THURBER

MEMORANDUM

To: Sanath Bandara, P.Eng.
District of Sechelt

Date: October 4, 2018

From: Caleb Scott, EIT
(Reviewed by David Tara, P.Eng.)

Thurber File No. 11680

LOT 6 SINKHOLE
THE SHORES, PHASE 1 DEVELOPMENT, SECHELT, B.C.

On September 19, 2018 a new sinkhole appeared on Lot 6 which is private property. At the request of the District of Sechelt (District), Thurber visited the site on September 24, 2018 and our observations and interim recommendations are documented in our Field Review Report No. 11680-17. This memorandum provides our comments on the interpreted process which resulted in this newest sinkhole. It also provides our recommendations for mitigating the ongoing sinkhole formation process and for mitigating the hazard to the residents, the general public, and District property.

It is a condition of this memorandum that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

1. BACKGROUND

Thurber Engineering Ltd. (Thurber) prepared a report titled "The Shores – Phase 1 Subdivision: Sinkhole Investigation and Geotechnical Assessment" dated July 16, 2015 (2015 Report). Since that time, Thurber has completed a limited number of site reviews and has reviewed a limited number of site inspection reports completed by District of Sechelt (District) personnel.

In 2017 Thurber completed a targeted drilling investigation following the discovery of a new sinkhole on Gale Avenue North at approximately Sta. 2+60 (adjacent to Lot 7 and Lot 23). The results and our recommendations addressing the zone of immediate concern were provided in our June 30, 2017 report. This investigation also identified a potential future sinkhole on Gale Avenue North at Sta. 2+80 (adjacent to Lot 8 and Lot 22). Temporary detours were implemented to direct traffic around the most severely affected areas, as indicated by the data, and it was recommended that heavy vehicles such as garbage trucks and fire trucks be restricted from advancing beyond about Sta. 2+50, which coincides approximately with the east property line of Lot 7 (6652 Gale Ave N).

The implications of the 2017 sinkhole and the unabated sinkhole formation processes were discussed in our memorandum dated July 11, 2017. We strongly recommended proactive groundwater management measures be taken to mitigate the ongoing erosion of subsurface soils which has resulted in sinkholes at the site. Further we warned that if measures are not taken soon to control the ongoing erosion of subsurface soils, new sinkholes will likely develop in the near term. To facilitate progress on these issues, we recommended a sequence of work

in our memorandum dated July 19, 2017. Since that time, the District has continued groundwater monitoring and site inspections. However, our recommendations have not been implemented. Our July 11, 2017 memorandum warned that if conditions continue to deteriorate, lack of action will likely result in access to Lots 7 and 8 being cut off in the relatively near future.

On May 25, 2018 District Staff observed new settlement and cracking in the patched asphalt within the temporary traffic detour on Gale Avenue North. Remaining geotechnical investigation options within the temporary detour were assessed to be impractical due to the presence of buried utilities and the potential for continually changing ground conditions. In the absence of groundwater management to mitigate the ongoing sinkhole process and pending sinkhole repairs, Thurber recommended full closure of Gale Avenue North to traffic to the west of Lot 6 in our memorandum dated June 15, 2018.

2. RECENT EVENTS

On September 19, 2018 residents of the development discovered a new sinkhole on Lot 6 which is private property with no structures. The surface expression of the sinkhole was approximately 1.5 m wide and 0.5 m deep. We understand that loose ground conditions were encountered to approximately 3 m depth when the base of the sinkhole was probed with a metal rod.

Plastic snow fencing has been installed around the perimeter of the Lot 6 sinkhole. No remedial work has been completed. The District installed yellow caution flagging along the edge of the Gale Avenue North right of way adjacent to Lot 6 and relocated the road closure traffic barriers approximately 20 m east (towards Crowston Road). Gale Avenue North is now closed to traffic between approximately the west edge of Lot 5 and the west edge of Lot 9.

3. COMMENTS ON RECENT LOT 6 SINKHOLE

3.1 Interpreted Sinkhole Formation Mechanism

The location of the sinkhole on Lot 6 coincides with the location of a groundwater spring mapped prior to construction (Figure 1). Available construction documents suggest that drainage blankets were installed where seepage was encountered during construction but that no filter exists between the fine native soils and coarse drainage blanket or that the filter is non-functioning. As such, there is a significant potential for groundwater related migration of native soils (i.e. subsurface soil erosion), resulting in undermining of fill embankments and structures.

In our opinion, the likely proximate cause of the Lot 6 sinkhole is an absent or non-functioning filter between the native soil and drainage blanket on Lot 6. Based on the groundwater monitoring data and site topography, it is very unlikely that the Lot 6 sinkhole is related to the buried storm sewer pipe situated between Lot 9 and Lot 10 or to the storm sewer along Gale Avenue North.

THURBER

3.2 Timing of Sinkhole Collapse

The Lot 6 sinkhole collapsed during the month of September. However, sinkhole collapses at the site typically have occurred between November and June when groundwater levels are rising or relatively high. In contrast in September, groundwater levels at the site are falling following the dry summer months (Figures 2 to 14). The unusual timing of the recent sinkhole collapse demonstrates that there is no period of the year during which sinkhole collapse is impossible.

The sinkhole collapsed following a period of intense rainfall. Environment Canada reported approximately 58 mm of precipitation within the 14 days prior to September 19, 2018. Climate Normals are not available for Sechelt but 58 mm of precipitation is the Normal total precipitation for all of September at the Gibsons – Gower Point weather station which typically receives more precipitation than Sechelt. The intense precipitation may be related to the timing of the sinkhole collapse but in our opinion the sinkhole formation mechanism had likely been active for years at this location prior to collapse.

3.3 Implications for the Site

In our opinion, the recent sinkhole on Lot 6 is symptomatic of the ongoing deterioration of subsurface conditions in this area and demonstrates that the sinkhole hazard is increasing with time and is not confined to locations where sinkholes have occurred previously.

4. RECOMMENDATIONS

4.1 Gale Avenue North

We strongly recommend that Gale Avenue North remain closed to vehicle traffic between approximately the west edge of Lot 5 and the west edge of Lot 9 in the interest of public safety. If remedial action including proactive groundwater management and repair of sinkholes is not completed, the closure of this section of Gale Avenue North should be considered permanent.

The sinkhole process also poses a hazard to pedestrians. While there is a relatively low probability that a pedestrian's weight would be sufficient to trigger collapse of an imminent sinkhole without some prior visible sign of ground deformation, we cannot guarantee this will not happen. Pedestrians need to be advised of the hazard and District Staff must continue to visually monitor the site for signs of ground surface deformation and actively deforming areas must be closed to pedestrian access. For example, a 2 m minimum pedestrian setback should be maintained from areas where the asphalt is showing signs of distress including locations where it has been patched.

The current limits of the road closure provide a geotechnical setback from the areas where sinkholes and ground settlement have been observed since 2012. However, these limits do not

represent a 'safe line' as the sinkhole hazard potentially affects all of the development west of Crowston Road.

4.2 Safety Warning Signs

We understand that the residents of The Shores development have been informed of the sinkhole hazard at the site. However, visitors to the site including service providers and passers-by may not be aware of the hazard which is not visible.

We recommend that warning signs be installed on Crowston Road at both entrances to the site including Gale Avenue North and Seawatch Lane to inform the general public of the sinkhole hazard (similar in purpose to rockfall hazard signs used on public highways) and to restrict access to local traffic.

4.3 Proactive Groundwater Management

The mounting evidence indicates that sinkholes continue to form and expand. Thurber continues to strongly recommend immediate proactive groundwater management to mitigate the ongoing erosion of subsurface soils which has resulted in sinkholes at the site and to mitigate the potential for piping erosion to expand. Groundwater management recommendations were provided in our July 11, 2017 memorandum.

4.4 Comprehensive Site Wide Sinkhole Investigation

We continue to recommend that a comprehensive site-wide investigation be completed immediately to identify areas where sinkholes may be developing. If this investigation is not completed, developing sinkholes may only be discovered when they collapse without warning which could result in harm to persons or property.

5. CLOSURE

The risk of sinkhole collapse is difficult to predict. In our opinion, the site will experience another sinkhole collapse in the near term. Future sinkholes could damage existing infrastructure such as underground utilities, roads or sidewalks, or private property including buildings and retaining walls. Injury or even death is a possible consequence. As such, we encourage in the strongest possible terms that all stakeholders proactively address the problems at the site. We recommend that the District advise the property owners, residents, potential users and other stakeholders of our recommendations.

We trust that this is sufficient for your present needs. Please contact us if you have any questions.

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
D. J. TARA

THURBER

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

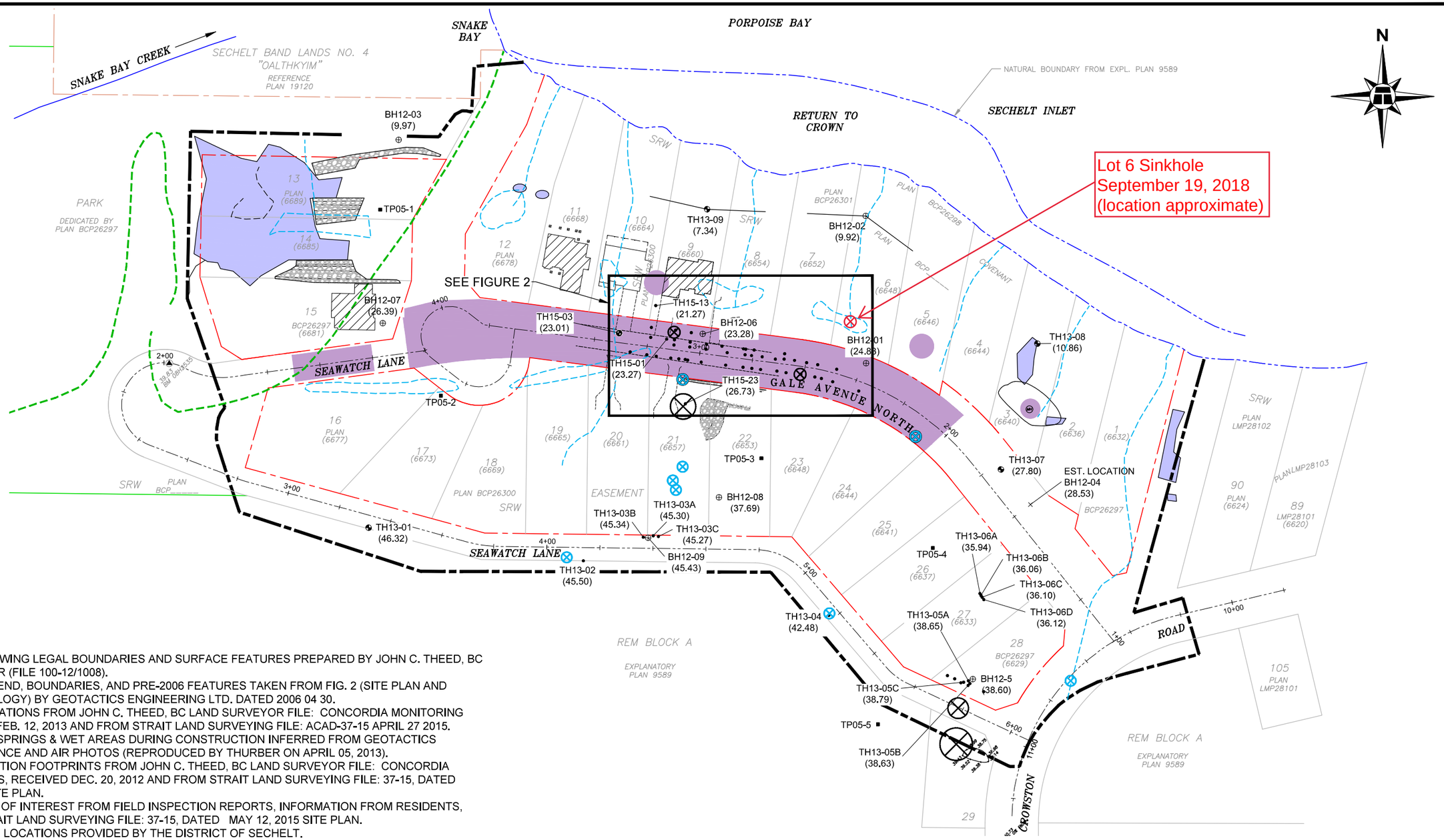
6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

Plotted: June 30, 2017



NOTES:

1. BASE PLAN SHOWING LEGAL BOUNDARIES AND SURFACE FEATURES PREPARED BY JOHN C. THEED, BC LAND SURVEYOR (FILE 100-12/1008).
2. PROPERTY LEGEND, BOUNDARIES, AND PRE-2006 FEATURES TAKEN FROM FIG. 2 (SITE PLAN AND SURFICIAL GEOLOGY) BY GEOTACTICS ENGINEERING LTD. DATED 2006 04 30.
3. TEST HOLE LOCATIONS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA MONITORING WELLS, DATED FEB. 12, 2013 AND FROM STRAIT LAND SURVEYING FILE: ACAD-37-15 APRIL 27 2015.
4. LOCATIONS OF SPRINGS & WET AREAS DURING CONSTRUCTION INFERRED FROM GEOTACTICS CORRESPONDENCE AND AIR PHOTOS (REPRODUCED BY THURBER ON APRIL 05, 2013).
5. HOUSE FOUNDATION FOOTPRINTS FROM JOHN C. THEED, BC LAND SURVEYOR FILE: CONCORDIA HOUSE LAYOUTS, RECEIVED DEC. 20, 2012 AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
6. 2015 FEATURES OF INTEREST FROM FIELD INSPECTION REPORTS, INFORMATION FROM RESIDENTS, AND FROM STRAIT LAND SURVEYING FILE: 37-15, DATED MAY 12, 2015 SITE PLAN.
7. 2017 TEST HOLE LOCATIONS PROVIDED BY THE DISTRICT OF SECHELT.

PROPERTY LEGEND (SEE NOTE 2):

- SUBJECT PROPERTY
- PROPERTY LINES
- NATURAL BOUNDARY
- IR RESERVE
- PARK BOUNDARY
- COVENANT
- RIGHT-OF-WAY
- PHASE 1 BOUNDARY
- ENVIRONMENTAL COVENANT LINE
- STREAMS

TEST HOLE LEGEND:

- ⊕ TEST HOLE WITH GROUNDWATER MONITORING WELL BY THURBER
- ● TEST HOLE BY THURBER
- ⊕ BOREHOLE WITH GROUNDWATER MONITORING WELL BY GOLDER
- × BOREHOLE BY GOLDER
- ■ TEST PIT BY OTHERS (FEB 2005, SEE NOTE 2)
- (38.65) ELEVATION OF WELL COVER OR GROUND SURFACE (m)

FEATURES LEGEND (LOCATIONS AND EXTENTS ARE APPROXIMATE):

- PRE 2006 SINKHOLE
- PRE 2006 SPRING OR STREAM
- POST 2006 SINKHOLE
- ROCK STACK RETAINING WALL (ONLY THOSE SURVEYED)
- HOUSE INCOMPLETE OR UNOCCUPIED (ONLY THOSE SURVEYED).
- PRE 2012 SPRING OR WET AREA NOTED DURING CONSTRUCTION
- 2015 SPRING OR WET AREA

THURBER ENGINEERING LTD.

CLIENT: DISTRICT OF SECHELT

TEST HOLE LOCATION AND SITE PLAN

THE SHORES - PHASE 1 SUBDIVISION — SECHELT, BC

DESIGNED	DRAWN	APPROVED
CHS	NAK/MOM	DJT

DATE	SCALE
30/06/17	1:1500

PROJECT No.	FIG. No.	REV.
11680	1	0

S:\Data\BST Projects\11xxx\11680\08_Drafting\03_Working\11680.dwg

CANCEL PRINTS BEARING EARLIER LETTER

THIS DRAWING IS THE PROPERTY OF THURBER AND MAY CONTAIN PROPRIETARY INFORMATION. WRITTEN APPROVAL MUST BE GIVEN BY THURBER PRIOR TO ANY INFORMATION CONTAINED HEREIN BEING USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT WAS ISSUED.

Figure 2. Change in Groundwater Elevations Since Initial Reading

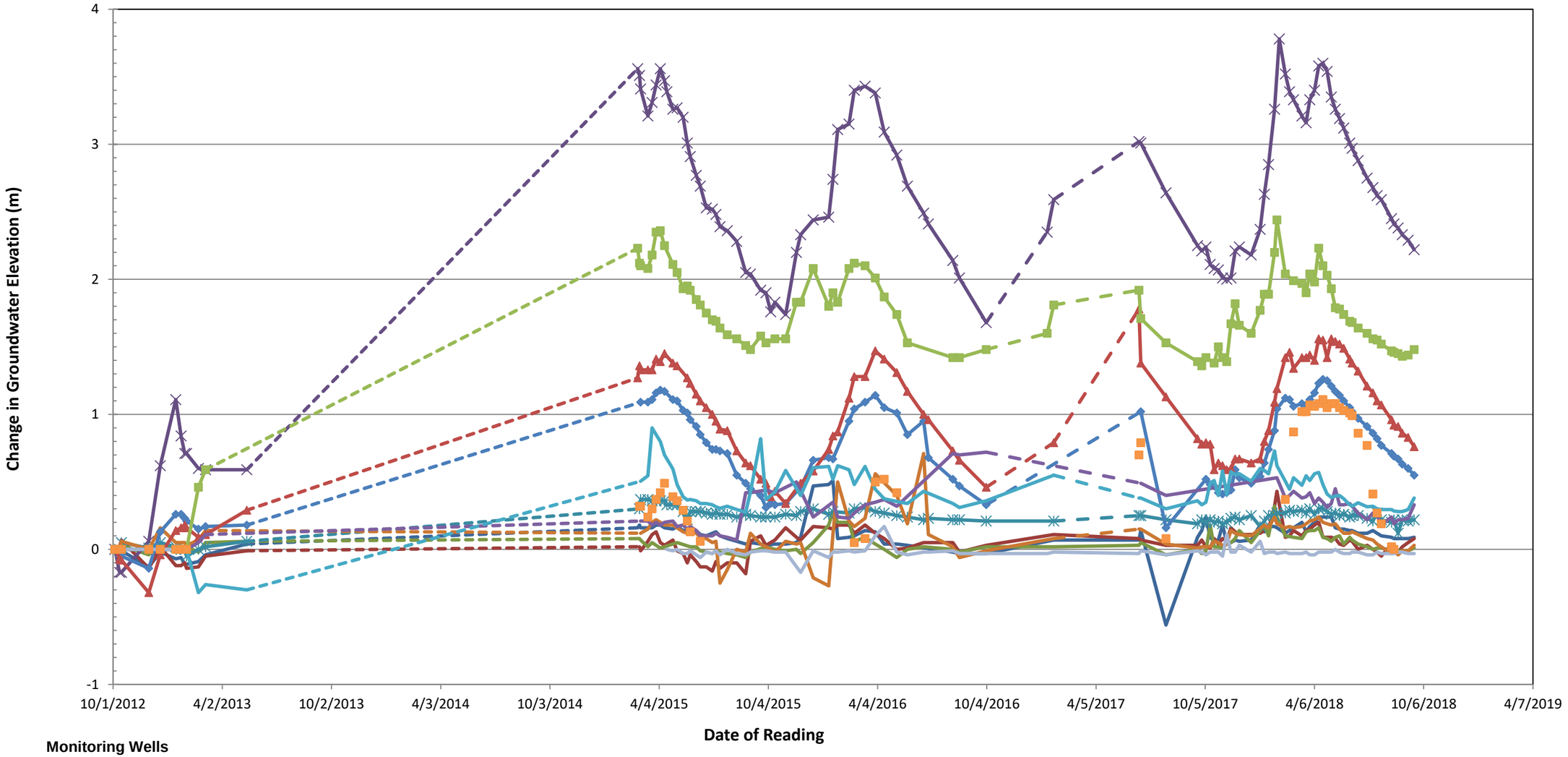


Figure 3. BH12-01 - Year to Year Comparison

(Mid-Slope adjacent to Lot 6)

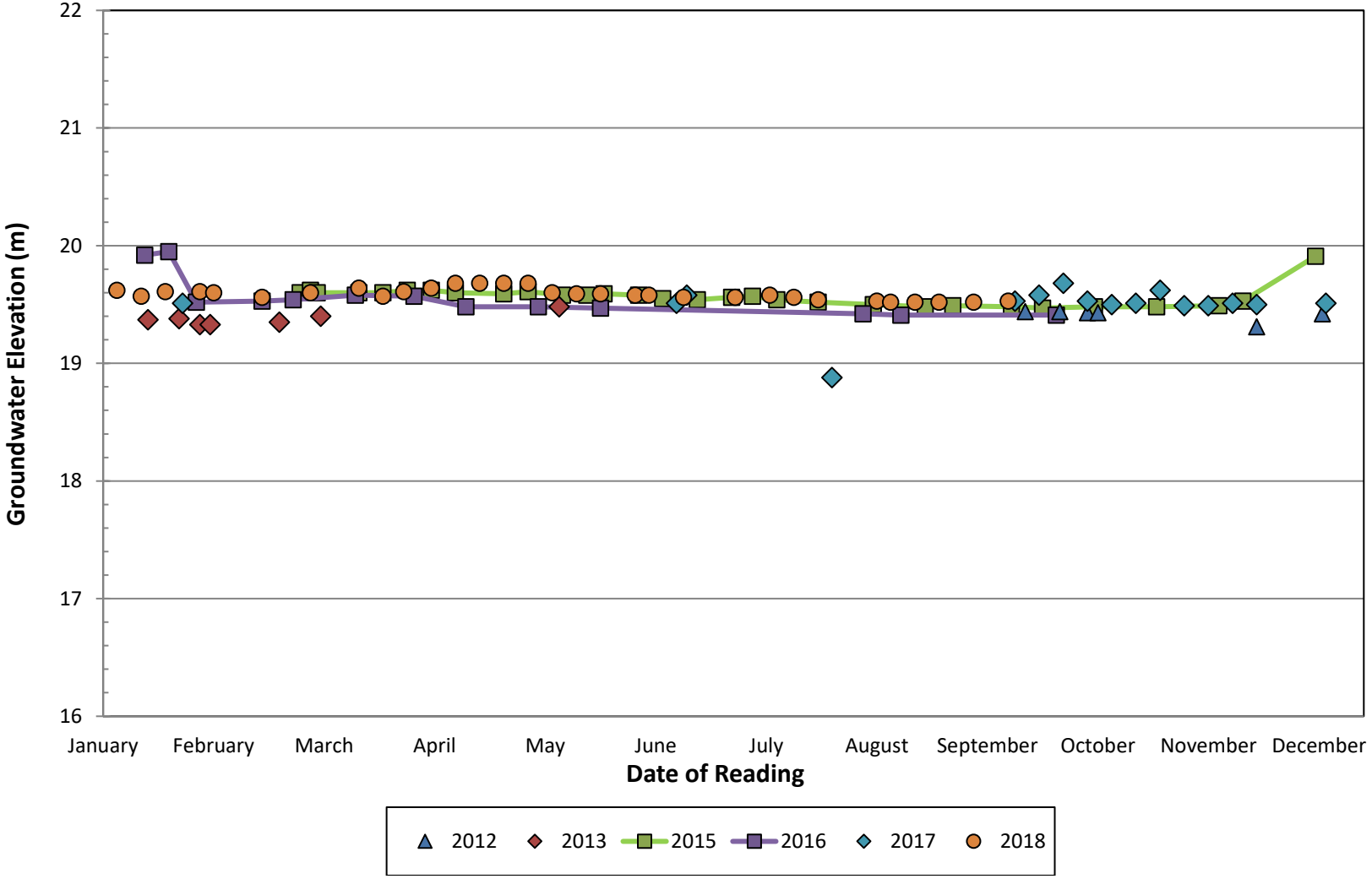


Figure 4. BH12-02 - Year to Year Comparison

(Lower-Slope adjacent to Lot 6)

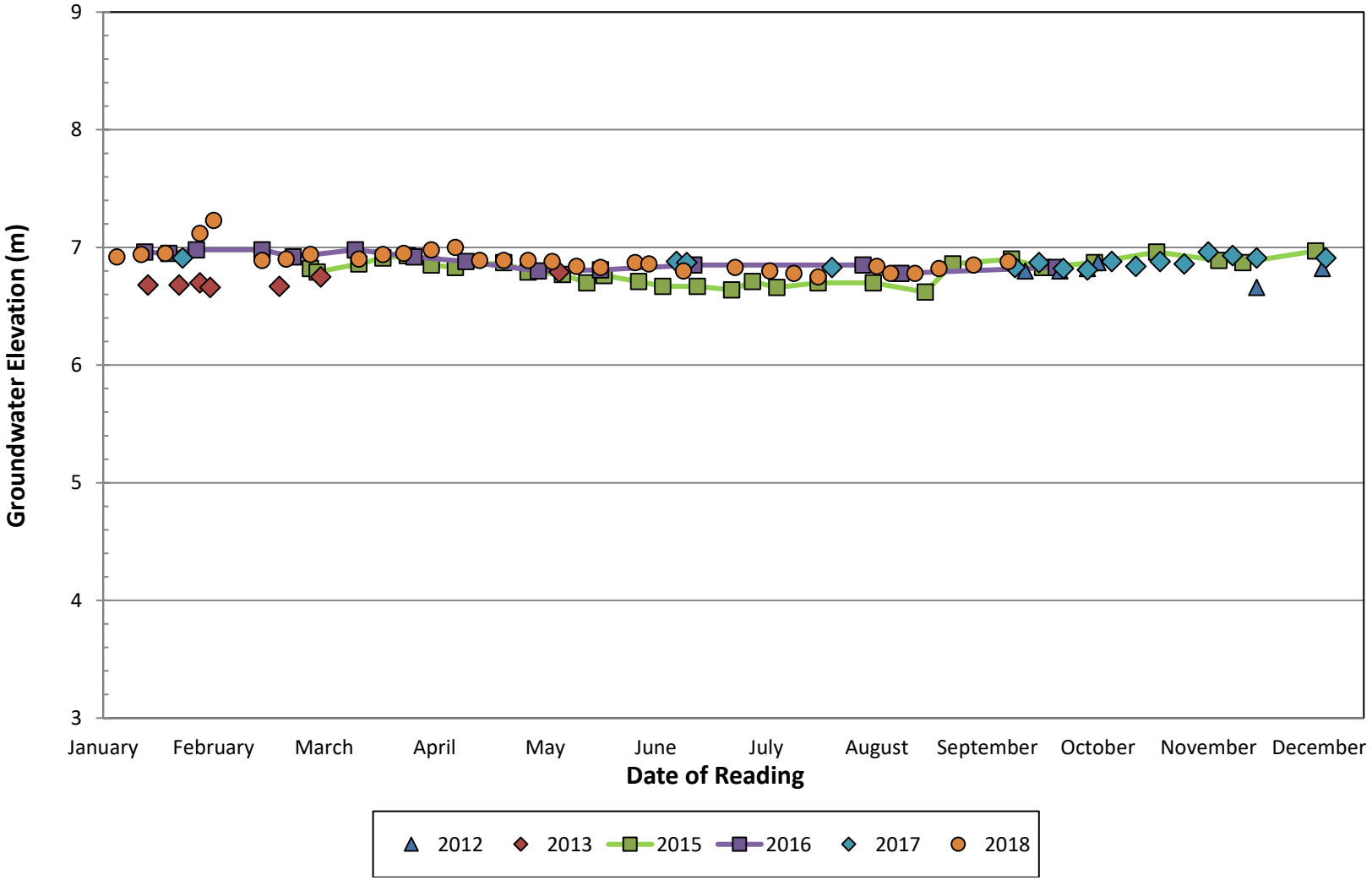


Figure 5. BH12-03 - Year to Year Comparison

(Lower-Slope adjacent to Lot 13)

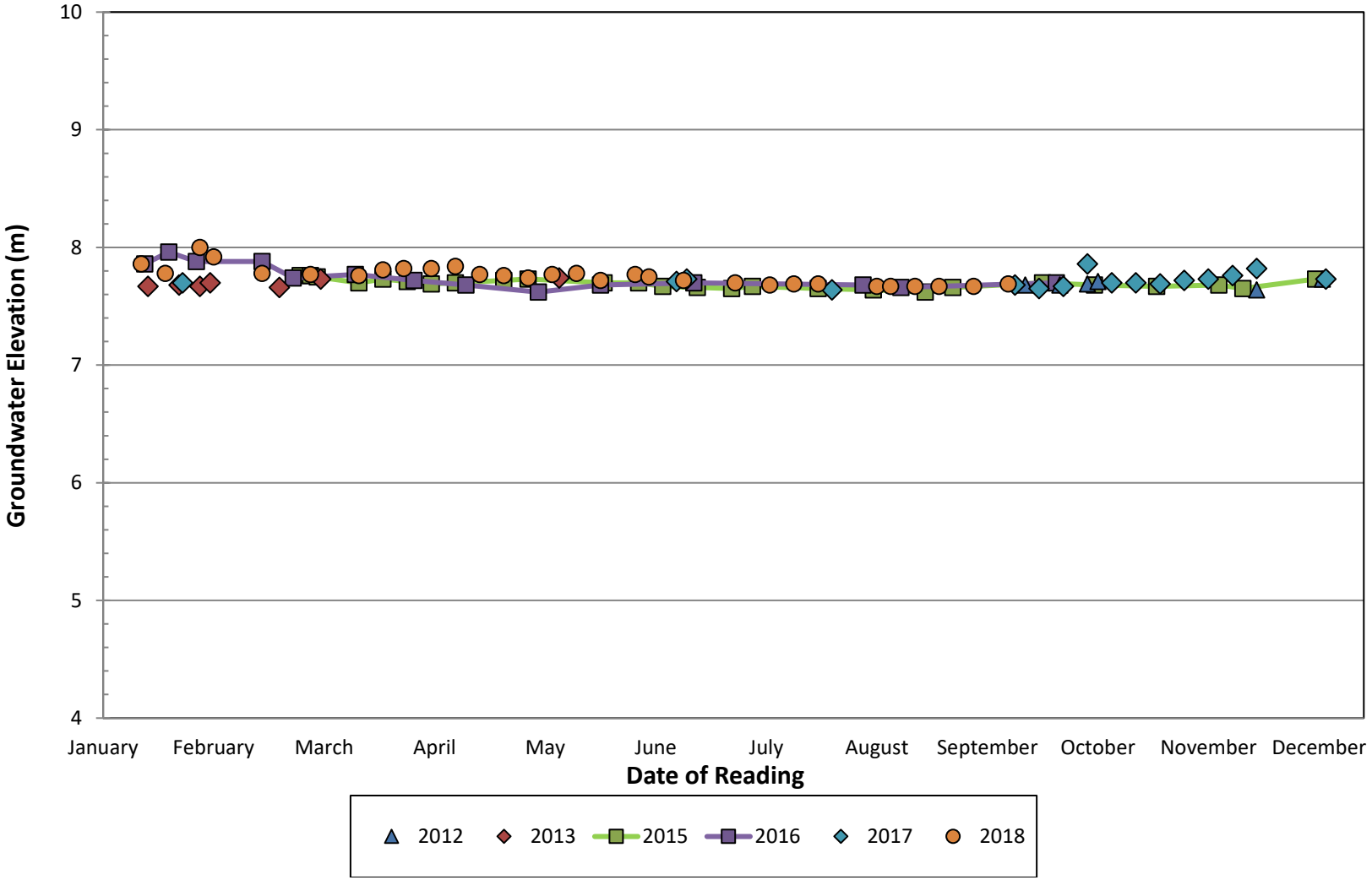


Figure 6. BH12-05 - Year to Year Comparison

(Upper-Slope at Lot 28)

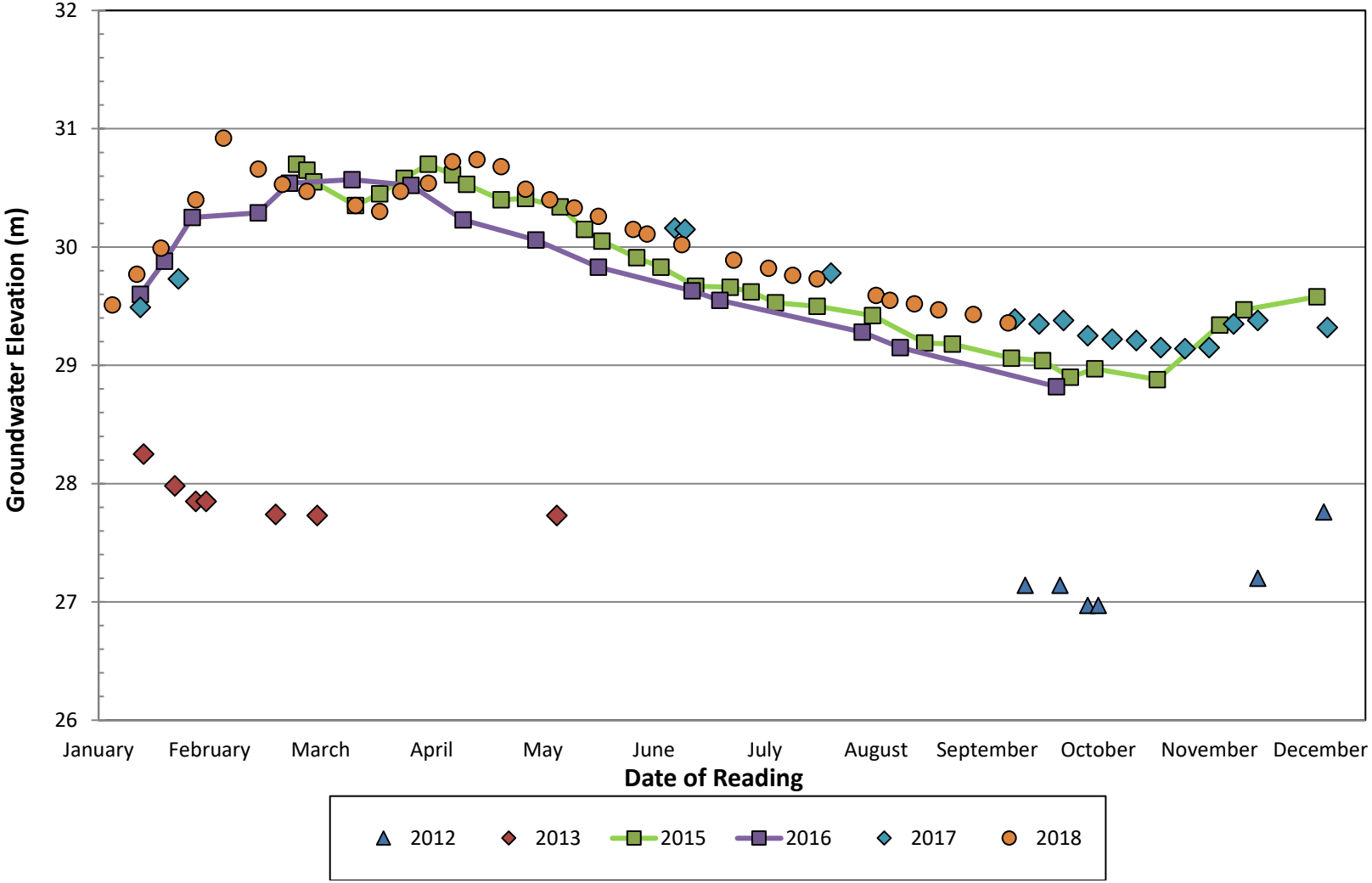


Figure 7. BH12-06- Year to Year Comparison

(Mid-Slope adjacent to Lot 9)

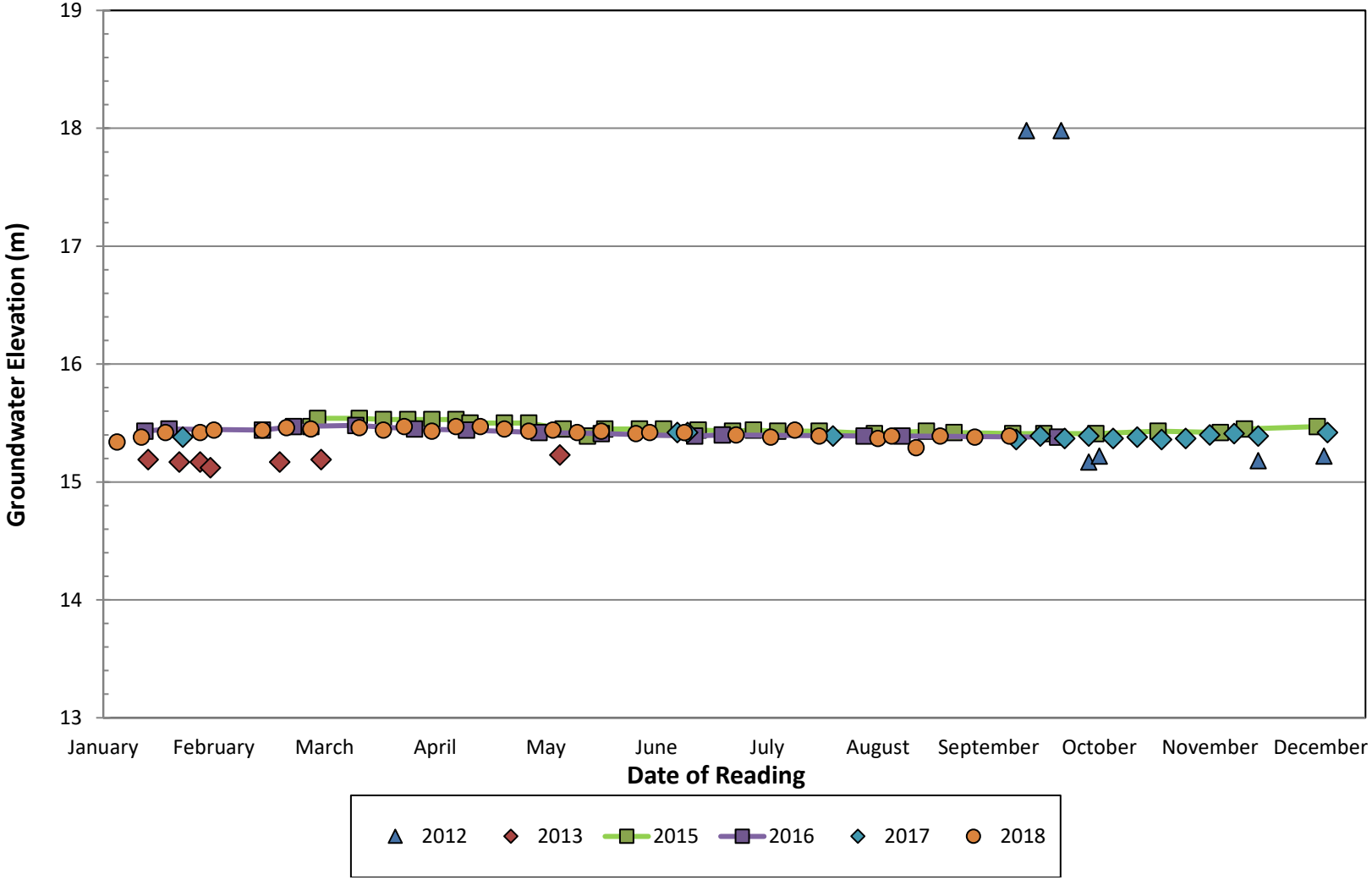


Figure 8. BH12-07 - Year to Year Comparison

(Mid-Slope at Lot 15)

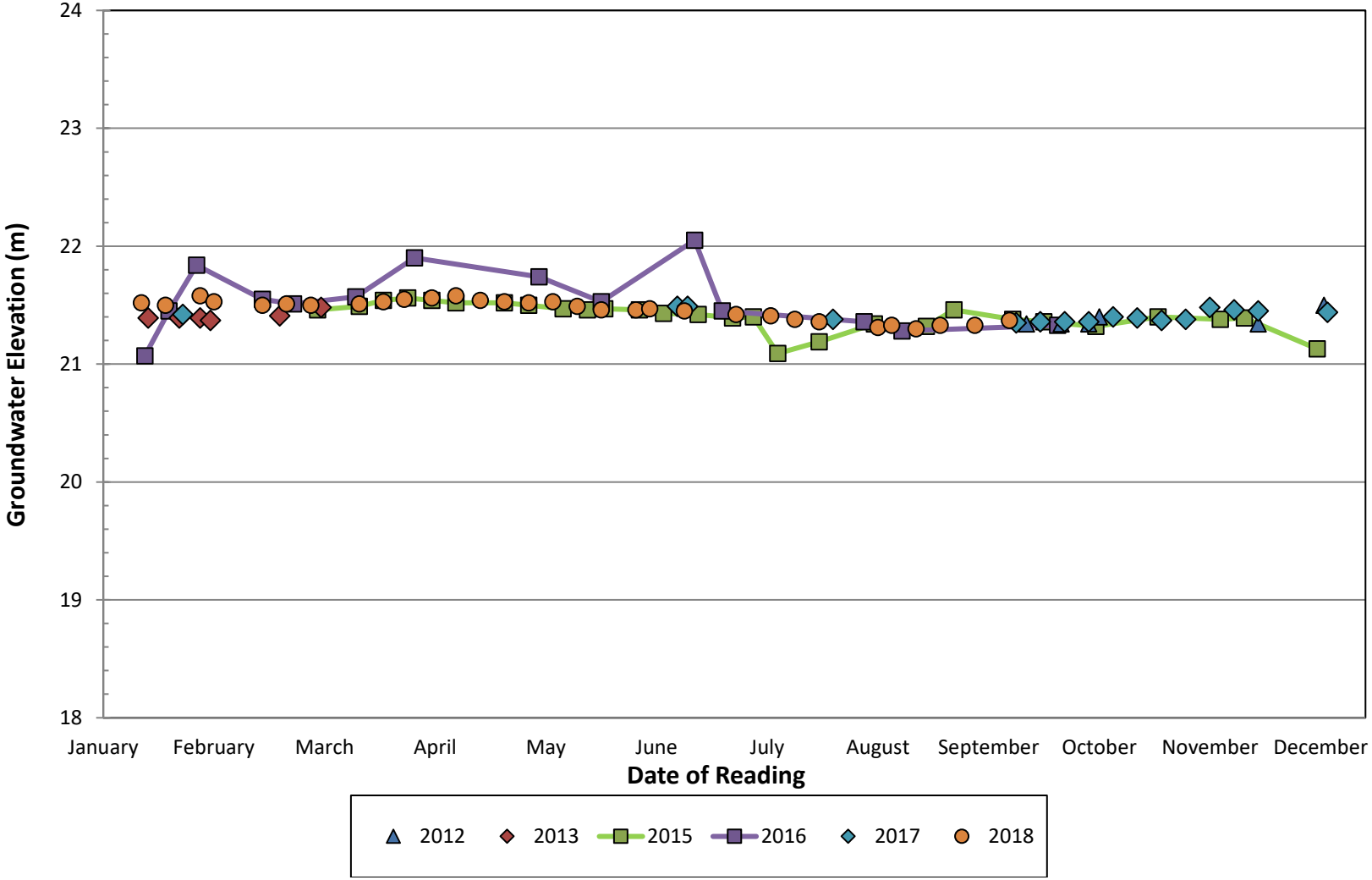


Figure 9. BH12-08 - Year to Year Comparison

(Upper-Slope at Lot 22)

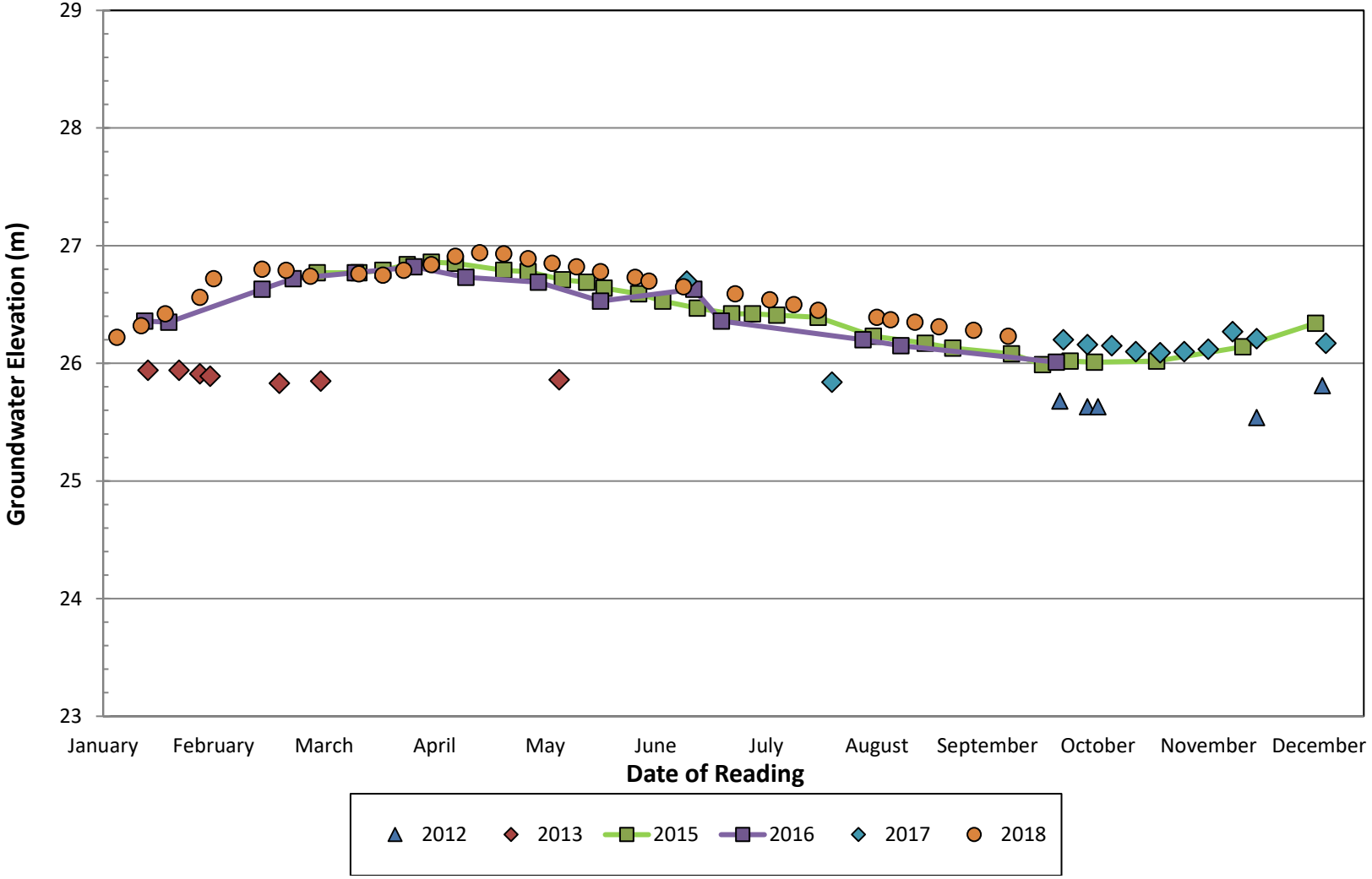


Figure 10. BH12-09 - Year to Year Comparison

(Upper-Slope at Lots 20 and 21)

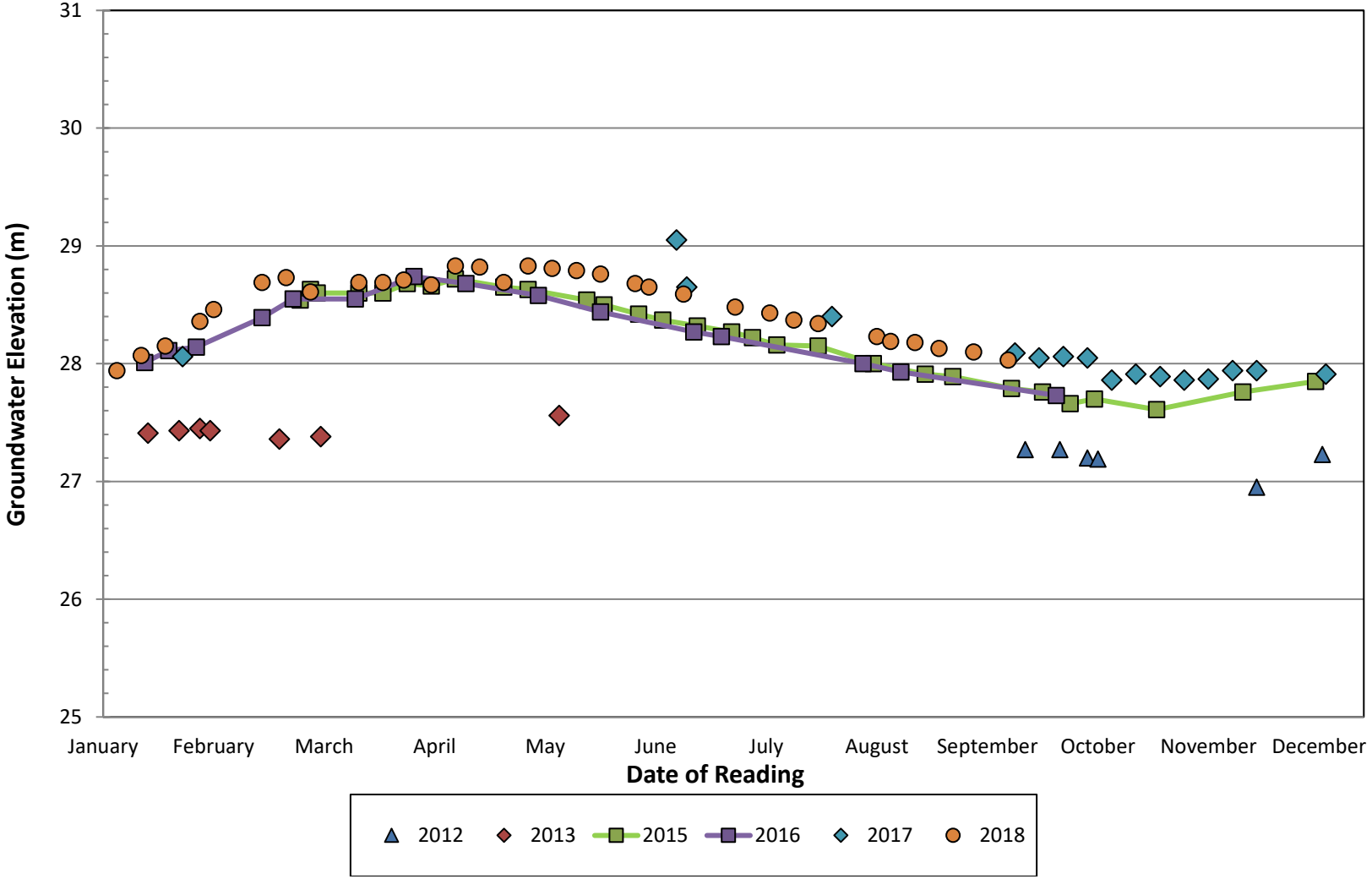


Figure 11. BH13-01 - Year to Year Comparison

(Upper-Slope at Lot 17)

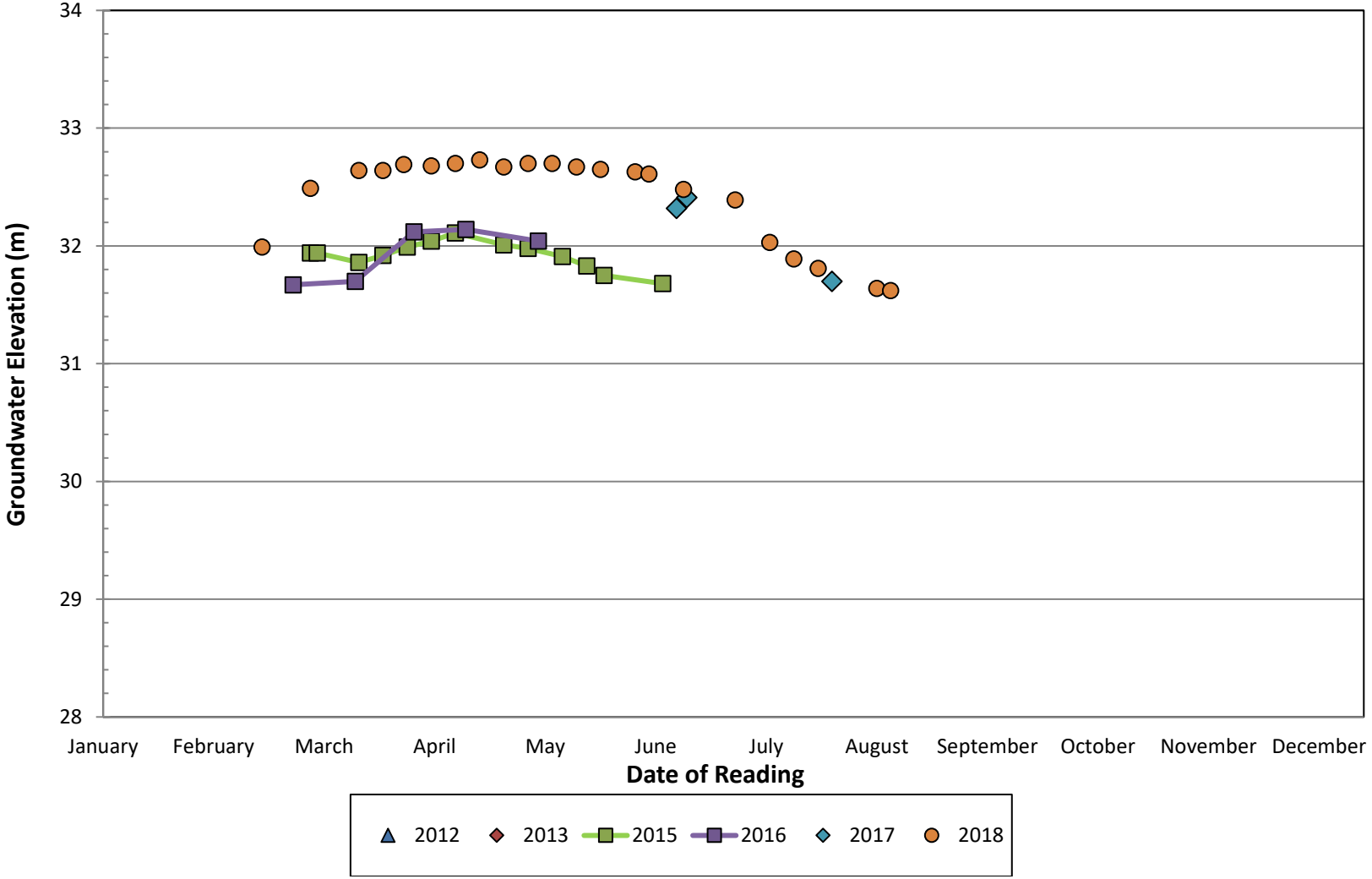


Figure 12. BH13-07 - Year to Year Comparison

(Mid-Slope adjacent to Lot 3)

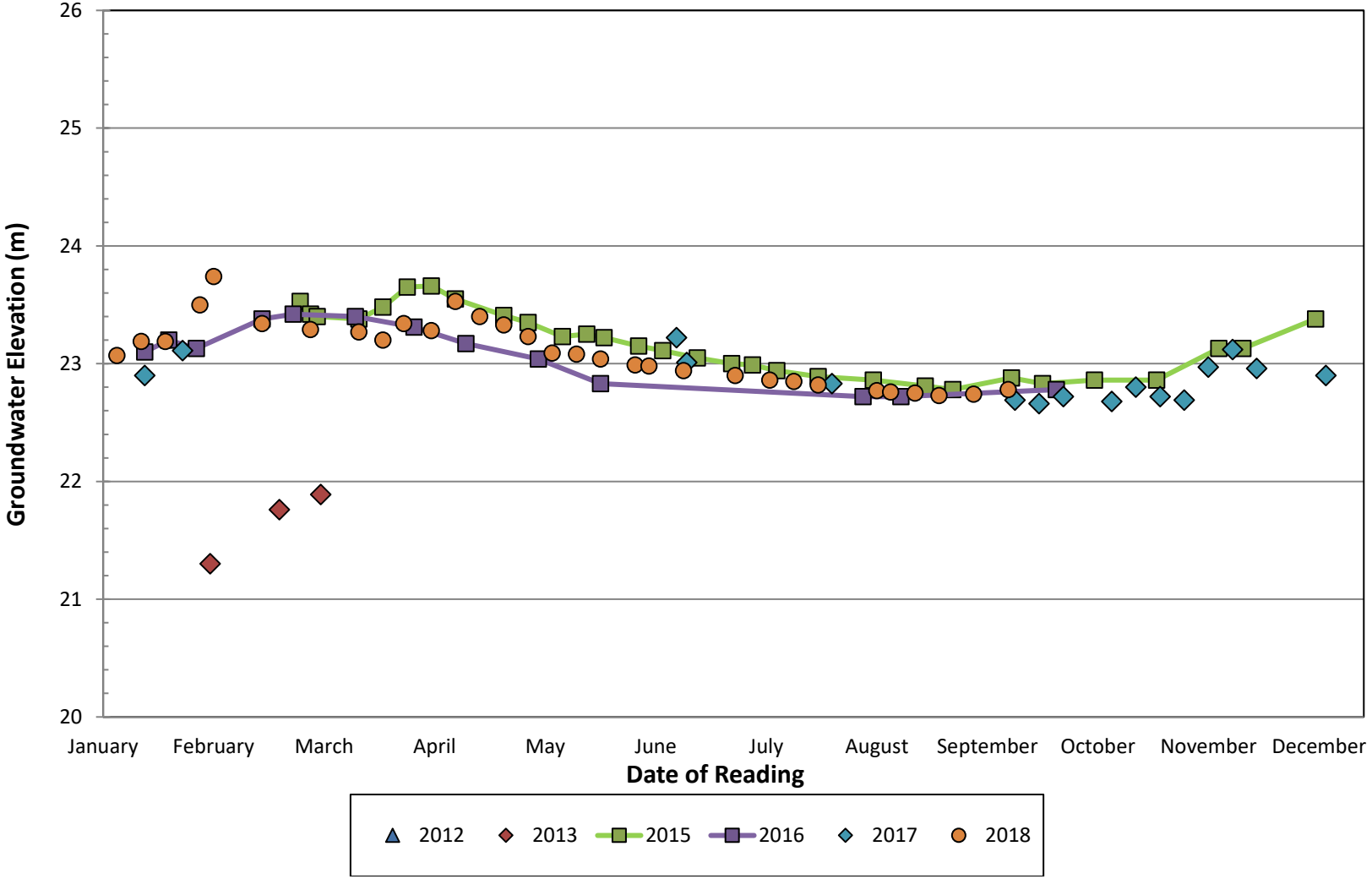


Figure 13. BH13-08 - Year to Year Comparison

(Lower-Slope adjacent to Lot 3)

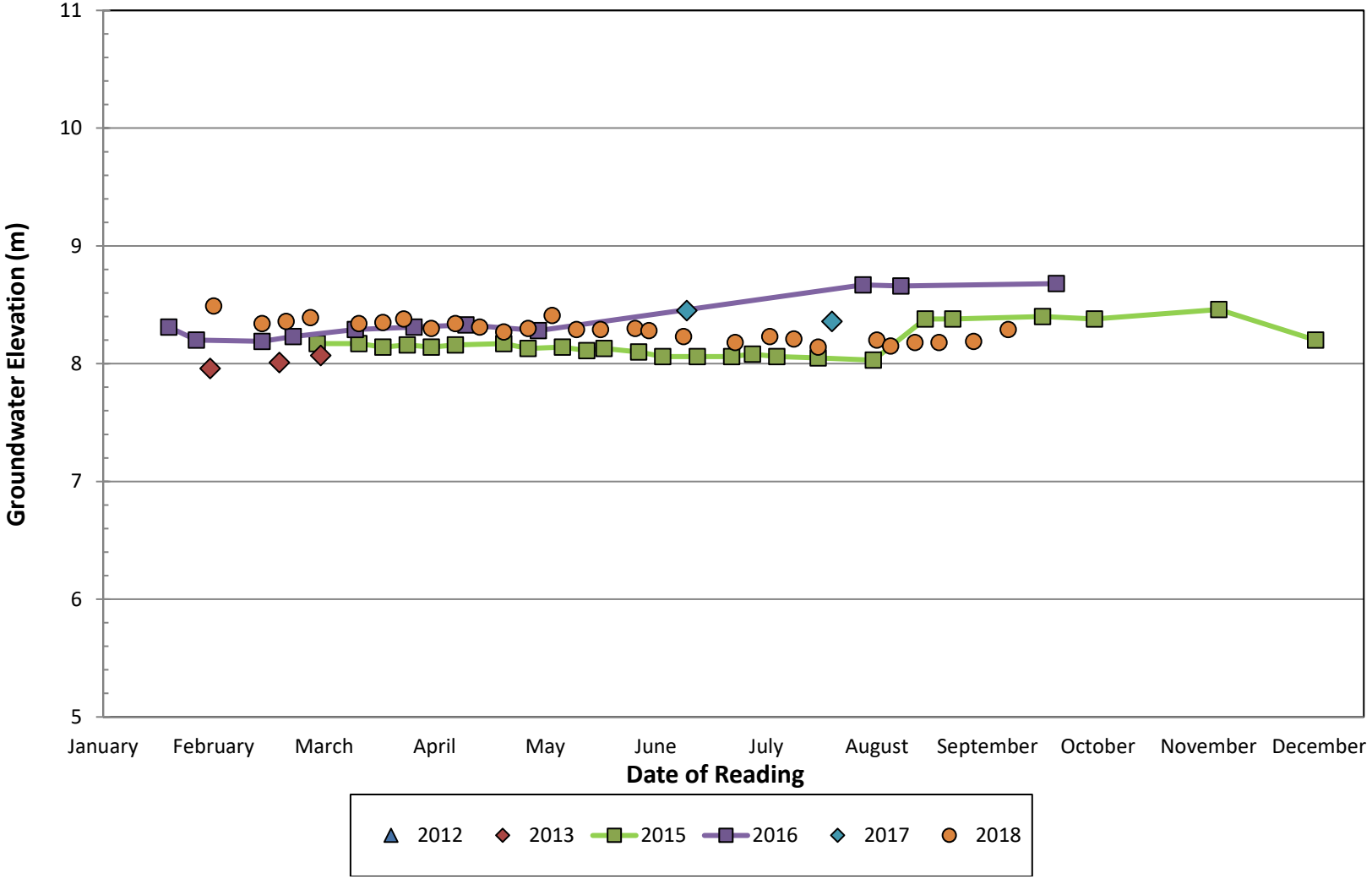


Figure 14. BH13-09 - Year to Year Comparison

(Lower-Slope adjacent to Lot 9)

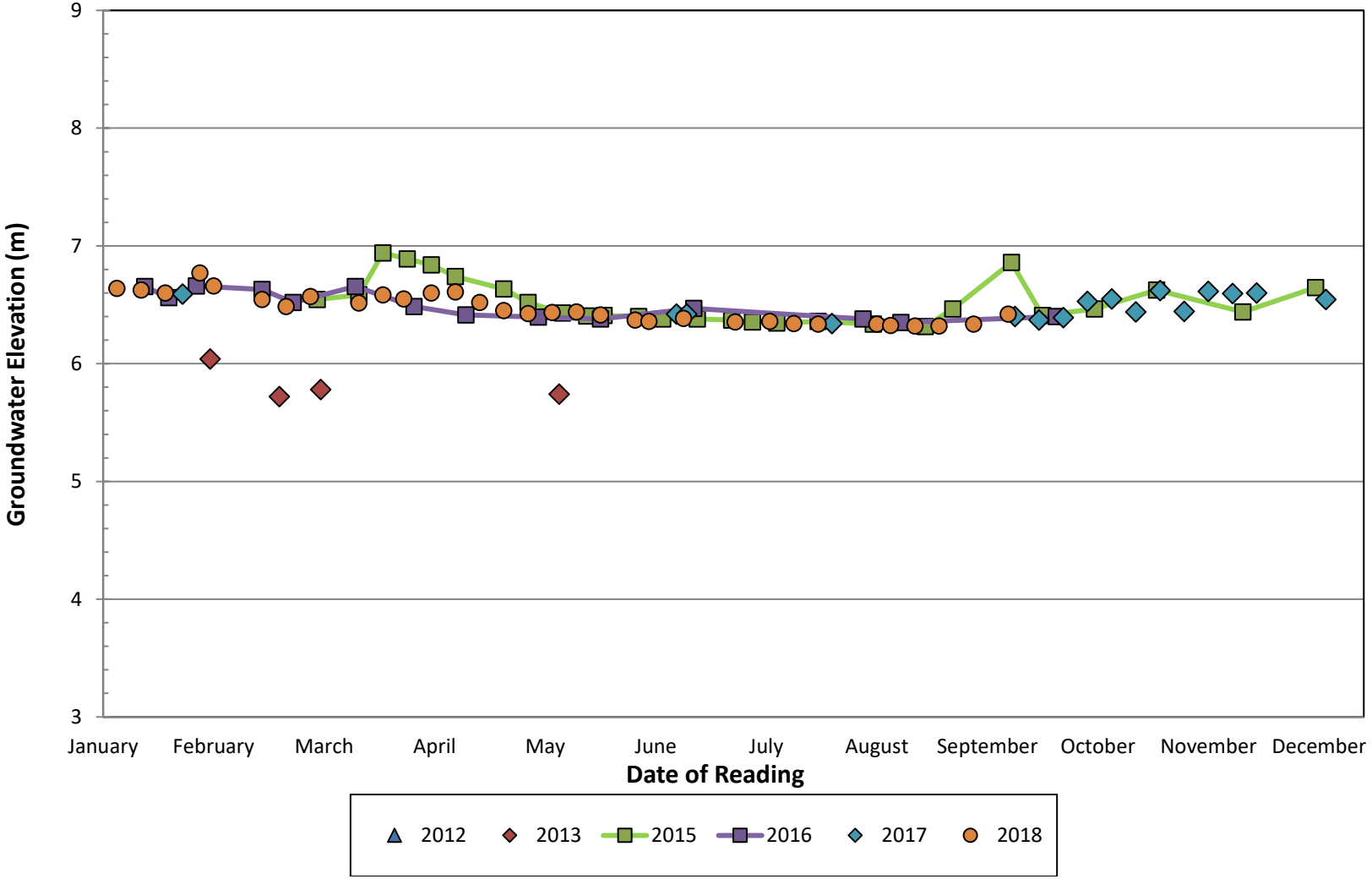


Figure 15. BH15-03 - Year to Year Comparison

(Mid-Slope adjacent to Lot 10)

