	12.91674	23.96567	-29.27378	-9.978498	12.76975	24.31073	-31.57372	36.80055	12.76975	22.17136	-24.83189	2.273689	12.76975	20.3895
23	6/26/2018 7:15	6153	13.18	22.19	-25.81917	15.47961	12.76975	20.31622	-53.2468	35.0385	12.91674	23.54089	-29.19379	-10.07007	12.76975	24.21227	-31.57977	36.8092	12.76975	22.3822	-24.99971	2.196203	12.76975	20.25607
24	6/26/2018 7:20	6154	13.18	22.19	-26.1129	15.25066	12.76975	19.82877	-53.23131	35.04213	12.91674	23.84622	-29.2651	-10.04787	12.76975	24.07512	-31.39229	36.82227	12.76975	22.36902	-24.9314	2.219913	12.76975	20.24274

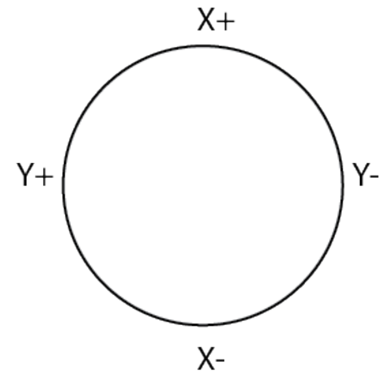
3. The columns consist of the following:

a. TIMESTAMP - date and time the reading was taken.
b. RECORD - consecutive reading that was taken since last data logger reboot.
c. Batt_volt - voltage of data logger battery at time of reading.
d. PTemp - temperature measured at the data logger.
e. X_(n) - X-axis tilt reading, in mm/m
f. Y_(n) - Y-axis tilt reading, in mm/m
g. Volt(n) - voltage input to the sensor, in V
h. Temp(n) - temperature measured by sensor node, in °C
where n = sensor node location (1 is the top sensor, 2 is second from the top, etc.)

Calculations

Calculating Tilt in mm/m

It is not necessary to calculate tilt, as the GeoFlex system outputs the tilt in mm/m natively. The sign of the result indicates the direction of the tilt. The X+ direction of the sensor node is marked on every node.



Calculating Tilt in Degrees

$Tilt(degrees) = \arcsin(Tilt_{mm/m}/1000)$

Calculating Deviation

To calculate deviation over the gauge length of the sensor node, use one of the formulas below:

$Deviation_{mm} = Tilt_{mm/m} \text{ x } 0.6m$
or
$Deviation_{in} = Tilt_{mm/m} \text{ x } (24 \text{ in} / 1000 \text{ in})$

Calculating Displacement

Displacement (movement) is the change in deviation:

$Displacement = Deviation_{current} - Deviation_{initial}$

CHAPTER 4

Connection to Data Loggers

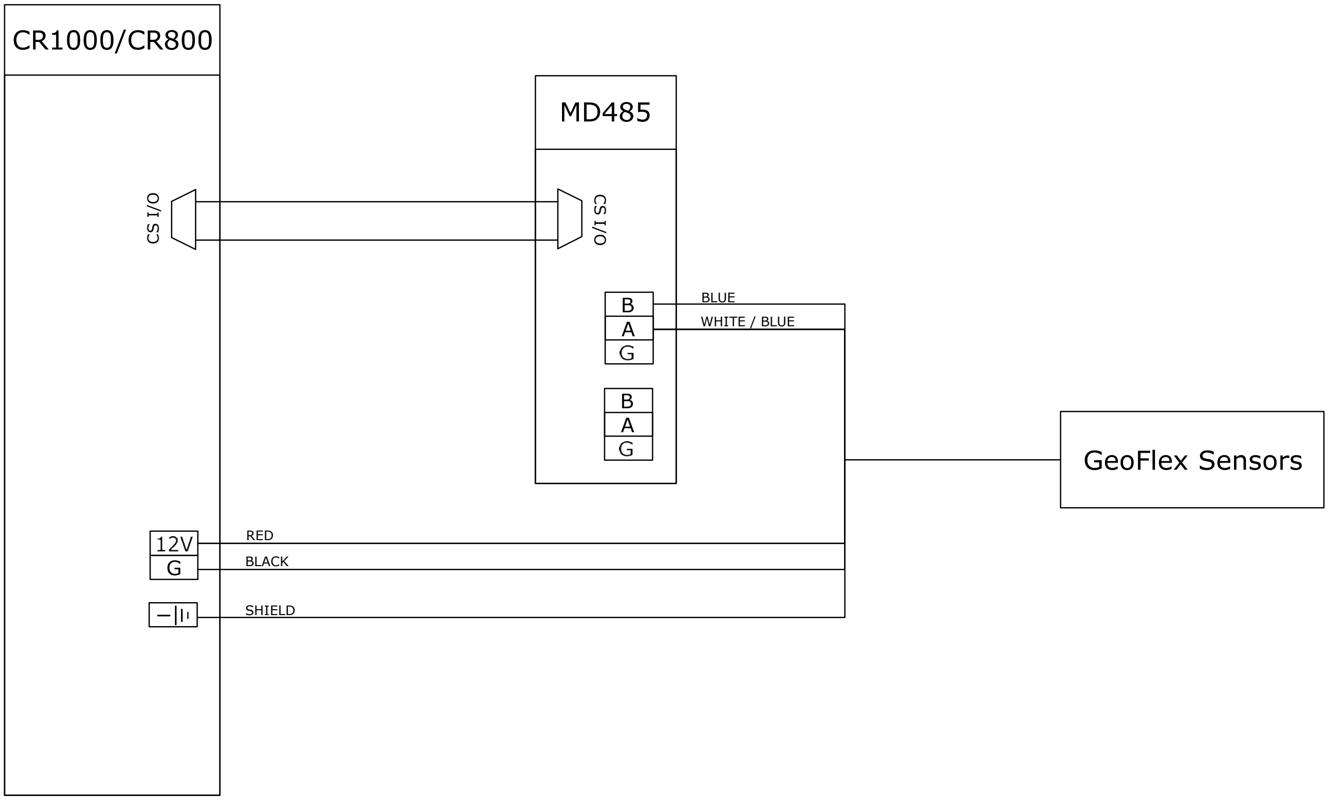
Overview

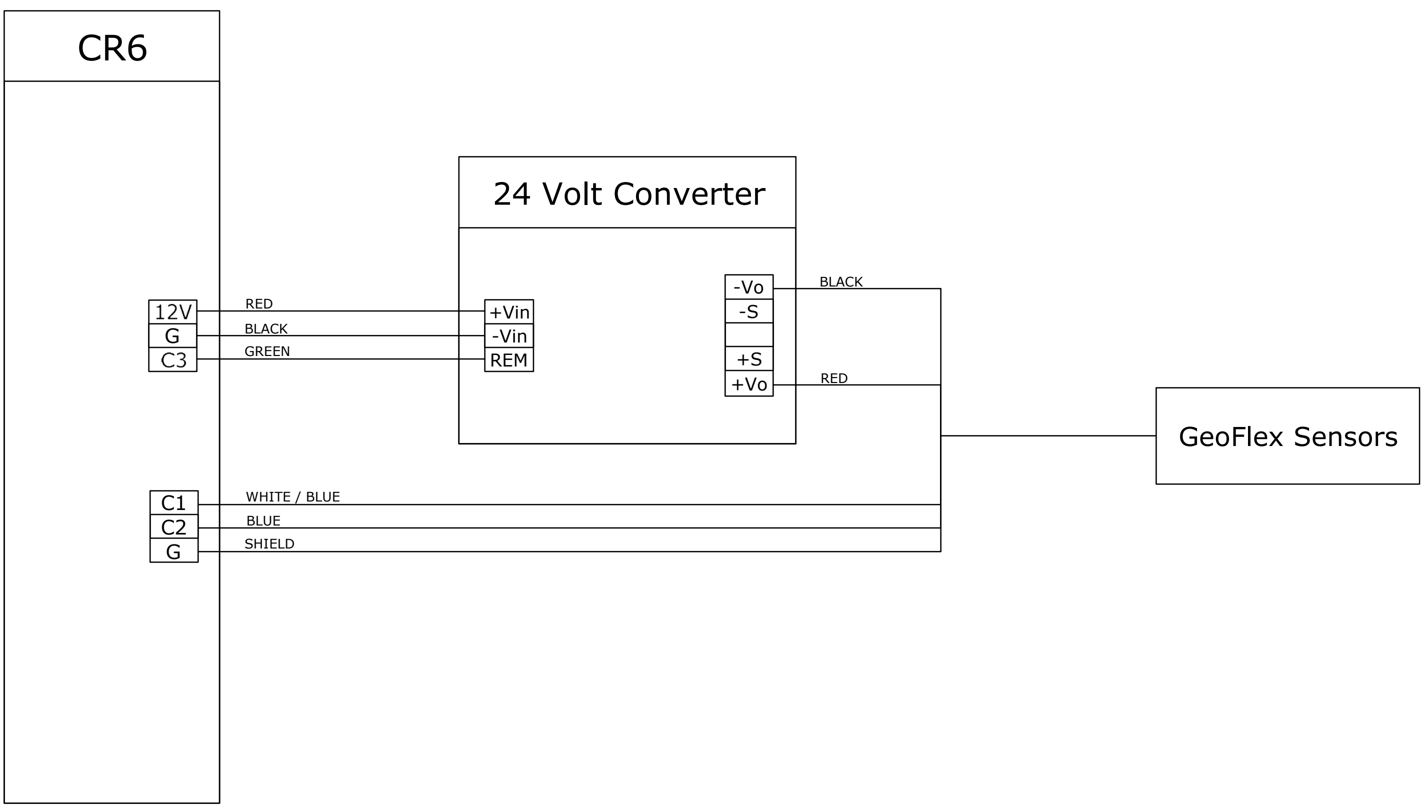
These instruction provide information needed for reading the GeoFlex system with the Campbell Scientific CR300, CR800, CR1000, CR1000X or CR6 data loggers. Please note that the diagrams presented on the following page are examples and do not cover every potential connection type. A wiring diagram will be provided with each data logger system that is purchased.

Limitations

The last sensor node in the chain must receive 8 volts. This limits the number of sensor nodes that can be connected based on the distance of the chain from the data logger.

Number of Nodes	Jumper Length, m (12V supply)	Jumper Length, m (24V supply)
10	320	-
25	122	-
50	52	215
75	24	139
100	5	97
125	-	69
150	-	47
175	-	28
200	-	12


CR1000/CR800
MD485
CS I/O
CS I/O
B
A
G
B
A
G
BLUE
WHITE / BLUE
GeoFlex Sensors
12V
G
RED
BLACK
SHIELD


CR6
24 Volt Converter
12V
G
C3
RED
BLACK
GREEN
+Vin
-Vin
REM
-Vo
-S
+S
+Vo
BLACK
RED
GeoFlex Sensors
C1
C2
G
WHITE / BLUE
BLUE
SHIELD