

# ***SLOPE INDICATOR***

## **GeoFlex In-Place Inclinator**

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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
  - 70mm (2.75 in) ABS Inclinometer Casing, or
  - 38mm (1.5 in) Schedule 40 PVC Pipe
- GeoFlex Suspension Kit (specific to type of casing)
- GeoFlex Segments (3m or 10 ft, Custom Length)
- 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 3 meters (10 feet) long, can be shipped in a carton measuring approximately 64 x 64 x 64 cm (26 x 26 x 26 in) and which weighs less than 22 kilograms (50 pounds). 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 can be supplied in either connectorized or hard-wired configurations. The connectorized version is available in 3m (10 ft) segments to provide flexibility for future installations. The hard-wired (custom length) version is ideal for long-term monitoring of inclinometers with known lengths. 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.

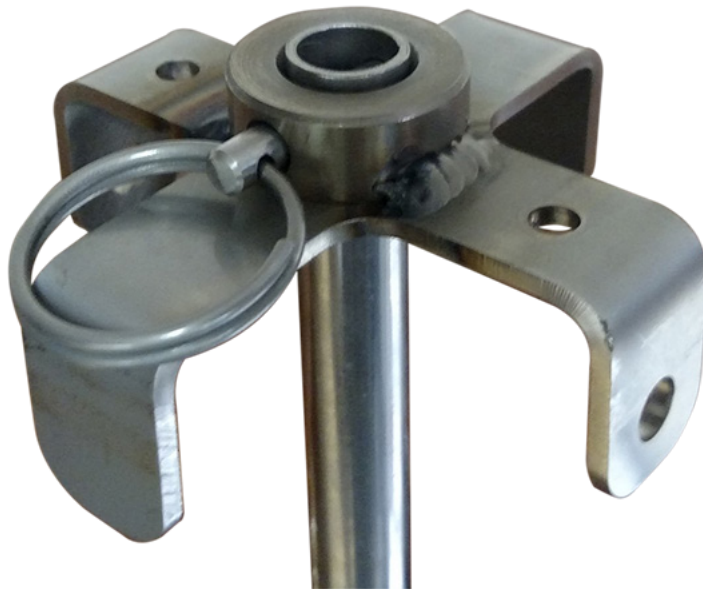


Figure 2: GeoFlex suspension kit mounted on top segment

## *GeoFlex segments or chains*

**Standard Configuration:** Each standard GeoFlex segment is either 3 m or 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 0.6 m or 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 Configuration:** GeoFlex systems can be ordered with custom length string for long-term monitoring projects. The custom system has one male connector at the upper end and no female connectors. Please note that custom length systems cannot be reconfigured once they are manufactured and therefore are not eligible to be returned for credit.



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 (Standard Configuration)

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.

## Installation (Custom Configuration)

Attach the suspension kit to the top of the string.

Insert the bottom end of the string 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 string 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 centralizer and the casing.

Lower the last node 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

- 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™.
- Once imported, the data will appear as below:

J	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(1)	Y_1(1)	Volt(1)	Temp(1)	X_1(2)	Y_1(2)	Volt(2)	Temp(2)	X_1(3)	Y_1(3)	Volt(3)	Temp(3)	X_1(4)	Volt(4)	Temp(4)	X_1(5)	Y_1(5)	Volt(5)	Temp(5)	
2	6/25/2018 18:30	6132	13.12	24.43	-25.41509	15.96104	12.62276	23.61629	-53.13737	35.18684	12.78975	25.26657	-29.16236	-10.1446	12.62276	24.23318	-31.57721	36.82491	12.62276	22.28995	-34.71881	2.042961	12.78975	20.21806
3	6/25/2018 18:35	6133	13.13	24.28	-25.38844	15.95506	12.78975	22.76472	-53.17498	35.06727	12.78975	25.14713	-29.10887	-10.15671	12.62276	24.23227	-31.6962	36.63987	12.78975	22.21091	-34.85669	1.8814	12.78975	20.01596
4	6/25/2018 18:40	6134	13.14	24.13	-25.35001	15.99873	12.78975	22.70087	-53.11464	35.26652	12.78975	25.3395	-29.18621	-9.978201	12.78975	24.20315	-31.81725	36.34278	12.78975	22.26361	-34.9009	2.025182	12.78975	20.45621
5	6/25/2018 18:45	6135	13.14	24.01	-25.43385	15.94726	12.78975	22.60984	-53.02817	35.23344	12.78975	25.3395	-29.17641	-10.10246	12.78975	24.23318	-31.73335	36.71752	12.78975	22.28995	-34.78923	2.024313	12.78975	20.18939
6	6/25/2018 18:50	6136	13.14	23.87	-25.47583	16.06787	12.78975	22.39786	-53.13278	35.09396	12.78975	25.29132	-29.19359	-10.13824	12.78975	24.15381	-31.83185	36.71041	12.78975	22.15817	-34.8	2.027444	12.78975	20.29611
7	6/25/2018 18:55	6137	13.14	23.72	-25.46988	15.99638	12.78975	22.29245	-53.14171	35.26204	12.78975	25.18892	-28.9816	-10.13191	12.78975	24.07532	-31.75008	36.77681	12.78975	22.25043	-34.75964	2.059595	12.78975	20.08264
8	6/25/2018 19:00	6138	13.15	23.61	-25.44954	15.96796	12.78975	22.12119	-53.10346	35.09436	12.78975	25.1904	-29.17996	-10.11326	12.78975	24.07532	-31.61276	36.70624	12.78975	22.3822	-34.87817	1.977941	12.78975	20.17906
9	6/25/2018 19:05	6139	13.17	22.9	-25.23228	15.76681	12.78975	21.3175	-53.08345	35.12051	12.91674	24.88162	-29.05179	-10.14739	12.78975	24.14072	-31.69661	36.7724	12.78975	22.17136	-34.92956	2.022574	12.78975	19.90921
10	6/25/2018 19:10	6140	13.17	22.73	-25.17925	15.72147	12.78975	20.97498	-53.01663	35.24311	12.91674	24.80137	-29.22868	-10.14828	12.78975	24.17996	-31.52552	36.80054	12.78975	22.3295	-34.87981	1.915247	12.78975	19.89587
11	6/25/2018 19:15	6141	13.17	22.7	-25.37894	15.50137	12.78975	20.76416	-53.07822	35.22713	12.91674	24.56382	-29.08897	-10.13514	12.78975	24.00995	-31.66167	36.7502	12.78975	22.18454	-34.89609	2.061257	12.78975	20.05197
12	6/25/2018 19:20	6142	13.17	22.87	-25.61325	15.66672	12.78975	20.8432	-53.04002	35.13475	12.91674	24.43685	-29.13255	-10.13229	12.78975	24.15381	-31.63008	36.64246	12.78975	22.11084	-34.85298	2.016898	12.78975	20.00259
13	6/26/2018 0:00	6143	13.17	22.75	-25.66435	15.59787	12.78975	20.61923	-53.20204	34.96492	12.91674	24.271	-29.2796	-10.21519	12.78975	24.04916	-31.47316	36.82603	12.78975	22.30313	-34.86719	2.119423	12.78975	20.40283
14	6/26/2018 1:00	6144	13.17	22.67	-25.7326	15.58302	12.78975	20.41478	-53.02592	35.14884	12.91674	24.3241	-29.17831	-10.09005	12.78975	24.08841	-31.57091	36.81695	12.78975	22.52716	-34.908	1.946134	12.78975	20.06931
15	6/26/2018 2:00	6145	13.17	22.73	-25.73293	15.42134	12.78975	20.21718	-52.96874	35.20765	12.91674	24.271	-29.13514	-10.00175	12.78975	24.13073	-31.53248	36.82796	12.78975	22.3822	-34.82204	1.827177	12.78975	19.78935
16	6/26/2018 3:00	6146	13.17	22.53	-25.9886	15.35701	12.78975	19.88344	-53.15527	35.09901	12.91674	23.84622	-29.41597	-10.04373	12.78975	24.57227	-31.62371	36.83503	12.78975	22.40857	-34.91397	1.968321	12.78975	20.17906
17	6/26/2018 4:00	6147	13.18	22.32	-25.81741	15.42162	12.78975	19.93414	-53.05482	35.11893	12.91674	24.00549	-29.18802	-10.18329	12.78975	23.9767	-31.55962	36.82271	12.78975	22.21091	-34.95663	2.068547	12.78975	20.17616
18	6/26/2018 5:00	6148	13.18	22.34	-25.89179	15.38186	12.78975	19.74969	-53.07444	35.03955	12.91674	23.79132	-29.23854	-10.09816	12.78975	24.23227	-31.5202	36.861	12.78975	22.3295	-34.92749	2.175043	12.78975	20.32278
19	6/26/2018 6:00	6149	13.19	22.06	-26.03517	15.30545	12.78975	19.85747	-53.19392	35.0756	12.91674	23.63382	-29.17479	-10.14585	12.78975	24.27148	-31.4164	36.94072	12.78975	22.53351	-34.8672	2.005518	12.78975	20.20273
20	6/26/2018 7:00	6150	13.18	22.19	-26.07293	15.43572	12.78975	20.18448	-53.12897	35.05233	12.91674	23.71347	-29.17314	-10.08518	12.78975	24.28458	-31.53749	36.85278	12.78975	22.34268	-34.96626	2.145589	12.78975	20.20273
21	6/26/2018 7:05	6151	13.18	22.19	-25.90891	15.52159	12.78975	20.09225	-53.14169	35.03426	12.91674	23.62054	-29.20765	-10.08603	12.78975	24.13073	-31.5278	36.85155	12.78975	22.3822	-34.93555	2.21705	12.78975	20.3895
22	6/26/2018 7:10	6152	13.18	22.19	-25.93235	15.51396	12.78975	20.29034	-52.9977	35.05701	12.91674	23.96367	-29.27378	-9.974936	12.78975	24.13073	-31.57372	36.80055	12.78975	22.17136	-34.83189	2.273889	12.78975	20.3895
23	6/26/2018 7:15	6153	13.18	22.19	-25.81917	15.47961	12.78975	20.31822	-53.14668	35.0385	12.91674	23.54009	-29.19179	-10.07007	12.78975	24.23227	-31.57977	36.8692	12.78975	22.3822	-34.99971	2.196205	12.78975	20.25687
24	6/26/2018 7:20	6154	13.18	22.19	-26.1129	15.25066	12.78975	19.82877	-53.21111	35.04213	12.91674	23.84622	-29.2651	-10.06787	12.78975	24.07532	-31.89229	36.82227	12.78975	22.38902	-34.9314	2.119913	12.78975	20.34234

- The columns consist of the following:

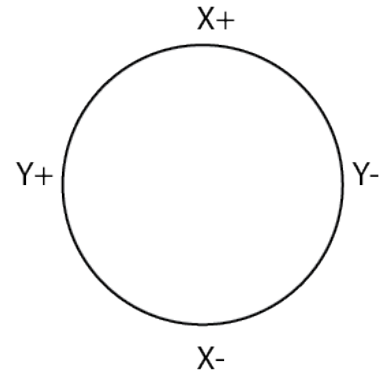
- TIMESTAMP - date and time the reading was taken.
- RECORD - consecutive reading that was taken since last data logger reboot.
- Batt\_volt - voltage of data logger battery at time of reading.
- PTemp - temperature measured at the data loggers.
- X<sub>(n)</sub> - X-axis tilt reading, in mm/m
- Y<sub>(n)</sub> - Y-axis tilt reading, in mm/m
- Volt(n) - voltage input to the sensor, in V
- 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

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

## Calculating Deviation

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

$$\text{Deviation}_{\text{mm}} = \text{Tilt}_{\text{mm/m}} \times 0.6\text{m}$$

or

$$\text{Deviation}_{\text{in}} = \text{Tilt}_{\text{mm/m}} \times (24 \text{ in} / 1000 \text{ in})$$

## Calculating Displacement

Displacement (movement) is the change in deviation:

$$\text{Displacement} = \text{Deviation}_{\text{current}} - \text{Deviation}_{\text{initial}}$$

# CHAPTER 4

## CONNECTION TO DATA LOGGERS

### Overview

These instructions 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

