GPR Experiences

Depths to Utility Targets as Determined by GPR Imaging: A Field Study of Factors that Affect Depth Calculations

Author: Dennis Prezbindowski, Ph.D., GPR Instructor and Trainer with Staking University

Let's talk about ground penetrating radar (GPR) depth determinations as part of a continuing discussion of the use of GPR imaging to locate subsurface utilities (conductive and non-conductive) and subsurface structures and features that might represent financial and safety risks. In my experience, one of the most common questions that a GPR operator must deal with is "How deep is that target?" As all experienced GPR operators know, but sometimes fail to explain to others, GPR depth determinations can be erroneous due to changes in soil properties. GPR instruments measure the two-way travel time of an electromagnetic (EM) pulse from the transmitting antenna to a subsurface target and the reflected, returning EM portion of that pulse. The GPR depth to target is calculated by the GPR instrument using the two-way travel time (accurately measured) and an average substrate EM velocity (estimated). The biggest challenge in calculating an accurate depth to GPR target is the limitation in measuring accurate EM velocities to be used in-depth calculations over the project area.

What can a GPR operator do to determine a reasonable substrate velocity at a new project site? The GPR instrument manufacturers have provided several ways to approximate the EM subsurface velocities in the field so that approximate depths to GPR targets can be calculated. These are:

1) The ability to select among multiple, soil compositional types that closely approximates the soil conditions at your project site. These values can be in the form of a table (that can be manually entered), or soil condition categories provided as part of the setup procedure in the GPR instrument.

2) The calibration of the GPR can be accomplished by imaging a subsurface target of known depth (determined by exposure or probing) in your project area. This will allow the instrument to calculate an average substrate EM velocity for that location.

3) Use the technique of GPR target hyperbole (curve) matching to estimate the average velocity of the GPR EM pulses through the substrate at that location.

4) Measure the soil properties using a ground conductivity meter.

Each of these approaches has limitations and potential sources of error. As a result, the accuracies of calculated GPR target depths can vary across the project site. Based on my experience, the two most significant sources of error to GPR derived depth estimates are:

1) Error associated with the technique(s) used to estimate the substrate GPR velocities at the project site.

2) The lateral and vertical variations in substrate electromagnetic properties (GPR velocities) within a project area. Subsurface variability is common at many project sites. From a practical project point of view, it is impossible to quantify the amount of error that is associated with project-wide depth determinations made with a single velocity estimate.

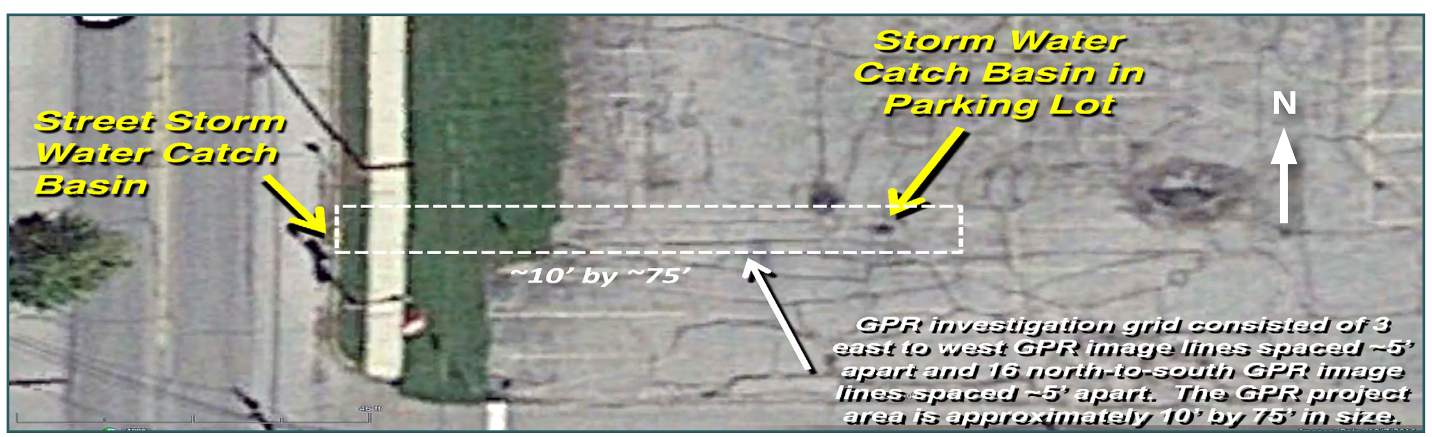


Fig. 1: Google Earth photograph of a Northeast street corner in North Webster, Indiana. An extensive GPR survey was conducted to locate underground utilities and structures before the start of a construction project. This short article focuses on a small, detailed GPR grid imaging of a stormwater line that runs from the street stormwater catch basin to the stormwater catch basin located in the parking lot (the area inside the white dashed rectangle).

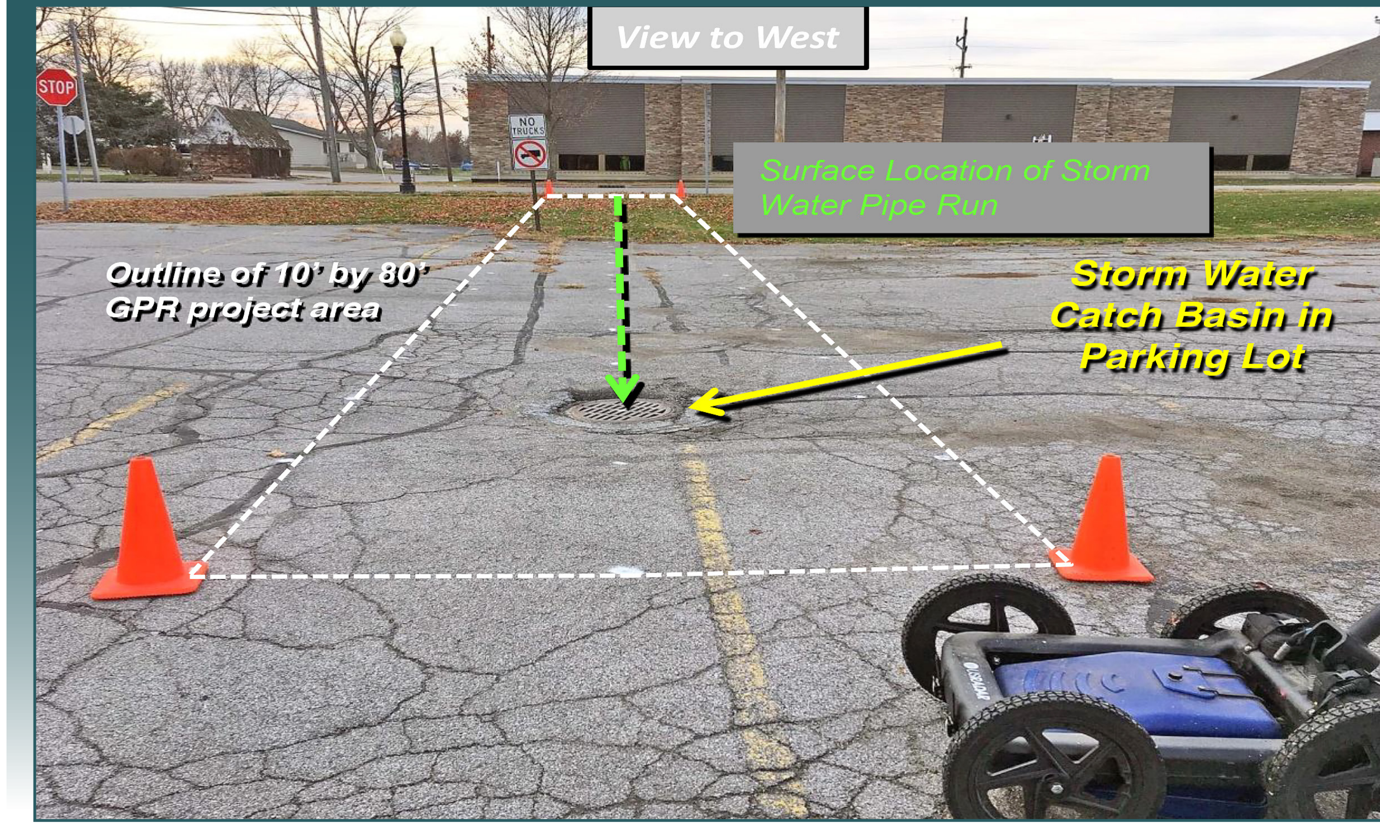


Fig. 2: Outline of the particular GPR grid project area (10' by 75' white dashed area) is shown. The green illustrates the approximate surface location of the subsurface, 12" diameter, metal, corrugated stormwater line running from the street to the storm water catch basin in the parking lot dashed arrow.

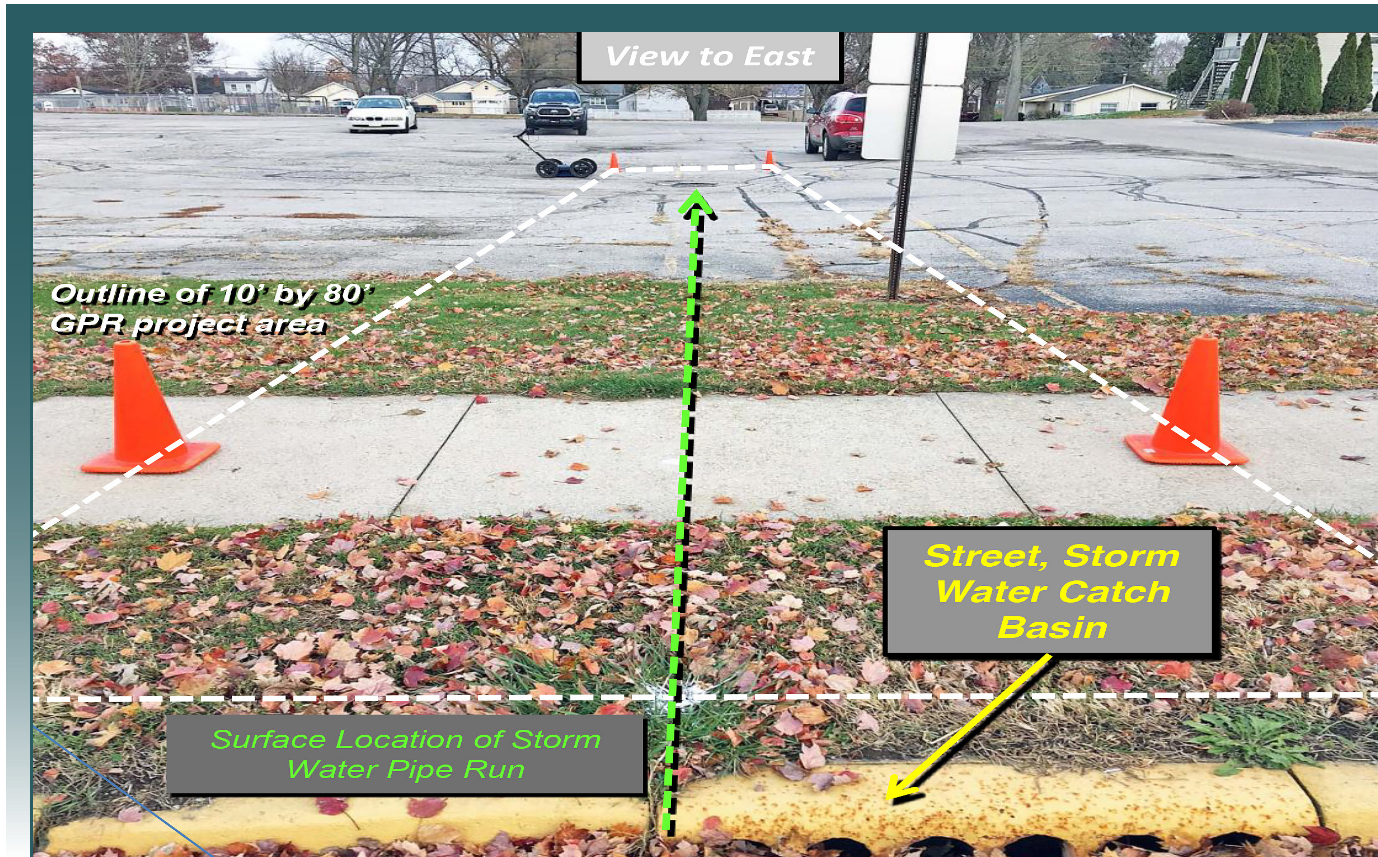
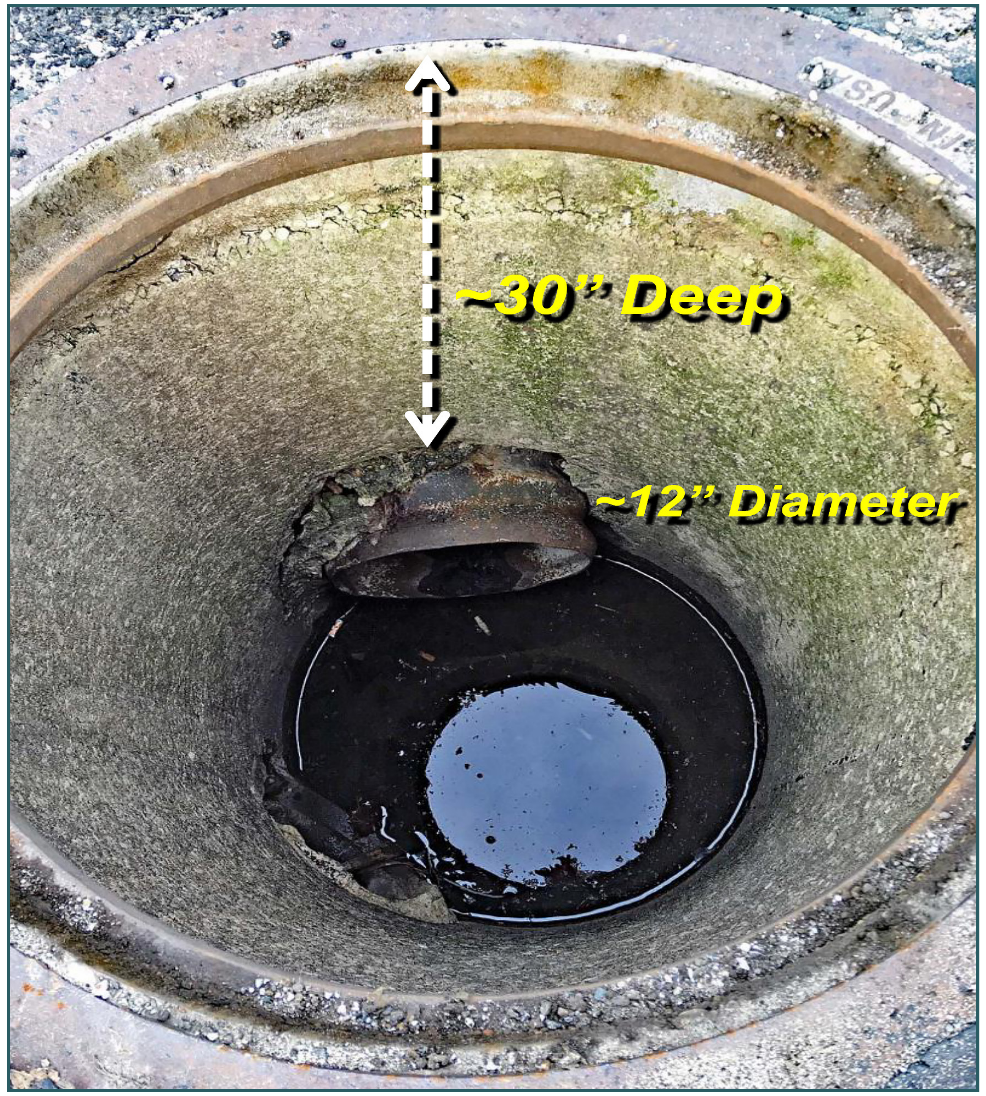


Fig. 3: Picture of the origin point of the 12" diameter, metal corrugated stormwater line running from the street to the storm water catch basin in the parking lot.

Case Study of Rapid Lateral Changes in GPR Substrate Velocities...

During nearly 18 years of conducting GPR imaging projects, I have noted that significant changes in GPR velocities in both lateral and vertical directions and seasonal changes are the norm. Recently, I conducted a GPR survey to help locate utilities and underground structures in a parking lot area that was to undergo redevelopment for a new town library. While conducting the initial GPR survey, I noted that there seemed to be significant changes in substrate GPR velocities over short distances as measured by curve matching of a single utility target. I returned to this site to investigate and potentially document these rapid, lateral changes in substrate GPR velocities.

I conducted a 10' by 75' GPR imaging grid project with 5-foot line spacing (Figure 1) along the axis of a previously imaged, continuous stormwater pipe that runs from the edge of a street to a stormwater catch basin located in a parking lot (Figures 2, 3 and 4). This stormwater pipe had a 12" diameter and a visible initiation and termination points (Figures 2 and 3). The depth to the top of this metal stormwater pipe at the catch basin measured 30 inches (Figure 4).



Selected results of the GPR grid project are presented in Figures 5, 6 and 7. The GPR image profile along the axis of the metal stormwater pipe has a strong top of pipe reflection that varies in depth and amplitude from the stormwater catch basin to the street catch basin (Figure 5). Symmetric hyperbola reflections from the metal stormwater pipe are apparent in the multiple north-to-south GPR image profiles (Figure 6). A US Radar, Inc. Quantum Imager, used in this study, can estimate the dielectric constant of the substrate by using the curve (hyperbole) matching technique. The dielectric constants were determined for eight successive perpendicular GPR image lines 5 foot apart over a distance 35 feet (Figure 7) where the surface appeared to be very uniform (asphalt parking lot, see Figures 1, 2 and 3). The estimated dielectric constants determined every 5-feet shows high variability (approximately 30%) over a short distance of 35 feet (Figure 7). It is my opinion that the apparent roller coaster like depth profile illustrated in the up-the-axis GPR image profile of the stormwater pipe (Figure 7) is primarily controlled by changes in substrate properties. When EM velocities change along a GPR image line whose target depths are calculated from a single soil velocity estimate, target depth errors will occur. In this case, an unrealistic, imaged stormwater pipe run profile (Figure 5) is due to significant lateral changes in substrate GPR velocities that are not accounted for in the depth calculations.

Fig. 4: Picture of the open "Storm Water Catch Basin" in the parking lot imaging the termination point of the ~12" diameter, metal corrugated storm water line. The top of the pipe is approximately 30" from the surface.

Take Aways...

1) This GPR project demonstrates that GPR depth estimate errors using a single estimated GPR velocity for a project area are possible with changing substrate properties.

2) The internal geometry of subsurface 3D GPR project image cubes and cross-sections can be distorted by lateral and vertical changes in substrate GPR velocities (EM properties). Depth distortions occur when a single GPR velocity

3) GPR depth determinations should only be considered estimates. If depth values are essential to the project objectives direct exposure, or direct probing of the imaged target(s) should be completed to establish accurate depths.

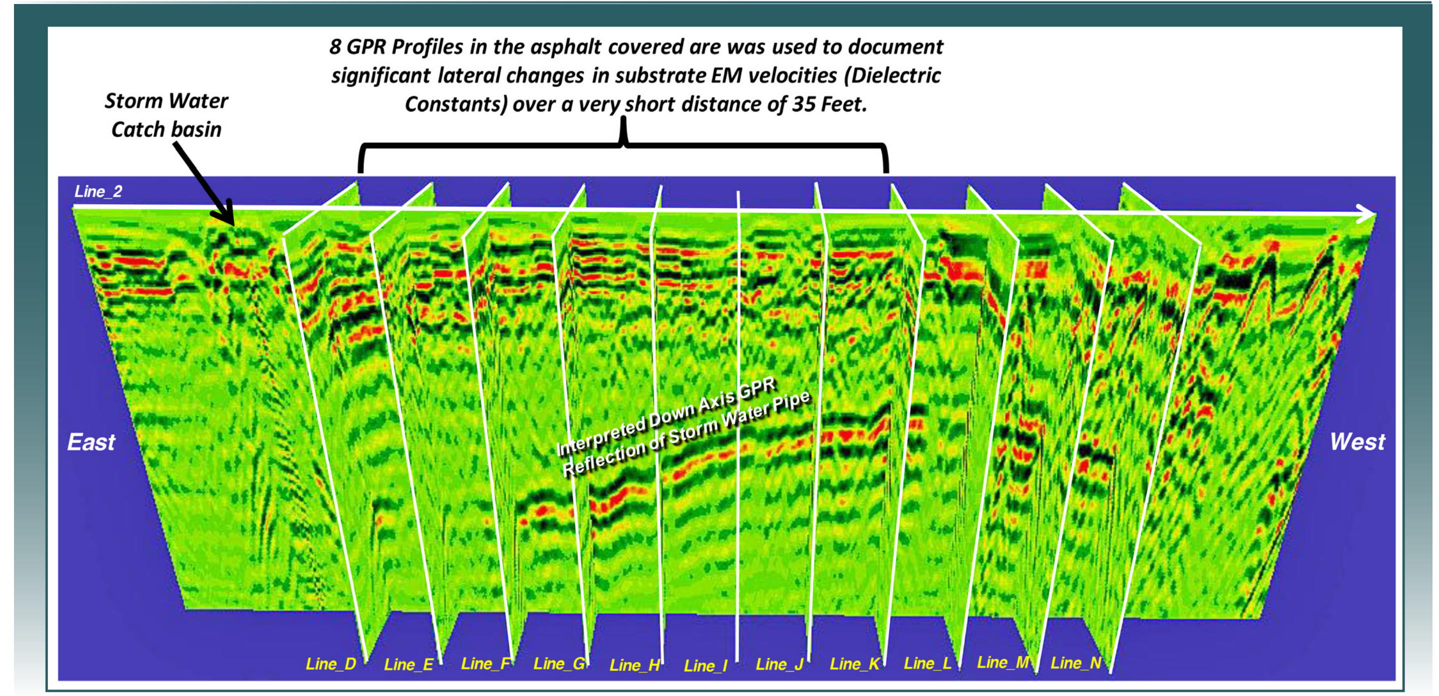


Fig. 5: GPR image grid using selected east to west and north to south GPR lines of the stormwater line. Eight consecutive GPR lines on the asphalt parking lot surface were used to investigate lateral changes in subsurface GPR velocities.

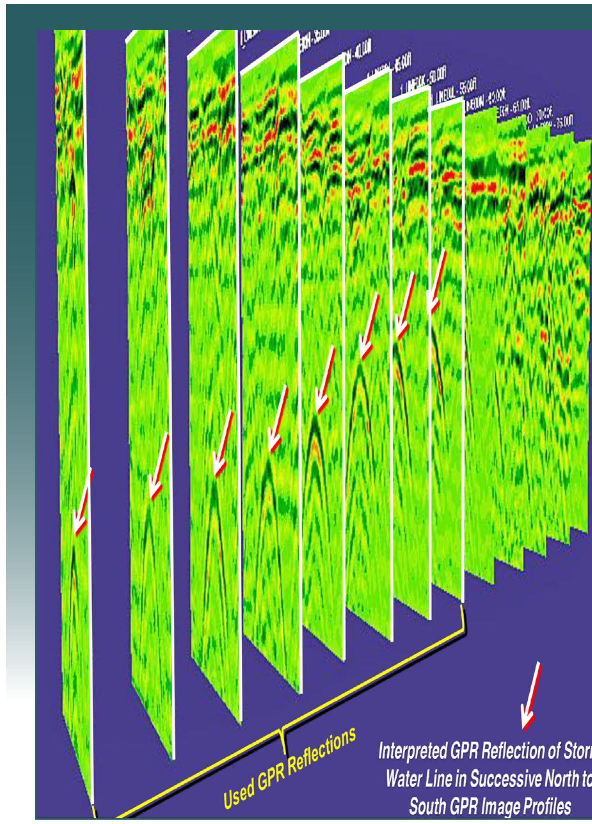


Fig. 6: GPR image grid using selected east to west GPR lines of the stormwater line. Eight consecutive north to south GPR lines across the asphalt parking lot surface was used to investigate lateral changes in subsurface GPR velocities using the GPR reflections from the surface stormwater pipe. A velocity was estimated for each successive target reflection (stormwater pipe) using a curve matching technique.

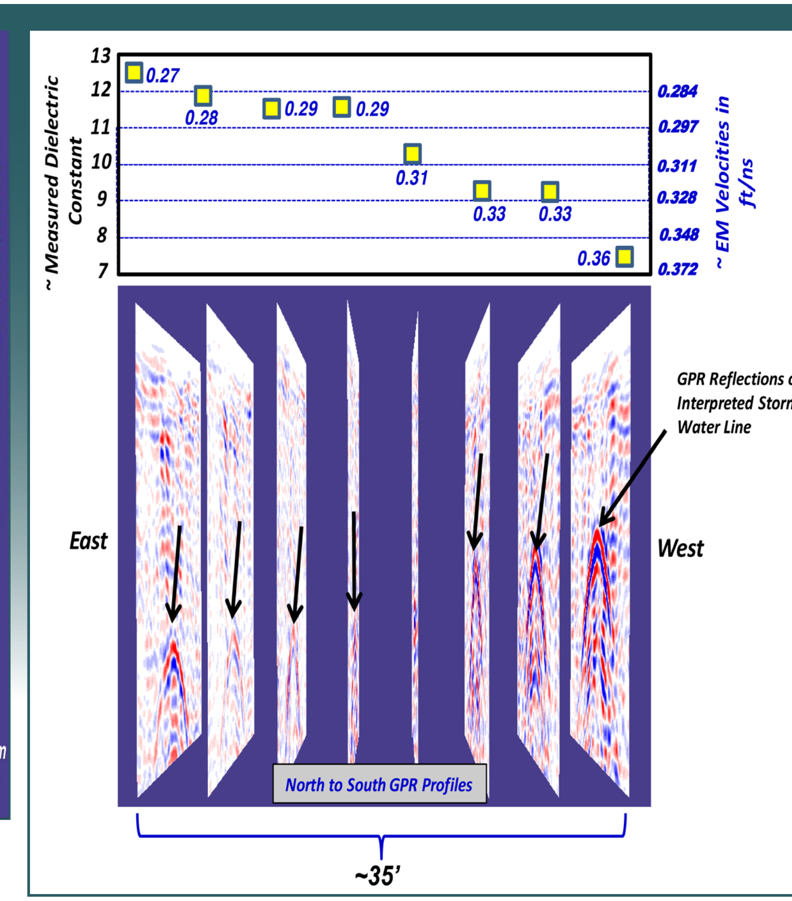


Fig. 7: The curve matched GPR velocities for each successive GPR target reflection of the stormwater pipe is illustrated above the successive GPR image profiles. Note that there is an ~30% change in subsurface velocities over a 35-foot distance along the stormwater pipe. This result implies that any depth determines made from using a single GPR velocity (single curve matching number) could have very significant depth errors.