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Resource Assessment Service
MARYLAND GEOLOGICAL SURVEY
Stephen Van Ryswick, Director

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LAND SUBSIDENCE MONITORING TO ASSESS POTENTIAL EFFECTS OF GROUNDWATER WITHDRAWALS FROM COASTAL PLAIN AQUIFERS IN MARYLAND:

FALL, 2023 SURVEY

by

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Prepared in cooperation with the
Anne Arundel County Department of Public Works, Dominion Cove Point LNG/LP,
and the U.S. Geological Survey

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CONTENTS

Page

Key results 1
Introduction 2
Historical GPS Data 2
GPS Survey 2
Change in Ellipsoid Height Over Time 3
Acknowledgements 4
References 5
Appendix
A. Observation form used to document the occupation of GPS benchmark 13
B. OPUS Projects network adjustment for the Fall, 2023 GPS survey 14

ILLUSTRATIONS

Figure **Page**

1. Map showing the location of the study area and MGS survey marks 6
2. Change in Ellipsoid Height from 1999 to present for marks ARNO, BROA, and CROF 7
3. Change in ellipsoid heights from 2016 to present for marks COV1, LEX1, and WAL1 8
4. Change in ellipsoid heights from 2020 to present for marks MSTP and PTNK 9

TABLES

Table **Page**

1. GPS Sessions processed by OPUS Projects 10
2. CORS sites used in processing GPS data 11
3. Summary of 2023 (Fall) GPS data 12

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KEY RESULTS

A GPS campaign was conducted October 2-6, 2023, to determine heights of nine 3d marks to assess the potential effect of groundwater withdrawals from aquifers in the Coastal Plain of Maryland. Three marks are located at major well fields in Anne Arundel County, Maryland, at the Arnold Water Treatment Plant (ARNO), the Broad Creek Water Treatment Plant (BROA), and the Crofton Meadows Water Treatment Plant (CROF). Three marks are located at or near major well fields in southern Maryland, at Cove Point State Park (COV1), Lexington Park (LEX1), and Waldorf (WAL1). An additional southern Maryland mark is located at Rosaryville State Park (ROS1), where groundwater use is relatively low. Two marks are located on the Eastern Shore of Maryland in the Blackwater National Wildlife Refuge in Dorchester County, at Money Stump (MSTP) and Peter's Neck (PTNK). The marks at the Blackwater National Wildlife Refuge are located in low-lying areas near the shoreline of the Chesapeake Bay where inundation, caused by relative sea-level rise, makes assessing the role of land subsidence all the more critical. The GPS data were processed using the National Geodetic Survey's Online Positioning User Service (OPUS) Projects (5.2) utility in the International Terrestrial Reference System of 2014. The 2023 ellipsoid heights determined through OPUS Projects processing of GPS data were 3.598 meters at ARNO, -6.225 meters at BROA, 7.046 meters at CROF, -1.558 meters at COV1, -2.110 meters at LEX1, 28.740 meters at WAL1, -35.677 meters at MSTP, and -36.060 meters at PTNK. Raw GPS data acquired at ROS1 did not meet OPUS Projects data quality thresholds; therefore no GPS data from ROS1 was processed for the 2023 survey. Computed height uncertainties, following the final network adjustment in OPUS Projects, for all marks is +/- 0.1 cm. Uncertainty computed in the latitudinal and longitudinal positions of MGS marks, following the final network adjustment in OPUS Projects, is smaller than could be detected by OPUS Projects. Including these ellipsoid height data from 2023, vertical velocities have been updated for the nine 3d marks. In Anne Arundel County, ARNO is subsiding at 3.1 mm/yr., BROA is subsiding at 2.5 mm/yr., and CROF is subsiding at 2.6 mm/yr. In southern Maryland, COV1 is subsiding at 4.4 mm/yr., LEX1 is subsiding at 3.0 mm/yr., and WAL1 is subsiding at 6.7 mm/yr. In the Blackwater National Wildlife Refuge, MSTP is subsiding at 13.2 mm/yr. and PTNK is subsiding at 6.6 mm/yr.

INTRODUCTION

Groundwater from the confined aquifers of the Maryland coastal plain has been withdrawn for decades as the primary source of water supply. The geological formations of the coastal plain are composed of stacked layers of predominantly unconsolidated sediment consisting of gravel, sand, silt, and clay. Sand and gravel layers contain water stored in interstitial pore spaces between the sediment grains with relatively high permeability, forming aquifers. Clay layers, with relatively low permeability, form confining units. Withdrawal of water from confined aquifers has lowered groundwater levels in Maryland's coastal plain aquifer systems (Staley and others, 2020). A lowering of groundwater levels in a confined aquifer corresponds to a decrease in hydrostatic pressure in the interstitial pore spaces of the aquifer sediments and in the adjacent confining units. A decrease in hydrostatic pressure can lead to the compaction of unconsolidated sediment and the subsidence of the land surface as the load from overlying sediment increases.

Studies have shown that parts of the Atlantic Coastal Plain region are experiencing elevated rates of land subsidence compared to physiographic provinces west of the Fall Line (Karegar and others, 2016). The Fall Line is a boundary that separates the unconsolidated Atlantic Coastal Plain sediments from the consolidated bedrock of the Piedmont province (fig. 1). Land subsidence rates attributable to groundwater withdrawals from the Potomac Group aquifer system in the Lower Chesapeake Bay region (Franklin and Suffolk, Virginia) have been reported in the range of 1.5 to 3.7 millimeters per year (mm/yr) (Davis, 1987; Pope and Burbey, 2004; Eggleston and Pope (2013)).

HISTORICAL GPS DATA

Starting in 1994, the Maryland State Highway Administration Division of Plats and Surveys began GPS surveys in Anne Arundel County at 3d rod marks at the Arnold Water Treatment Plant (ARNO) and the Broad Creek Water Treatment Plant (BROA), and a bronze survey disk embedded in a concrete structure at the Crofton Meadows Water Treatment Plant (CROF). The surveys were conducted on a yearly basis, occupying marks for a minimum of 5.5 hours over three consecutive days. In 2016, the Maryland Geological Survey took over the surveying of the marks. In 2015, four 3d rod marks were constructed and added to the monitoring network at Cove Point State Park (COV1), Lexington Park (LEX1), Rosaryville State Park (ROS1), and Waldorf (WAL1) to bring the total monitoring network to seven. In 2019 and 2020, two additional 3d rod marks were constructed and added to the network in the Blackwater National Wildlife Refuge at Money Stump (MSTP) and Peter's Neck (PTNK). The historical GPS data from the Maryland State Highway Administration as well as GPS data collected since 2016 by the Maryland Geological Survey were reprocessed in OPUS Projects using the International Terrestrial Reference System of 2014 (ITRF2014). Data available for reprocessing began in 1999.

GPS SURVEY

A GPS occupation of marks ARNO, BROA, COV1, CROF, LEX1, MSTP, ROS1, and WAL1 was conducted October 2-6, 2023. Mark PTNK was occupied October 3-10, 2023. Trimble NetR9 receivers were used with Zephyr 3 Geodetic Antennas for all marks[1].

The GPS occupation of each survey mark was documented on a standardized observation log sheet (app A). Observation log sheets contain information about equipment deployed at each mark that is essential in data processing, such as antenna type and antenna reference point (ARP). Observation log sheets and RINEX data files will be archived, as in previous years, for open access at UNAVCO and Zenodo as part of a larger archive of data for the Chesapeake Bay region (Kronebusch and others, 2022; Troia and others, 2022).

[1] The use of company names, trade names, or product names in this report is for identification purposes only and does not constitute endorsement by the Maryland Geological Survey.

The data were processed using the National Geodetic Survey's (NGS) OPUS Projects (5.2) online utility to determine ellipsoid heights of the marks. Ellipsoid heights were used as opposed to orthometric heights to avoid potential loss of accuracy associated with geoid models. OPUS Projects provides geodetic network solutions through baseline processing of simultaneous GPS observations. A detailed technical discussion of the concepts and processing used in OPUS Projects is provided in Armstrong (2015). The occupation period was divided into five sessions (tab. 1). Data processing parameters specified in OPUS Projects included a piecewise linear tropospheric model with an interval of 7,200 seconds, an elevation cutoff of 15.0 degrees, and normal constraint weights. Session processing was done using user-established data quality thresholds. If GPS data did not meet these data quality thresholds for a given GPS day of occupation, they were removed from that GPS day's session processing. Data collected at ROS1 did not meet any of the quality thresholds and was excluded from each GPS day's session processing step and the final network adjustment. The location of the ROS1 benchmark among large standing vegetation diminishes satellite visibility and may contribute to the poor data quality. Data for PTNK was only processed through October 6, 2023 to only include data that was collected concurrently with the other survey benchmarks. The final network adjustment used twelve Continuously Operating Reference Stations (CORS) to establish baselines with MGS survey marks. All CORS data were constrained in three dimensions during the network adjustment, except for the distant CORS STKR used for tropospheric correction. CORS stations used to process session network baselines and in network adjustment are shown in Table 2. Ellipsoid heights determined by OPUS Projects network adjustment are given in Table 3.

CHANGE IN ELLIPSOID HEIGHT OVER TIME

The changes in ellipsoid height relative to the 1999 measurement at marks ARNO, BROA, and CROF are shown in Figure 2. Over the 25-year period of record, the ellipsoid height decreased by 88 mm at ARNO, 66 mm at BROA, and 65 mm at CROF. The changes in ellipsoid height relative to the 2016 measurement at the marks COV1, LEX1, and WAL1 are shown in Figure 3. Over the 8-year period of record, the ellipsoid heights decreased by 37 mm at COV1, 26 mm at LEX1and 39 mm at WAL1. The changes in ellipsoid height relative to the 2020 measurement at the marks MSTP and PTNK are shown in Figure 4. Over the 4-year period of record, the ellipsoid heights decreased by 34 mm at MSTP and 14 mm at PTNK. Ellipsoid heights decreased over time at marks ARNO, BROA, CROF, COV1, LEX1, WAL1, MSTP, and PTNK .

Vertical velocities for each mark were computed by plotting the ellipsoid height derived from data processing in OPUS Projects versus time (figs. 2, 3, and 4). A linear trendline was fit to the ellipsoid height data and the slope of that trendline is the reported vertical velocity (tab. 3). The vertical velocities for the three Anne Arundel County marks ARNO, BROA, and CROF are -3.1 mm/yr., -2.5 mm/yr., and -2.6 mm/yr. respectively. The vertical velocities for the three southern Maryland marks, COV1, LEX1, WAL1, are -4.4 mm/yr., -3.0 mm/yr, and -6.7 mm/yr. respectively. The vertical velocities for the two marks on the eastern shore of Maryland, MSTP and PTNK are -13.2 mm/yr. and -6.6 mm/yr.

The variance around the trendline is quantified by the coefficients of determination (R^2) seen in Figures 2-4. Values of R^2 greater than 0.8 show a high correlation between ellipsoid height and time. The correlation between ellipsoid height and time is not as strong at southern Maryland marks COV1, LEX1, ROS1, and WAL1. The shorter period of record at these marks, compared to the three marks in Anne Arundel County, does not provide as much data to reveal as strong of a trend. The R^2 values quantifying the correlation between ellipsoid height and time at these southern Maryland benchmarks have been increasing as the survey continues year to year. For example, following the 2020 GPS occupation of the LEX1 benchmark, the correlation between ellipsoid height and time could be quantified by an R^2 value of 0.1809. This indicates that the slope of the linear trendline (taken as the rate of subsidence) does not fully describe the correlation between ellipsoid height and time. Following the 2023 occupation of COV1, an R^2 value of 0.6764 quantifies the correlation. This indicates that the slope of the trendline is improving in describing how ellipsoid height changes in time, therefore we can gain confidence in the rate of subsidence. A similar situation exists for the data from the Eastern Shore marks (MSTP and PTNK), having only a 4-year period

of record. Year-to-year variation in computed ellipsoid heights and a shorter length of data record may obscure trends that would be present over a longer period of record. However, an R^2 value of 0.9772 and 0.8141 at MSTP and PTNK show that one can have confidence that the linear trendline is describing how the ellipsoid height changes through time.

ACKNOWLEDGMENTS

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Troia, G., Stamps, D.S., Lotspeich, R.R., Duda, J., McCoy, K.J., Moore, W., Hensel, P., Hippenstiel, R., McKenna, T., Andreasen, D., Geoghegan, C., Ulizio, T.P., Kronenbusch, M., Carr, J., Walters, D., Winn, N., 2022, GPS data from 2019 and 2020 campaigns in the Chesapeake Bay region towards quantifying vertical land motions. Scientific Data 9, 744, 5 p.

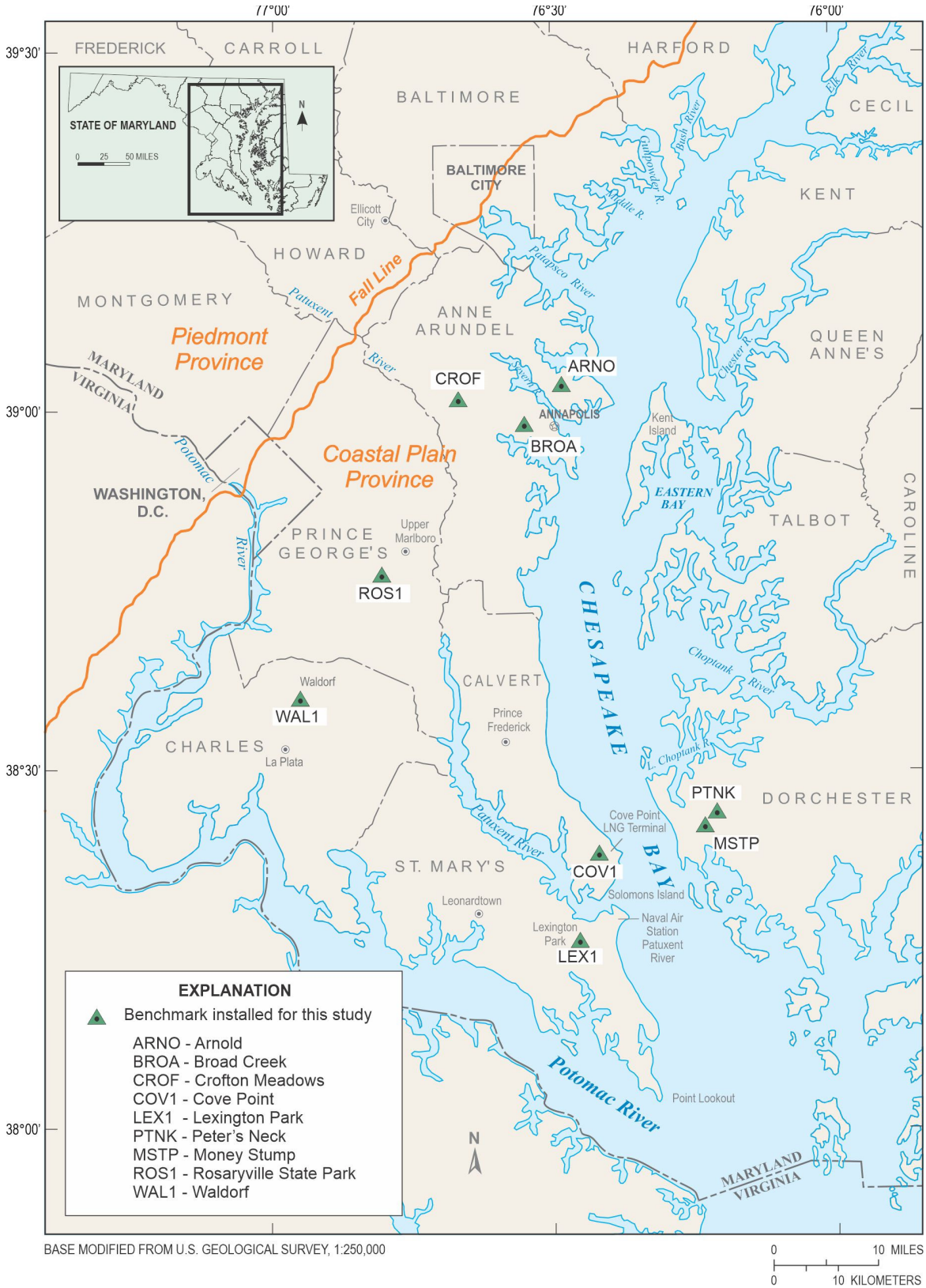

Figure 1. Location of the study area and MGS survey marks.

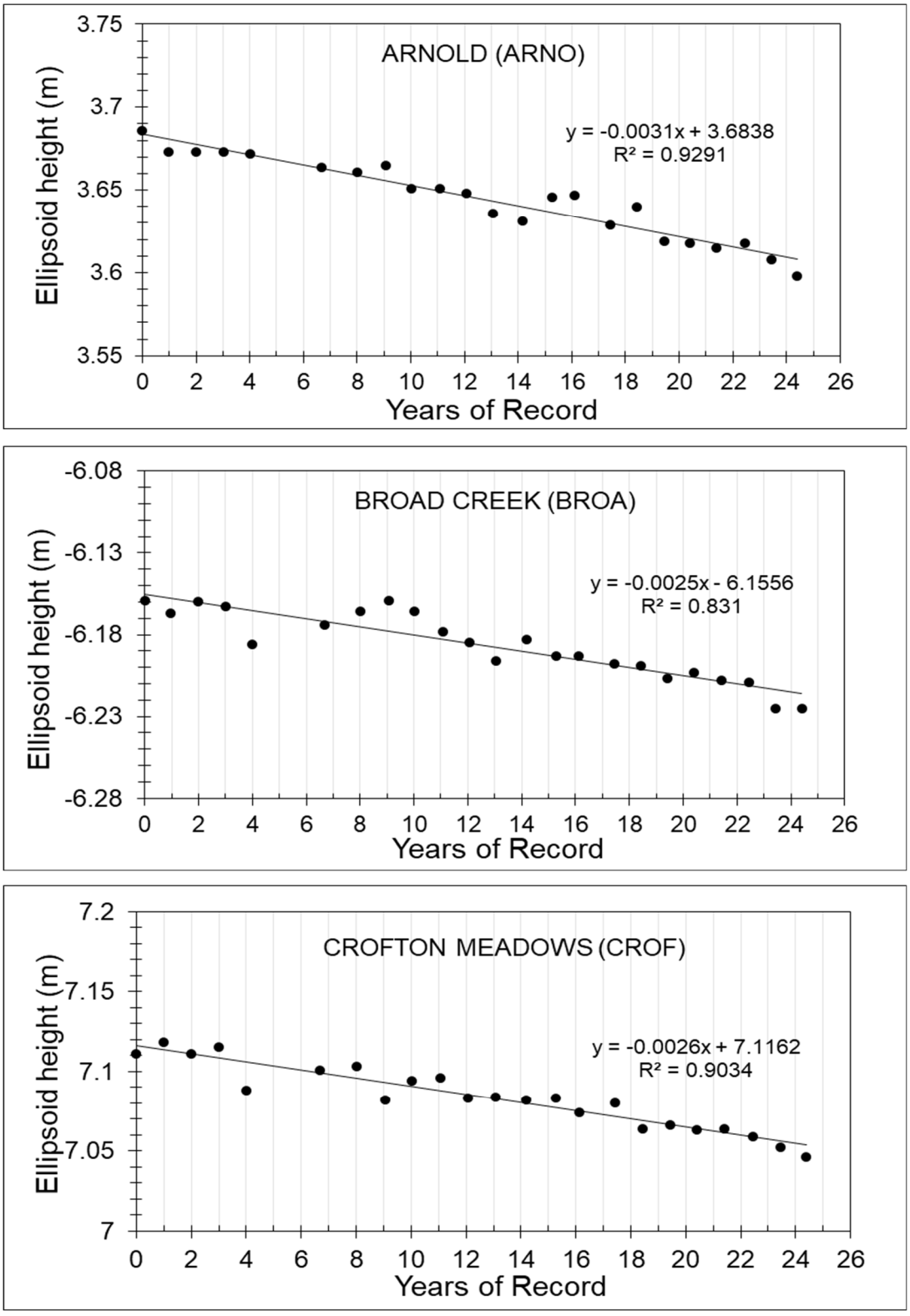

Figure 2. Change in ellipsoid heights from 1999 to present for marks ARNO, BROA, and CROF.

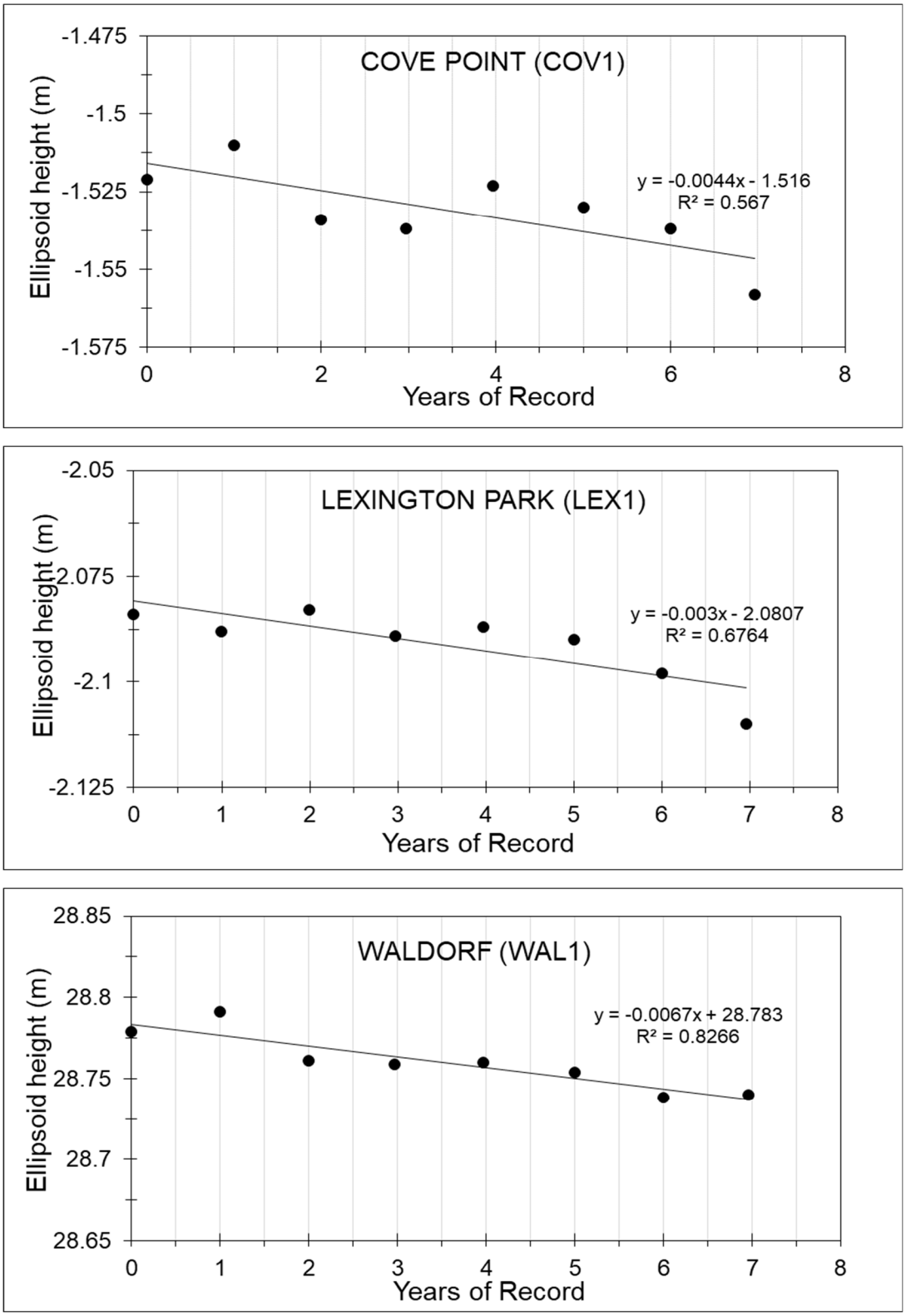

Figure 3. Change in ellipsoid heights from 2016 to present for marks COV1, LEX1, and WAL1.

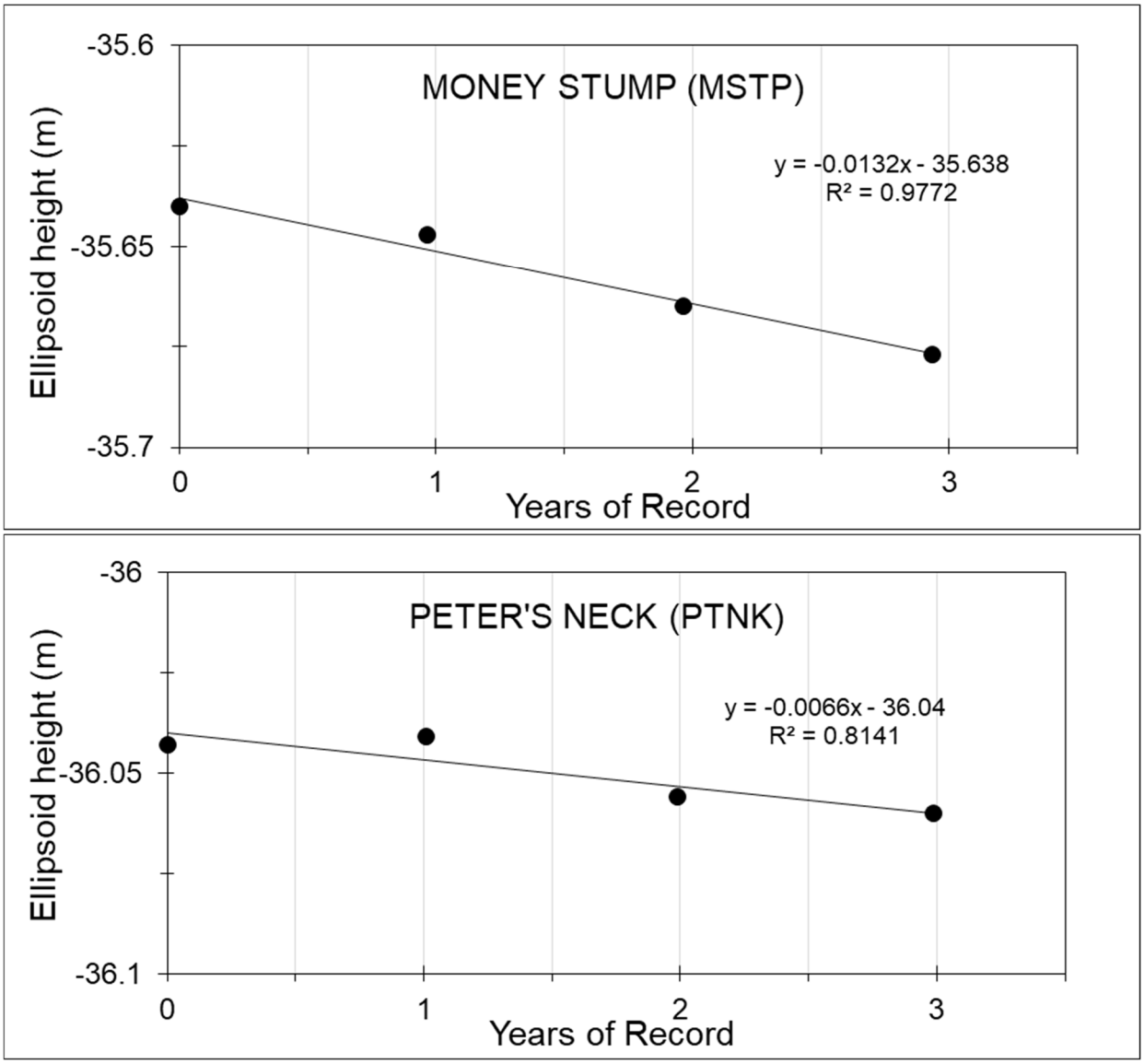

Figure 4. Change in ellipsoid heights from 2020 to present for marks MSTP and PTNK.

Table 1. GPS Sessions processed by OPUS Projects.

Session	Period (Coordinated Universal Time)	Hub CORS
1 (Day 275-A)	10/18/2023 0:00 to 23:59	GODE
2 (Day 276-A)	10/19/2023 0:00 to 23:59	GODE
3 (Day 277-A)	10/20/2023 0:00 to 23:59	GODE
4 (Day 278-A)	10/21/2023 0:00 to 23:59	GODE
5 (Day 279-A)	10/22/2023 0:00 to 23:59	GODE

Table 2. CORS sites used in processing GPS data.

CORS site	Start of record	State	Use in OPUS Projects	
BACO	1999	MD		Constrained
CORB	1999	VA		Constrained
DENE	2007	DE		Constrained
GODE	1993	MD	Hub	Constrained
GODZ		MD		Constrained
HNPT	1995	MD		Constrained
LOY8	2005	VA		Constrained
LOYF	2006	MD		Constrained
LOYO	2006	VA		Constrained
MDAI	2017	MD		Constrained
STKR	2000	OH	Troposphere Correction	Unconstrained
ZDC1	2003	VA		Constrained

Table 3. Summary of 2023 (Fall) GPS data.

Mark	Horizontal (ITRF2014)		Vertical (ITRF2014)	
	Latitude	Longitude	Ellipsoid height (m)	Vertical Velocity (mm/yr.)
ARNO	39.03487°	-76.49035°	3.598	-3.1
BROA	38.98176°	-76.55864°	-6.225	-2.5
COV1	38.38644°	-76.42280°	-1.558	-4.4
CROF	39.01710°	-76.67458°	7.046	-2.6
LEX1	38.26324°	-76.45570°	-2.110	-3.0
MSTP	38.42996°	-76.22607°	-35.677	-13.2
PTNK	38.45108°	-76.20378°	-36.060	-6.6
ROS1	38.77434°	-76.81999°	---	0.1*
WAL1	38.59907°	-76.93986°	28.740	-6.7

*The reported vertical velocity at mark ROS1 is based on data collected from 2016 to 2022.

Appendix A. Observation form used to document the occupation of GPS benchmark.

Chesapeake Bay Regional Vertical Land Motion Project

STATIC GNSS OBSERVATION FORM

CAMPAIGN YEAR (circle one): 2020 2021 2022 ✓ 2023
STATION 4CID: ARNO
DAY OF YEAR: 275

NAME / PARTY	STATION NAME / DESCRIPTION	NGS PID (if applicable)
Thomas Ulizio	Arnold Water Treatment Plant (ARNO)	N/A

AFFILIATION	CONTACT INFORMATION
Maryland Geological Survey	PHONE NUMBER (_____) ____ - _____ EMAIL thomas.ulizio@maryland.gov

STATION CITY	STATION STATE	GEOGRAPHIC INFORMATION
Arnold	MD	SOURCE Google Earth Pro ELEVATION 126 ✓ Feet Meters (Circle one) +/- _____ DATUM WGS84 LAT (Dec.Deg) 39 . 03467 LONG (Dec.Deg) -76 . 49047 DATUM WGS84

OBSERVATION SESSION START TIME (GMT)	OBSERVATION SESSION END TIME (GMT)	TIME DATUM ADJUSTMENT
DATE 10 / 02 / 2023 TIME 14 : 05	DATE 10 / 06 / 20223 TIME 13 : 02	EST + 5 = GMT EDT + 4 = GMT

EQUIPMENT INVENTORY

GNSS RECEIVER
Model: Trimble Net R9
Part no: 67668-30
S/N: 5834R50357
Firmware version: _____
Agency ID: NGS-FOB K

GNSS ANTENNA
Model: Zephyr 3
Part no: 115000-00
S/N: 6122223804
Agency ID: NGS-FOB K
Radome: Yes ✓ No

TRIPOD
Type: Collapsible ✓ Fixed-Height
Agency ID: MGS 27
Calibration date: 09 / 26 / 2023

BATTERY
Voltage: 12 V Amp-hr: 18
Start: 12.34 V End: 11.46 V

SOLAR PANEL ✓ Yes No
Wattage 50 W
Agency ID: USGS

ANTENNA HEIGHT (m)
START: 1.9985 m
END: 1.9985 m
(1 ft = 0.3048 m)

RECEIVER PROGAMMING INFORMATION
COLLECTION INTERVAL 30 seconds (30-seconds is standard)
ELEVATION MASK 0 degrees (0 degrees is standard)

PHOTOGRAPHS (Take the following photographs and archive in campaign database)

	Description	Filename	Comments
1.	Close-up of monument	ARNO_closeup_20231002.jpg	
2.	Equipment setup	ARNO_setup_20231002.jpg	
3.	Horizon view North	ARNO_north_20231002.jpg	
4.	Horizon view East	ARNO_east_20231002.jpg	
5.	Horizon view South	ARNO_south_20231002.jpg	
6.	Horizon view West	ARNO_west_20231002.jpg	
7.	Receiver serial number	ARNO_receiver_20231002.jpg	
8.	Antenna serial number	ARNO_antenna_20231002.jpg	

GENERAL COMMENTS

File Download Date: 10 / 06 / 2023
Downloaded by: Thomas Ulizio
Raw Filename: 5834R0357202310020000.T02 (through 1006
Raw File Size: 0.194-0.476 MB
Edits made to raw file? Yes
If edits made to raw file, explain: Changed raw file name to reflect VLM group naming conventions, 4CID, GPS day

RINEX Conversion Date: 10 / 06 / 2023
Converted by: Thomas Ulizio
RINEX filename: ARNO2750.23o - ARNO2790.23o
RINEX File Size: 0.739-1.851 MB

Ver. 20200909

page 1 of 1

Appendix B. Continued.

```
All coordinate accuracies reported here are 1x the formal
uncertainties from the solution. For additional information:
geodesy.noaa.gov/OPUS/Using_OPUS-Projects.html#accuracy

These positions were computed without any knowledge by the National
Geodetic Survey regarding the equipment or field operating procedures used.

SUBMITTED BY:                  thomas.ulizio
SOLUTION FILE NAME:            network-final.sum
SOLUTION SOFTWARE:             GPSCOM(2008.25)
SOLUTION DATE:                 2024-02-13T10:19:07 UTC
STANDARD ERROR OF UNIT WEIGHT: 0.821
TOTAL NUMBER OF OBSERVATIONS:  1474894
TOTAL NUMBER OF MARKS:         21
CONSTRAINED MARKS:             11 HORIZONTAL, 0 VERTICAL
baco N39:23:58.06805 W076:36:24.45999 127.0283m        ITRF2014 @ 2010.0000
baco         0.12cm           0.12cm     0.12cm        NEU SIGMAS
corb N38:12:07.85751 W077:22:24.58747  35.9312m        ITRF2014 @ 2010.0000
corb         0.12cm           0.10cm     0.13cm        NEU SIGMAS
dene N39:40:36.28071 W075:44:34.84496   5.2706m        ITRF2014 @ 2010.0000
dene         0.12cm           0.10cm     0.13cm        NEU SIGMAS
gode N39:01:18.21996 W076:49:36.59163  14.4978m        ITRF2014 @ 2010.0000
gode         0.12cm           0.12cm     0.12cm        NEU SIGMAS
godz N39:01:18.21996 W076:49:36.59160  14.4977m        ITRF2014 @ 2010.0000
godz         0.13cm           0.07cm     0.13cm        NEU SIGMAS
hnpt N38:35:19.74021 W076:07:49.34788 -27.9747m        ITRF2014 @ 2010.0000
hnpt         0.08cm           0.16cm     0.09cm        NEU SIGMAS
loy8 N38:16:58.72119 W077:27:09.48584  -6.2142m        ITRF2014 @ 2010.0000
loy8         0.12cm           0.10cm     0.12cm        NEU SIGMAS
loyf N38:58:28.10461 W076:31:19.90184 -15.7881m        ITRF2014 @ 2010.0000
loyf         0.12cm           0.10cm     0.13cm        NEU SIGMAS
loyo N38:03:00.65565 W077:20:51.19103  41.8661m        ITRF2014 @ 2010.0000
loyo         0.12cm           0.10cm     0.12cm        NEU SIGMAS
mdai N38:08:20.62172 W075:11:19.85741 -34.4832m        ITRF2014 @ 2010.0000
mdai         0.12cm           0.12cm     0.12cm        NEU SIGMAS
zdc1 N39:06:05.74479 W077:32:33.88523  79.6180m        ITRF2014 @ 2010.0000
zdc1         0.14cm           0.06cm     0.14cm        NEU SIGMAS

START TIME:                    2023-10-02T00:00:00 GPS
STOP TIME:                     2023-10-06T23:59:30 GPS
FREQUENCY:                     L1-ONLY TO ION-FREE [BY BASELINE LENGTH]
OBSERVATION INTERVAL:          30 s
ELEVATION CUTOFF:              15 deg
TROPO INTERVAL:                7200 s [PIECEWISE LINEAR PARAMETERIZATION]
DD CORRELATIONS:               ON

    INCLUDED SOLUTION            RMS    SOFTWARE         RUN DATE
--------------------------------------------------------------------------------
 1) 2023-275 A                    1.3 cm  page5(2008.25)   2024-02-13T10:05 UTC
 2) 2023-276 A                    1.2 cm  page5(2008.25)   2024-02-13T10:08 UTC
 3) 2023-277 A                    1.3 cm  page5(2008.25)   2024-02-13T10:10 UTC
 4) 2023-278 A                    1.3 cm  page5(2008.25)   2024-02-13T10:10 UTC
 5) 2023-279 A                    1.6 cm  page5(2008.25)   2024-02-13T10:12 UTC

  BASELINE      LENGTH         RMS       OBS   OMITTED    FIXED IN SOLUTION(S)
--------------------------------------------------------------------------------
 godz-gode      0.000 km      0.3 cm    75990     0.2%   100.0%    2, 3, 4, 5
 crof-gode     13.195 km      1.2 cm    62841     7.3%    98.2%    2, 3, 4, 5
 crof-godz     13.195 km      1.3 cm     7206    10.3%   100.0%    1
 broa-gode     23.651 km      1.4 cm    63265     7.1%    97.2%    2, 3, 4, 5
```

Appendix B. Continued.

```
 broa-godz     23.651 km      1.5 cm     6081    11.1%   100.0%    1
 loyf-gode     26.907 km      1.3 cm    75467     0.6%    94.0%    2, 3, 4, 5
 arno-godz     29.173 km      1.3 cm     7014     5.2%   100.0%    1
 arno-gode     29.173 km      1.2 cm    64559     3.1%    98.4%    2, 3, 4, 5
 84tb-godz     34.288 km      1.4 cm     6038     1.9%   100.0%    1
 84tb-gode     34.288 km      1.1 cm    67789     1.6%    98.6%    2, 3, 4, 5
 baco-godz     46.042 km      1.2 cm    18628     1.8%   100.0%    1
 baco-gode     46.042 km      1.4 cm    74961     1.4%    96.6%    2, 3, 4, 5
 wal1-gode     47.936 km      1.7 cm    54796    17.7%    97.9%    2, 3, 4, 5
 wal1-godz     47.936 km      1.9 cm     5757    20.6%    98.3%    1
 zdc1-godz     62.595 km      1.7 cm    18603     2.1%    92.1%    1
 zdc1-gode     62.595 km      1.5 cm    74601     1.8%    97.7%    2, 3, 4, 5
 hnpt-gode     77.261 km      1.4 cm    75212     0.6%    94.7%    2, 3, 4, 5
 hnpt-godz     77.261 km      1.4 cm    18729     0.9%    97.5%    1
 cov1-gode     78.794 km      1.3 cm    29915     4.1%    94.1%    4, 5
 ptnk-gode     83.350 km      2.2 cm    43431    29.3%    97.2%    3, 4, 5
 mstp-gode     83.930 km      1.6 cm    22528    21.6%    95.4%    2, 5
 lex1-godz     90.184 km      1.7 cm     4708    21.0%    93.2%    1
 lex1-gode     90.184 km      1.6 cm    40833    15.5%    92.0%    3, 4, 5
 loy8-godz     98.451 km      1.4 cm    18652     1.3%    94.6%    1
 loy8-gode     98.451 km      1.6 cm    74433     1.4%    91.9%    2, 3, 4, 5
 corb-gode    102.681 km      1.0 cm    78386     0.3%    99.7%    2, 3, 4, 5
 corb-godz    102.681 km      1.0 cm    18888     0.3%   100.0%    1
 loyo-gode    117.013 km      1.3 cm    74729     1.2%    92.0%    2, 3, 4, 5
 loyo-godz    117.013 km      1.2 cm    18638     1.1%    95.6%    1
 dene-godz    118.388 km      1.1 cm    18518     1.4%    96.5%    1
 dene-gode    118.388 km      1.4 cm    74756     0.6%    95.0%    2, 3, 4, 5
 mdai-godz    173.112 km      1.0 cm    17986     0.4%   100.0%    1
 mdai-gode    173.112 km      1.0 cm    70628     0.5%    99.8%    2, 3, 4, 5
 stkr-godz    457.384 km      1.2 cm    17980     1.9%    98.8%    1
 stkr-gode    457.384 km      1.3 cm    72348     1.1%    96.6%    2, 3, 4, 5

 MARK  ESTIMATED - A PRIORI COORDINATE SHIFTS
--------------------------------------------------------------------------------
 84tb  N:      0.005 m (0.000 m) E:      0.001 m (0.000 m) H:     -0.017 m (0.001 m)
 arno  N:      0.004 m (0.000 m) E:      0.000 m (0.000 m) H:     -0.003 m (0.001 m)
 baco  N:      0.002 m (0.000 m) E:      0.001 m (0.000 m) H:     -0.006 m (0.000 m)
 broa  N:      0.002 m (0.000 m) E:      0.000 m (0.000 m) H:     -0.012 m (0.001 m)
 corb  N:      0.003 m (0.000 m) E:      0.002 m (0.000 m) H:      0.000 m (0.000 m)
 cov1  N:      0.001 m (0.000 m) E:      0.003 m (0.000 m) H:     -0.009 m (0.001 m)
 crof  N:      0.004 m (0.000 m) E:     -0.001 m (0.000 m) H:      0.002 m (0.001 m)
 dene  N:     -0.002 m (0.000 m) E:     -0.004 m (0.000 m) H:      0.001 m (0.000 m)
 gode  N:      0.001 m (0.000 m) E:      0.000 m (0.000 m) H:      0.003 m (0.000 m)
 godz  N:      0.002 m (0.000 m) E:      0.001 m (0.000 m) H:      0.001 m (0.000 m)
 hnpt  N:     -0.002 m (0.000 m) E:      0.000 m (0.000 m) H:      0.000 m (0.000 m)
 lex1  N:      0.002 m (0.000 m) E:      0.003 m (0.000 m) H:     -0.016 m (0.001 m)
 loy8  N:      0.000 m (0.000 m) E:     -0.003 m (0.000 m) H:      0.004 m (0.000 m)
 loyf  N:      0.001 m (0.000 m) E:     -0.001 m (0.000 m) H:      0.000 m (0.001 m)
 loyo  N:      0.001 m (0.000 m) E:     -0.002 m (0.000 m) H:      0.000 m (0.000 m)
 mdai  N:      0.001 m (0.000 m) E:      0.001 m (0.000 m) H:     -0.003 m (0.000 m)
 mstp  N:      0.002 m (0.000 m) E:      0.002 m (0.000 m) H:      0.007 m (0.001 m)
 ptnk  N:      0.002 m (0.000 m) E:      0.001 m (0.000 m) H:     -0.009 m (0.001 m)
 stkr  N:     -0.006 m (0.000 m) E:      0.004 m (0.000 m) H:      0.003 m (0.001 m)
 wal1  N:      0.000 m (0.000 m) E:      0.000 m (0.000 m) H:     -0.005 m (0.001 m)
 zdc1  N:     -0.003 m (0.000 m) E:      0.001 m (0.000 m) H:      0.000 m (0.000 m)

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UNCONSTRAINED MARKS
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MARK:      84tb (84tb    1)
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Appendix B. Continued.

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REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75797663
X:                1147537.217 m    0.000 m          1147536.253 m    0.000 m
Y:               -4809805.644 m    0.001 m         -4809804.206 m    0.001 m
Z:                4015048.331 m    0.000 m          4015048.290 m    0.000 m
LAT:           39 15 50.88797      0.000 m       39 15 50.92025      0.000 m
E LON:        283 25 08.16604      0.000 m      283 25 08.14085      0.000 m
W LON:         76 34 51.83396      0.000 m       76 34 51.85915      0.000 m
EL HGT:              -23.617 m    0.001 m             -24.899 m    0.001 m
ORTHO HGT:             9.231 m    0.015 m  (= EL HGT - -32.848 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4347279.912 m         177411.816 m
EASTING (X)        363599.807 m         436154.406 m
CONVERGENCE       -1.00080556 deg       0.26293889 deg
POINT SCALE        0.99982908           0.99997277
COMBINED FACTOR    0.99983278           0.99997648

US NATIONAL GRID DESIGNATOR: 18SUJ6360047280 (NAD 83)

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MARK:      arno (arno    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75775247
X:                1158910.173 m    0.000 m          1158909.211 m    0.000 m
Y:               -4823629.171 m    0.001 m         -4823627.730 m    0.001 m
Z:                3995327.605 m    0.000 m          3995327.562 m    0.000 m
LAT:           39 02 05.52446      0.000 m       39 02 05.55658      0.000 m
E LON:        283 30 34.73962      0.000 m      283 30 34.71473      0.000 m
W LON:         76 29 25.26038      0.000 m       76 29 25.28527      0.000 m
EL HGT:                4.887 m    0.001 m                3.598 m    0.001 m
ORTHO HGT:            38.142 m    0.015 m  (= EL HGT - -33.255 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4321702.619 m         152000.087 m
EASTING (X)        371008.293 m         444125.188 m
CONVERGENCE       -0.93874167 deg       0.31987500 deg
POINT SCALE        0.99980488           0.99995369
COMBINED FACTOR    0.99980411           0.99995292

US NATIONAL GRID DESIGNATOR: 18SUJ7100821703 (NAD 83)

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MARK:      broa (broa    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75793338
X:                1154021.086 m    0.000 m          1154020.125 m    0.000 m
Y:               -4828609.392 m    0.001 m         -4828607.950 m    0.001 m
Z:                3990739.531 m    0.000 m          3990739.487 m    0.000 m
LAT:           38 58 54.31400      0.000 m       38 58 54.34606      0.000 m
E LON:        283 26 28.89546      0.000 m      283 26 28.87055      0.000 m
W LON:         76 33 31.10454      0.000 m       76 33 31.12945      0.000 m
EL HGT:               -4.934 m    0.001 m               -6.225 m    0.001 m
ORTHO HGT:            28.251 m    0.015 m  (= EL HGT - -33.185 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
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Appendix B. Continued.

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NORTHING (Y)      4315907.107 m         146073.152 m
EASTING (X)        364996.448 m         438241.233 m
CONVERGENCE       -0.98064722 deg       0.27701389 deg
POINT SCALE        0.99982443           0.99995155
COMBINED FACTOR    0.99982520           0.99995232

US NATIONAL GRID DESIGNATOR: 18SUJ6499615907 (NAD 83)

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MARK:      cov1 (cov1    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.76114815
X:                1175163.269 m    0.000 m          1175162.313 m    0.000 m
Y:               -4866014.456 m    0.001 m         -4866013.005 m    0.001 m
Z:                3939155.573 m    0.001 m          3939155.526 m    0.001 m
LAT:           38 23 11.16070      0.000 m       38 23 11.19243      0.000 m
E LON:        283 34 37.91881      0.000 m      283 34 37.89454      0.000 m
W LON:         76 25 22.08119      0.000 m       76 25 22.10546      0.000 m
EL HGT:               -0.247 m    0.001 m               -1.558 m    0.001 m
ORTHO HGT:            34.145 m    0.017 m  (= EL HGT - -34.392 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4249650.217 m          80056.591 m
EASTING (X)        375737.326 m         450428.646 m
CONVERGENCE       -0.88361944 deg       0.36226944 deg
POINT SCALE        0.99979016           0.99998609
COMBINED FACTOR    0.99979020           0.99998613

US NATIONAL GRID DESIGNATOR: 18SUH7573749650 (NAD 83)

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MARK:      crof (crof    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75787747
X:                1143680.960 m    0.000 m          1143679.998 m    0.000 m
Y:               -4828541.798 m    0.001 m         -4828540.357 m    0.001 m
Z:                3993797.470 m    0.000 m          3993797.427 m    0.000 m
LAT:           39 01 01.56291      0.000 m       39 01 01.59496      0.000 m
E LON:        283 19 31.50618      0.000 m      283 19 31.48109      0.000 m
W LON:         76 40 28.49382      0.000 m       76 40 28.51891      0.000 m
EL HGT:                8.335 m    0.001 m                7.046 m    0.001 m
ORTHO HGT:            41.150 m    0.015 m  (= EL HGT - -32.815 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4320008.249 m         149954.805 m
EASTING (X)        355025.625 m         428181.650 m
CONVERGENCE       -1.05441944 deg       0.20424444 deg
POINT SCALE        0.99985880           0.99995288
COMBINED FACTOR    0.99985749           0.99995157

US NATIONAL GRID DESIGNATOR: 18SUJ5502620008 (NAD 83)

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MARK:      lex1 (lex1    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75903624
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Appendix B. Continued.

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X:                1174354.961 m    0.000 m          1174354.005 m    0.000 m
Y:               -4874932.316 m    0.001 m         -4874930.864 m    0.001 m
Z:                3928427.066 m    0.001 m          3928427.018 m    0.001 m
LAT:           38 15 47.65657      0.000 m       38 15 47.68820      0.000 m
E LON:        283 32 39.48264      0.000 m      283 32 39.45839      0.000 m
W LON:         76 27 20.51736      0.000 m       76 27 20.54161      0.000 m
EL HGT:              -0.796 m    0.001 m               -2.110 m    0.001 m
ORTHO HGT:           33.708 m    0.017 m  (= EL HGT - -34.504 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4236024.453 m          66364.199 m
EASTING (X)        372648.471 m         447635.910 m
CONVERGENCE       -0.90160000 deg       0.34162222 deg
POINT SCALE        0.99979974           1.00000660
COMBINED FACTOR    0.99979986           1.00000672

US NATIONAL GRID DESIGNATOR: 18SUH7264836024 (NAD 83)

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MARK:      mstp (mstp    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75776135
X:                1191143.022 m    0.000 m          1191142.065 m    0.000 m
Y:               -4859009.465 m    0.001 m         -4859008.015 m    0.001 m
Z:                3942920.434 m    0.001 m          3942920.388 m    0.001 m
LAT:           38 25 47.85548      0.000 m       38 25 47.88730      0.000 m
E LON:        283 46 26.14137      0.000 m      283 46 26.11728      0.000 m
W LON:         76 13 33.85863      0.000 m       76 13 33.88272      0.000 m
EL HGT:              -34.367 m    0.001 m               -35.677 m    0.001 m
ORTHO HGT:             0.541 m    0.015 m  (= EL HGT - -34.908 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4254233.466 m          85015.136 m
EASTING (X)        392983.817 m         467575.054 m
CONVERGENCE       -0.76214722 deg       0.48574444 deg
POINT SCALE        0.99974104           0.99997993
COMBINED FACTOR    0.99974643           0.99998532

US NATIONAL GRID DESIGNATOR: 18SUH9298454233 (NAD 83)

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MARK:      ptnk (ptnk    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.76022270
X:                1192685.677 m    0.000 m          1192684.719 m    0.000 m
Y:               -4857129.967 m    0.001 m         -4857128.517 m    0.001 m
Z:                3944756.404 m    0.001 m          3944756.358 m    0.001 m
LAT:           38 27 03.88503      0.000 m       38 27 03.91686      0.000 m
E LON:        283 47 46.38796      0.000 m      283 47 46.36387      0.000 m
W LON:         76 12 13.61204      0.000 m       76 12 13.63613      0.000 m
EL HGT:              -34.750 m    0.001 m               -36.060 m    0.001 m
ORTHO HGT:             0.195 m    0.015 m  (= EL HGT - -34.945 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4256551.346 m          87376.081 m
EASTING (X)        394960.117 m         469500.859 m
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Appendix B. Continued.

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CONVERGENCE       -0.74863611 deg       0.49973333 deg
POINT SCALE        0.99973588           0.99997715
COMBINED FACTOR    0.99974133           0.99998260

US NATIONAL GRID DESIGNATOR: 18SUH9496056551 (NAD 83)

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MARK:      stkr (0015; stkr a  3)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75750863
X:                 678451.048 m    0.000 m           678450.086 m    0.000 m
Y:               -4893799.723 m    0.001 m         -4893798.290 m    0.001 m
Z:                 4020496.779 m    0.000 m          4020496.700 m    0.000 m
LAT:           39 19 33.82475      0.000 m       39 19 33.85466      0.000 m
E LON:        277 53 34.37044      0.000 m      277 53 34.33888      0.000 m
W LON:         82 06 25.62956      0.000 m       82 06 25.66112      0.000 m
EL HGT:              178.038 m    0.001 m              176.788 m    0.001 m
ORTHO HGT:           212.224 m    0.018 m  (= EL HGT - -34.186 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 17)         SPC (3402 OH S)
NORTHING (Y)      4353545.414 m         147284.035 m
EASTING (X)        404572.972 m         633874.822 m
CONVERGENCE       -0.70166944 deg       0.24929167 deg
POINT SCALE        0.99971212           0.99993642
COMBINED FACTOR    0.99968420           0.99990849

US NATIONAL GRID DESIGNATOR: 17SMD0457353545 (NAD 83)

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MARK:      wal1 (wal1    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75777140
X:                1127888.794 m    0.000 m          1127887.836 m    0.000 m
Y:               -4862133.234 m    0.001 m         -4862131.788 m    0.001 m
Z:                 3957648.538 m    0.000 m          3957648.490 m    0.000 m
LAT:           38 35 56.63661      0.000 m       38 35 56.66827      0.000 m
E LON:        283 03 36.50694      0.000 m      283 03 36.48187      0.000 m
W LON:         76 56 23.49306      0.000 m       76 56 23.51813      0.000 m
EL HGT:              30.039 m     0.001 m              28.740 m     0.001 m
ORTHO HGT:           62.949 m     0.016 m  (= EL HGT - -32.910 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4274070.444 m         103501.657 m
EASTING (X)        331073.113 m         405238.854 m
CONVERGENCE       -1.21050000 deg       0.03774722 deg
POINT SCALE        0.99995142           0.99996145
COMBINED FACTOR    0.99994671           0.99995674

US NATIONAL GRID DESIGNATOR: 18SUH3107374070 (NAD 83)


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CONSTRAINED MARKS
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MARK:      baco (0008; baco a  2)
CONSTRAIN: 3-D NORMAL
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Appendix B. Continued.

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     N39:23:58.06805 W076:36:24.45999 127.0283m        ITRF2014 @ 2010.0000
            0.12cm           0.12cm     0.12cm        NEU SIGMAS
SHIFTS N:      0.002 m (0.000 m) E:      0.001 m (0.000 m) H:     -0.006 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75752064
X:               1143199.185 m    0.000 m          1143198.219 m    0.000 m
Y:              -4801171.601 m    0.000 m         -4801170.164 m    0.000 m
Z:               4026765.136 m    0.000 m          4026765.096 m    0.000 m
LAT:           39 23 58.03753      0.000 m       39 23 58.06992      0.000 m
E LON:        283 23 35.55691      0.000 m      283 23 35.53157      0.000 m
W LON:         76 36 24.44309      0.000 m       76 36 24.46843      0.000 m
EL HGT:              128.298 m    0.000 m             127.020 m    0.000 m
ORTHO HGT:           160.866 m    0.015 m  (= EL HGT - -32.568 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4362337.561 m         192424.923 m
EASTING (X)        361647.405 m         433869.645 m
CONVERGENCE       -1.02002778 deg       0.24679167 deg
POINT SCALE        0.99983568           0.99999155
COMBINED FACTOR    0.99981556           0.99997142

US NATIONAL GRID DESIGNATOR: 18SUJ6164762338 (NAD 83)

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MARK:      corb (corb a  8)
CONSTRAIN: 3-D NORMAL
     N38:12:07.85751 W077:22:24.58747  35.9312m        ITRF2014 @ 2010.0000
            0.12cm           0.10cm     0.13cm        NEU SIGMAS
SHIFTS N:      0.003 m (0.000 m) E:      0.002 m (0.000 m) H:      0.000 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75754303
X:               1097041.999 m    0.000 m          1097041.039 m    0.000 m
Y:              -4897239.888 m    0.000 m         -4897238.427 m    0.000 m
Z:               3923126.367 m    0.000 m          3923126.306 m    0.000 m
LAT:           38 12 07.82811      0.000 m       38 12 07.85937      0.000 m
E LON:        282 37 35.42972      0.000 m      282 37 35.40434      0.000 m
W LON:         77 22 24.57028      0.000 m       77 22 24.59566      0.000 m
EL HGT:              37.238 m     0.000 m              35.915 m     0.000 m
ORTHO HGT:           69.808 m     0.016 m  (= EL HGT - -32.570 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (4501 VA N)
NORTHING (Y)      4230910.098 m         2060045.530 m
EASTING (X)        292173.050 m         3598666.745 m
CONVERGENCE       -1.46838333 deg       0.70307500 deg
POINT SCALE        1.00013197           0.99997449
COMBINED FACTOR    1.00012613           0.99996865

US NATIONAL GRID DESIGNATOR: 18STH9217330910 (NAD 83)

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MARK:      dene (0013; dene a  3)
CONSTRAIN: 3-D NORMAL
     N39:40:36.28071 W075:44:34.84496   5.2706m        ITRF2014 @ 2010.0000
            0.12cm           0.10cm     0.13cm        NEU SIGMAS
SHIFTS N:     -0.002 m (0.000 m) E:     -0.004 m (0.000 m) H:      0.001 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75752106
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Appendix B. Continued.

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X:                1210598.676 m    0.000 m          1210597.705 m    0.000 m
Y:               -4764306.700 m    0.000 m         -4764305.253 m    0.000 m
Z:                4050429.566 m    0.000 m          4050429.529 m    0.000 m
LAT:           39 40 36.24958      0.000 m       39 40 36.28264      0.000 m
E LON:        284 15 25.17088      0.000 m      284 15 25.14636      0.000 m
W LON:         75 44 34.82912      0.000 m       75 44 34.85364      0.000 m
EL HGT:                6.546 m    0.000 m                5.258 m    0.000 m
ORTHO HGT:            39.548 m    0.015 m  (= EL HGT - -33.002 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (0700 DE)
NORTHING (Y)      4392142.876 m         186188.492 m
EASTING (X)        436278.659 m         172001.594 m
CONVERGENCE       -0.47439444 deg      -0.20835556 deg
POINT SCALE        0.99964999           1.00000465
COMBINED FACTOR    0.99964896           1.00000362

US NATIONAL GRID DESIGNATOR: 18SVJ3627992143 (NAD 83)

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MARK:      gode (0002; gode a  4)
CONSTRAIN: 3-D NORMAL
     N39:01:18.21996 W076:49:36.59163  14.4978m        ITRF2014 @ 2010.0000
             0.12cm           0.12cm     0.12cm        NEU SIGMAS
SHIFTS N:      0.001 m (0.000 m) E:      0.000 m (0.000 m) H:      0.003 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75885978
X:                1130774.428 m    0.000 m          1130773.463 m    0.000 m
Y:               -4831255.027 m    0.000 m         -4831253.571 m    0.000 m
Z:                3994200.523 m    0.000 m          3994200.471 m    0.000 m
LAT:           39 01 18.18976      0.000 m       39 01 18.22188      0.000 m
E LON:        283 10 23.42527      0.000 m      283 10 23.40000      0.000 m
W LON:         76 49 36.57473      0.000 m       76 49 36.60000      0.000 m
EL HGT:               15.788 m    0.000 m              14.482 m    0.000 m
ORTHO HGT:            48.168 m    0.015 m  (= EL HGT - -32.380 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4320774.472 m         150431.509 m
EASTING (X)        341854.666 m         414996.114 m
CONVERGENCE       -1.15043611 deg       0.10868889 deg
POINT SCALE        0.99990796           0.99995308
COMBINED FACTOR    0.99990548           0.99995060

US NATIONAL GRID DESIGNATOR: 18SUJ4185520774 (NAD 83)

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MARK:      godz (godz a  4)
CONSTRAIN: 3-D NORMAL
     N39:01:18.21996 W076:49:36.59160  14.4977m        ITRF2014 @ 2010.0000
             0.13cm           0.07cm     0.13cm        NEU SIGMAS
SHIFTS N:      0.002 m (0.000 m) E:      0.001 m (0.000 m) H:      0.001 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75401091
X:                1130774.430 m    0.000 m          1130773.463 m    0.000 m
Y:               -4831255.024 m    0.000 m         -4831253.571 m    0.000 m
Z:                3994200.522 m    0.000 m          3994200.470 m    0.000 m
LAT:           39 01 18.18978      0.000 m       39 01 18.22188      0.000 m
E LON:        283 10 23.42538      0.000 m      283 10 23.40000      0.000 m
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Appendix B. Continued.

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W LON:         76 49 36.57462      0.000 m       76 49 36.60000      0.000 m
EL HGT:                15.785 m    0.000 m              14.482 m    0.000 m
ORTHO HGT:             48.165 m    0.015 m  (= EL HGT - -32.380 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4320774.472 m         150431.510 m
EASTING (X)        341854.669 m         414996.116 m
CONVERGENCE       -1.15043611 deg       0.10868889 deg
POINT SCALE        0.99990796           0.99995308
COMBINED FACTOR    0.99990548           0.99995060

US NATIONAL GRID DESIGNATOR: 18SUJ4185520774 (NAD 83)

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MARK:      hnpt (0003; hnpt a  4)
CONSTRAIN: 3-D NORMAL
     N38:35:19.74021 W076:07:49.34788 -27.9747m        ITRF2014 @ 2010.0000
            0.08cm           0.16cm     0.09cm        NEU SIGMAS
SHIFTS N:     -0.002 m (0.000 m) E:      0.000 m (0.000 m) H:      0.000 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75752093
X:                1196627.025 m    0.000 m          1196626.057 m    0.000 m
Y:               -4846359.963 m    0.000 m         -4846358.487 m    0.000 m
Z:                3956723.209 m    0.000 m          3956723.149 m    0.000 m
LAT:           38 35 19.70999      0.000 m       38 35 19.74212      0.000 m
E LON:        283 52 10.66801      0.000 m      283 52 10.64378      0.000 m
W LON:         76 07 49.33199      0.000 m       76 07 49.35622      0.000 m
EL HGT:              -26.670 m    0.000 m             -28.009 m    0.000 m
ORTHO HGT:             8.230 m    0.015 m  (= EL HGT - -34.900 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4271753.561 m         102722.193 m
EASTING (X)        401553.851 m         475762.993 m
CONVERGENCE       -0.70510000 deg       0.54580833 deg
POINT SCALE        0.99971935           0.99996232
COMBINED FACTOR    0.99972353           0.99996650

US NATIONAL GRID DESIGNATOR: 18SVH0155471754 (NAD 83)

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MARK:      loy8 (0011; loy8 a  2)
CONSTRAIN: 3-D NORMAL
     N38:16:58.72119 W077:27:09.48584  -6.2142m        ITRF2014 @ 2010.0000
            0.12cm           0.10cm     0.12cm        NEU SIGMAS
SHIFTS N:      0.000 m (0.000 m) E:     -0.003 m (0.000 m) H:      0.004 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75750447
X:                1089063.549 m    0.000 m          1089062.586 m    0.000 m
Y:               -4893299.386 m    0.000 m         -4893297.921 m    0.000 m
Z:                3930144.037 m    0.000 m          3930143.973 m    0.000 m
LAT:           38 16 58.69164      0.000 m       38 16 58.72294      0.000 m
E LON:        282 32 50.53128      0.000 m      282 32 50.50568      0.000 m
W LON:         77 27 09.46872      0.000 m       77 27 09.49432      0.000 m
EL HGT:              -4.906 m    0.000 m              -6.233 m    0.000 m
ORTHO HGT:           27.631 m    0.015 m  (= EL HGT - -32.537 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
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Appendix B. Continued.

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                UTM (Zone 18)         SPC (4501 VA N)
NORTHING (Y)      4240057.446 m        2068930.986 m
EASTING (X)        285480.302 m        3591633.294 m
CONVERGENCE       -1.52009444 deg       0.65368333 deg
POINT SCALE        1.00016678           0.99996533
COMBINED FACTOR    1.00016755           0.99996610

US NATIONAL GRID DESIGNATOR: 18STH8548040057 (NAD 83)

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MARK:      loyf (loyf a  2)
CONSTRAIN: 3-D NORMAL
     N38:58:28.10461 W076:31:19.90184 -15.7881m        ITRF2014 @ 2010.0000
            0.12cm           0.10cm     0.13cm        NEU SIGMAS
SHIFTS N:      0.001 m (0.000 m) E:     -0.001 m (0.000 m) H:      0.000 m (0.001 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75888416
X:                1157209.557 m    0.000 m          1157208.588 m    0.000 m
Y:               -4828361.999 m    0.000 m         -4828360.535 m    0.000 m
Z:                3990104.481 m    0.000 m          3990104.425 m    0.000 m
LAT:           38 58 28.07433      0.000 m       38 58 28.10656      0.000 m
E LON:        283 28 40.11464      0.000 m      283 28 40.08968      0.000 m
W LON:         76 31 19.88536      0.000 m       76 31 19.91032      0.000 m
EL HGT:              -14.498 m    0.001 m             -15.815 m    0.001 m
ORTHO HGT:            18.782 m    0.015 m  (= EL HGT - -33.280 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4315044.792 m         145279.936 m
EASTING (X)        368140.228 m         441403.598 m
CONVERGENCE       -0.95755556 deg       0.29988889 deg
POINT SCALE        0.99981410           0.99995133
COMBINED FACTOR    0.99981637           0.99995360

US NATIONAL GRID DESIGNATOR: 18SUJ6814015045 (NAD 83)

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MARK:      loyo (0010; loyo a  3)
CONSTRAIN: 3-D NORMAL
     N38:03:00.65565 W077:20:51.19103  41.8661m        ITRF2014 @ 2010.0000
            0.12cm           0.10cm     0.12cm        NEU SIGMAS
SHIFTS N:      0.001 m (0.000 m) E:     -0.002 m (0.000 m) H:      0.000 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75750669
X:                1101542.002 m    0.000 m          1101541.046 m    0.000 m
Y:               -4906910.941 m    0.000 m         -4906909.478 m    0.000 m
Z:                3909857.635 m    0.000 m          3909857.575 m    0.000 m
LAT:           38 03 00.62626      0.000 m       38 03 00.65746      0.000 m
E LON:        282 39 08.82588      0.000 m      282 39 08.80076      0.000 m
W LON:         77 20 51.17412      0.000 m       77 20 51.19924      0.000 m
EL HGT:              43.178 m     0.000 m               41.852 m    0.000 m
ORTHO HGT:           75.862 m     0.021 m  (= EL HGT - -32.684 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (4501 VA N)
NORTHING (Y)      4213983.646 m        2043203.429 m
EASTING (X)        294018.049 m        3601150.706 m
CONVERGENCE       -1.44742222 deg       0.71926667 deg
POINT SCALE        1.00012258           0.99999707
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Appendix B. Continued.

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 COMBINED FACTOR    1.00011580          0.99999029

 US NATIONAL GRID DESIGNATOR: 18STH9401813984 (NAD 83)

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 MARK:      mdai (0014; mdai a  1)
 CONSTRAIN: 3-D NORMAL
      N38:08:20.62172 W075:11:19.85741 -34.4832m        ITRF2014 @ 2010.0000
             0.12cm          0.12cm     0.12cm        NEU SIGMAS
 SHIFTS N:      0.001 m (0.000 m) E:      0.001 m (0.000 m) H:     -0.003 m (0.000 m)

 REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75745935
 X:                1284020.348 m    0.000 m          1284019.392 m    0.000 m
 Y:               -4855993.772 m    0.000 m         -4855992.314 m    0.000 m
 Z:                3917574.577 m    0.000 m          3917574.536 m    0.000 m
 LAT:           38 08 20.59162      0.000 m       38 08 20.62371      0.000 m
 E LON:        284 48 40.15723      0.000 m      284 48 40.13457      0.000 m
 W LON:         75 11 19.84277      0.000 m       75 11 19.86543      0.000 m
 EL HGT:              -33.162 m    0.000 m             -34.488 m    0.000 m
 ORTHO HGT:             3.129 m    0.019 m  (= EL HGT - -36.291 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
 NORTHING (Y)      4221260.290 m          54012.449 m
 EASTING (X)        483451.244 m         558771.984 m
 CONVERGENCE       -0.11662500 deg       1.13674167 deg
 POINT SCALE        0.99960337           1.00003190
 COMBINED FACTOR    0.99960857           1.00003710

 US NATIONAL GRID DESIGNATOR: 18SVH8345121260 (NAD 83)

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 MARK:      zdc1 (0024; zdc1 a  2)
 CONSTRAIN: 3-D NORMAL
      N39:06:05.74479 W077:32:33.88523  79.6180m        ITRF2014 @ 2010.0000
             0.14cm          0.06cm     0.14cm        NEU SIGMAS
 SHIFTS N:     -0.003 m (0.000 m) E:      0.001 m (0.000 m) H:      0.000 m (0.000 m)

 REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2023.75751554
 X:                1069126.503 m    0.000 m          1069125.531 m    0.000 m
 Y:               -4839600.096 m    0.000 m         -4839598.650 m    0.000 m
 Z:                4001126.300 m    0.000 m          4001126.243 m    0.000 m
 LAT:           39 06 05.71461      0.000 m       39 06 05.74634      0.000 m
 E LON:        282 27 26.13261      0.000 m      282 27 26.10608      0.000 m
 W LON:         77 32 33.86739      0.000 m       77 32 33.89392      0.000 m
 EL HGT:              80.897 m     0.000 m               79.602 m    0.000 m
 ORTHO HGT:          113.250 m     0.016 m  (= EL HGT - -32.353 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (4501 VA N)
 NORTHING (Y)      4331128.271 m        2159710.545 m
 EASTING (X)        280119.884 m        3582802.377 m
 CONVERGENCE       -1.60434167 deg       0.59744167 deg
 POINT SCALE        1.00019535           0.99998402
 COMBINED FACTOR    1.00018266           0.99997133
US NATIONAL GRID DESIGNATOR: 18STJ8012031128 (NAD 83)
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A message to Maryland's citizens

The Maryland Department of Natural Resources (DNR) seeks to balance the preservation and enhancement of the living and physical resources of the state with prudent extraction and utilization policies that benefit the citizens of Maryland. This publication provides information that will increase your understanding of how DNR strives to reach that goal through the earth science assessments conducted by the Maryland Geological Survey.

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