SolSpec
AERIAL ANALYTICS

August 28, 2019

Rosemary Chiavetta
Secretary
Pennsylvania Public Utility Commission
400 North Street
Harrisburg, PA 17120

RE: **Docket No. L-2019-3010267**
Advance Notice of Proposed Rulemaking
Hazardous Liquid Public Utility Safety Standards at 52 Pa. Code Chapter 59

Dear Secretary Chiavetta:

Thank you for the opportunity to comment on the Advance Notice of Proposed Rulemaking (ANOPR) regarding the amendment and enhancement of Chapter 59 (52 Pa. Code Ch. 59) of the Pennsylvania Public Utility Commission's (Commission) regulations to enable the Commission to more comprehensively regulate public utilities transporting petroleum products and other hazardous liquids in intrastate commerce.

SolSpec was founded in 2017 with a vision to improve environmental and public safety and to increase efficiencies for the energy industry. SolSpec's software platform services the widespread use of aerial imagery, and while Unmanned Aerial Vehicles (UAVs) and other aerial data acquisition tools are an important part of the process, at SolSpec they're the just first step in advancing pipeline integrity technology with decision tools for risk and resource management. SolSpec's easy-to-interpret geospatial models show companies where vulnerabilities to environmental hazards like slips and unstable soils exist, where contractors might have missed the mark with re-vegetation, erosion control, and more. Our experts provide pipeline operators and their contractors with extensive support to ensure that data deliverables meet clients' specific needs for compliance, risk management, and business efficiencies. Our data processing is extremely fast: SolSpec has reduced the time it takes to process and deliver complex aerial data into the hands of clients from 4 months to 72 hours.

The ANOPR related to pipeline safety regulations notes that Pennsylvania has adopted the minimum federal pipeline safety standards and participates in the pipeline safety program administered by the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA). While participating states must adopt the minimum federal pipeline safety standards, they may pass more stringent regulations. As such, the Commission may adopt standards beyond the minimum federal pipeline safety standards.

The Commission's ANOPR offered several possible subject areas that commenters may wish to address, including:

- Pipeline material and specification.
- **Cover over buried pipelines**.
- Underground clearances.
- **Valves**.
- Pipeline conversion.
- **Construction compliance**.
- Pressure testing and maximum operating pressure.
- **Line markers**.
- **Inspections of pipeline right-of-way (ROW)**.
- Emergency flow restricting devices.
- **Leak detection**.
- Corrosion control and cathodic protection.

- Utility interactions with local government officials.
- Requirements for periodic public awareness meetings.
- Pennsylvania specific enhancements to utility public awareness programs.
- Regulation of construction techniques such as horizontal directional drilling.
- Accident and incident reporting criteria.
- Protection of public and private water wells and supplies.
- Land agents and eminent domain.
- Background investigations of employees and contractors.
- Integration of new regulations on existing facilities.

While the Commission offered those subject areas for possible comment, it also emphasized that the scope of comments is not limited to just those areas, and concerned parties may wish to raise additional matters.

In response to the Commission's request, SolSpec respectfully offers herein comments and evidence supporting the use of aerial inspection and analytics to enhance pipeline safety performance in Pennsylvania. **In order to empower operators with the information they need to proactively identify, manage, and mitigate environmental threats to pipeline integrity, SolSpec requests that policy makers and regulators endorse/allow the use of aerial inspection and analytics as a tool for achieving compliance with pipeline design, construction, and operations requirements.**

Generally, federal, state and local policies require that pipeline construction and operations comply with a myriad of public and environmental health and safety protocols, such as stormwater inspection and geohazard identification and monitoring. With the potential for multiple levels of regulation, aerial analytics technology provides environmental inspectors, collaborating agencies, and pipeline operators overseeing infrastructure construction and operations projects with an environmental hazard planning, monitoring, and inspection tool that offers improved cost-effectiveness, depth of deliverables, safety, transparency, compliance, and scalability.

Although not specifically mentioned in the ANOPR, the Commission must work together with the Pennsylvania Department of Environmental Protection (PADEP), which is responsible for administering a host of permitting and plan approval requirements related to the siting and construction of natural gas and related facilities. PADEP responsibilities include permits to guard against erosion, sedimentation and increased stormwater runoff; to ensure wetlands and waterways are protected; and to protect rare, threatened and endangered species and their habitat.[1]

Moreover, PADEP is authorized to delegate certain permitting and enforcement responsibilities for erosion, sedimentation and stormwater management programs to county conservation districts. This generally includes environmental permits for transmission pipelines, transmission system compressor locations, gas purification and scrubber facilities.[2]

Municipal governments (boroughs, cities and townships) that choose to enact zoning and related ordinances can determine in which zoning districts compressor stations, processing plants and well pads may be located. Municipalities may also establish standards related to issues such as noise, dust and light. However, municipalities are precluded from adopting standards which seek to regulate the same features of oil and gas operations that are regulated by the PADEP.[3]

Counties may also choose to adopt zoning and related ordinances that are applicable to municipalities within the county that have not adopted their own zoning and related ordinances.[4]

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[1] Pipeline Oversight the Role of Government Agencies for Pennsylvania Pipeline Projects https://marcelluscoalition.org/wp-content/uploads/2015/10/Pipeline-Oversight-Fact-Sheet.pdf
[2] Pipeline Oversight the Role of Government Agencies for Pennsylvania Pipeline Projects https://marcelluscoalition.org/wp-content/uploads/2015/10/Pipeline-Oversight-Fact-Sheet.pdf
[3] IBID
[4] IBID

Regarding the routing of pipelines, PADEP has limited authority. All pipeline proponents are required to propose a route that complies with the requirements of PADEP's laws and regulations and demonstrates that no feasible alternative exists with respect to impacts on water resources.

A pipeline's route is selected by the pipeline company. PADEP's environmental permitting regulations affect the pipeline's route in limited areas based upon potential impacts to water and wetland resources across the project corridor. However, the permitting changes do not result in widespread changes to the route chosen by the pipeline company. PADEP cannot arbitrarily, and without regulatory basis, dictate where a pipeline is sited.

Once installed, the regulation or enforcement of standard safety practices for the transportation of natural gas or natural gas liquids through the pipeline is outside the scope of PADEP's Chapter 102 (erosion and sedimentation)[5] and 105 (waterway management)[6] permitting authority.[7]

Finally, the Commission and the federal Pipeline Hazardous Materials Safety Administration (PHMSA) oversee and enforce issues related to the safety of pipeline construction and maintenance/operation.

Federal Governance of Pipeline Safety

Between 1999 to 2018, the Pipeline and Hazardous Materials Safety Administration (PHMSA) reported a total of 11,991 incidents of compromised pipeline integrity, resulting in 318 deaths and 1,304

[5] 25 Pa. Code Chapter 102 (Erosion and Sediment Control)
https://www.pacode.com/secure/data/025/chapter102/025_0102.pdf
[6] 25 Pa. Code Chapter 105 (Dam Safety and Waterway Management)
https://www.pacode.com/secure/data/025/chapter105/025_0105.pdf
[7] Testimony of Ramez Ziadeh, P.E., Executive Deputy Secretary for Programs, PADEP before the House Veterans Affairs & Emergency Preparedness Committee, 8/21/2019
https://dingo.telicon.com/PA/library/2019/20190821TX.PDF

injuries, with over $8 billion in total cost.[8] Between 2010 and 2017, environmental damage and remediation accounted for nearly 30% of total costs from hazardous liquid pipeline incidents in the U.S., with an average annual cost of $140 million.[9] Combined with the material failures that are exacerbated by geohazards and soil movement, the annual cost since 1999 has ranged from $7 million to more than $1.4 billion.[10]

PHMSA is the agency within the U.S. Department of Transportation's Office of Pipeline Safety responsible for developing and enforcing federal regulations to ensure the safe and secure movement of natural gas and hazardous liquids by all modes of transportation, including pipelines. Per rules set forth by PHMSA, both natural gas and hazardous liquid pipelines must be designed[11] and constructed to withstand anticipated external pressures[12] including those imposed by environmental forces. Once in service, pipeline operators must maintain a patrol program to monitor surface conditions on and adjacent to the pipeline ROW, with a focus on detecting both slowly occurring and acute earth movements that may affect current or future pipeline safety (§§ 192.705[13] and 195.401(b) [14]).

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[8] Pipeline and Hazardous Materials Safety Administration (PHMSA), "Pipeline Incident 20 Year Trend," see "All Reported Incident 20 Year Trend," accessed June 18, 2019, https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-20-year-trends

[9] Rick Kowalewski, "A Report to the Secretary of Transportation Pipeline Integrity Management An Evaluation to Help Improve PHMSA's Oversight of Performance-Based Pipeline Safety Programs," Pipeline Safety Trust, published October 31, 2013, http://pstrust.org/wp-content/uploads/2015/10/Kowalewski-IM-PE_Report.pdf

[10] Pipeline and Hazardous Materials Safety Administration (PHMSA), "Pipeline Incident 20 Year Trend," see "All Reported Incident 20 Year Trend," accessed June 18, 2019, https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-20-year-trends.

[11] 49 CFR §192.103 (Pipe design – General)
https://www.ecfr.gov/cgi-bin/text-idx?SID=c13557a849202253158cddf6172346b3&mc=true&node=se49.3.192_1103&rgn=div8

[12] 49 CFR §195.110 (External loads)
https://www.ecfr.gov/cgi-bin/text-idx?SID=c13557a849202253158cddf6172346b3&mc=true&node=se49.3.195_1110&rgn=div8

[13] 49 CFR §192.705 (Transmission lines: Patrolling)
https://www.ecfr.gov/cgi-bin/text-idx?SID=c13557a849202253158cddf6172346b3&mc=true&node=se49.3.192_1705&rgn=div8

[14] 49 CFR §195.401 (General requirements)

All unsatisfactory surface conditions require corrective action, even if they do not pose an immediate safety threat (§§ 192.613(a)[15] and 195.401(b)).

PHMSA pipeline safety regulations use the concept of High Consequence Areas (HCAs) to identify specific locales and areas where a failure could have the most significant adverse consequences. Operators are required to devote additional resources to preventing and mitigating hazards to pipeline safety within HCAs – a process referred to as Integrity Management (§§ 192.935[16] and 195.452(i)[17]).

PHMSA began requiring Integrity Management programs for hazardous liquids pipelines in 2001 and gas transmission pipelines in 2004. Traditional Integrity Management programs have focused primarily on the integrity of the pipeline itself, leading to the development of technologies such as In-Line Inspection (ILI) tools to examine pipeline structure, strain, and stability. Yet, a pipeline's stability is also largely dependent on the stability of its environmental surroundings; a pipeline that is solid in structure but buried within a hillslope prone to mass soil movement is not safe.

PHMSA recognized the increase of environmentally induced pipeline incidents with the recent issuance of two advisory bulletins:

- *Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Flooding, River Scour, and River Channel Migration*[18] and

https://www.ecfr.gov/cgi-bin/text-idx?SID=c13557a849202253158cddf6172346b3&mc=true&node=se49.3.195_1401&rgn=div8

[15] 49 CFR §192.613 (Continuing surveillance) https://www.ecfr.gov/cgi-bin/text-idx?SID=c13557a849202253158cddf6172346b3&mc=true&node=se49.3.192_1613&rgn=div8

[16] 49 CFR §192.935 (What additional preventive and mitigative measures must an operator take?) https://www.ecfr.gov/cgi-bin/text-idx?SID=c13557a849202253158cddf6172346b3&mc=true&node=se49.3.192_1935&rgn=div8

[17] 49 CFR §195.452 (Pipeline integrity management in high consequence areas) https://www.ecfr.gov/cgi-bin/text-idx?SID=ab38857b2295dbba6b8dca83ec8d2501&mc=true&node=se49.3.195_1452&rgn=div8

[18] PHMSA, 4/11/2019, "Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Flooding, River Scour, and River Channel Migration," 84 FR 14715

- *Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Earth Movement and Other Geological Hazards*[19]

Unique Challenges in the Marcellus

The PHMSA advisory bulletin on earth movement describes seven major pipeline incidents that have occurred in the last three years as a result of geologic forces. Notably, five of the seven incidents occurred in the Appalachian Basin. The Appalachian Basin's steep slopes, unstable soils, and high-intensity rain events make the region among the most susceptible to landslide events in the country (see Figure 1). These environmental conditions pose a unique challenge to the safe construction and operation of oil and gas infrastructure throughout the Marcellus shale play, whose rapid development over the last decade has catapulted Pennsylvania to leading the nation in energy production, second only to Texas. Moreover, research conducted by SolSpec indicates that landslide events are occurring along pipeline corridors in the Marcellus region more frequently and at lower angles than predicted by U.S. Geological Survey models for the area (see Figure 2). This is likely a result of land disturbance, tree removal, and subsequent shifts in surface and subsurface hydrologic flow that destabilize soils on and near the pipeline ROW.

https://www.govinfo.gov/content/pkg/FR-2019-04-11/pdf/2019-07132.pdf

[19] PHMSA, 5/02/2019, "Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Earth Movement and Other Geological Hazards," 84 FR 18919
https://www.govinfo.gov/content/pkg/FR-2019-05-02/pdf/2019-08984.pdf

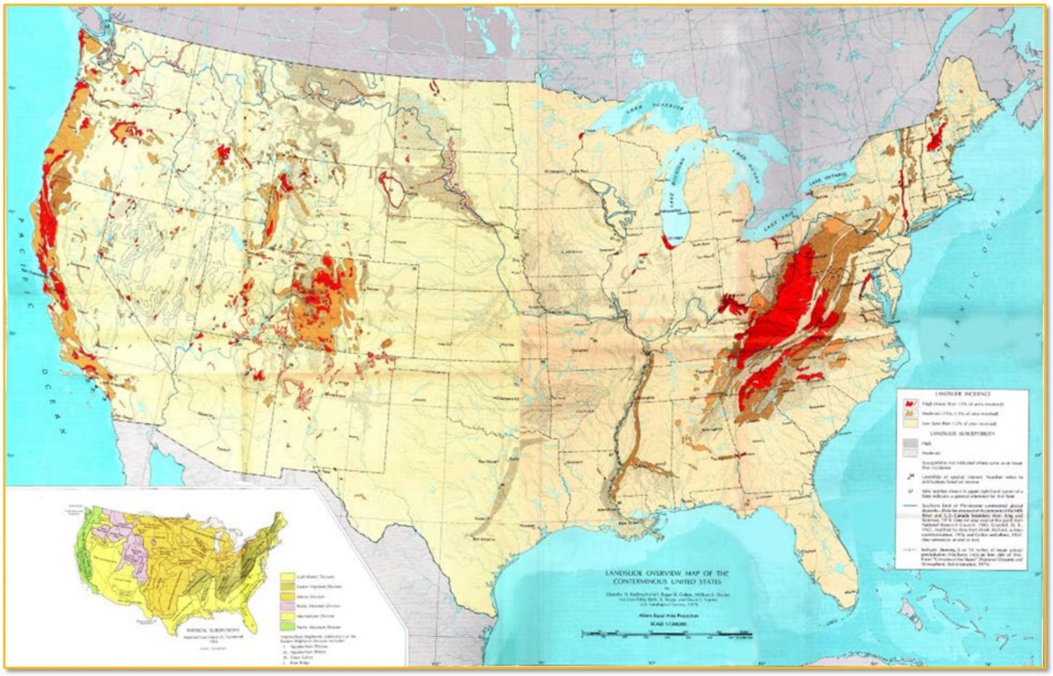

Figure 1. Pleistocene and modern landslide incident occurrence in the conterminous U.S. Source: U.S. Geological Survey (1978).

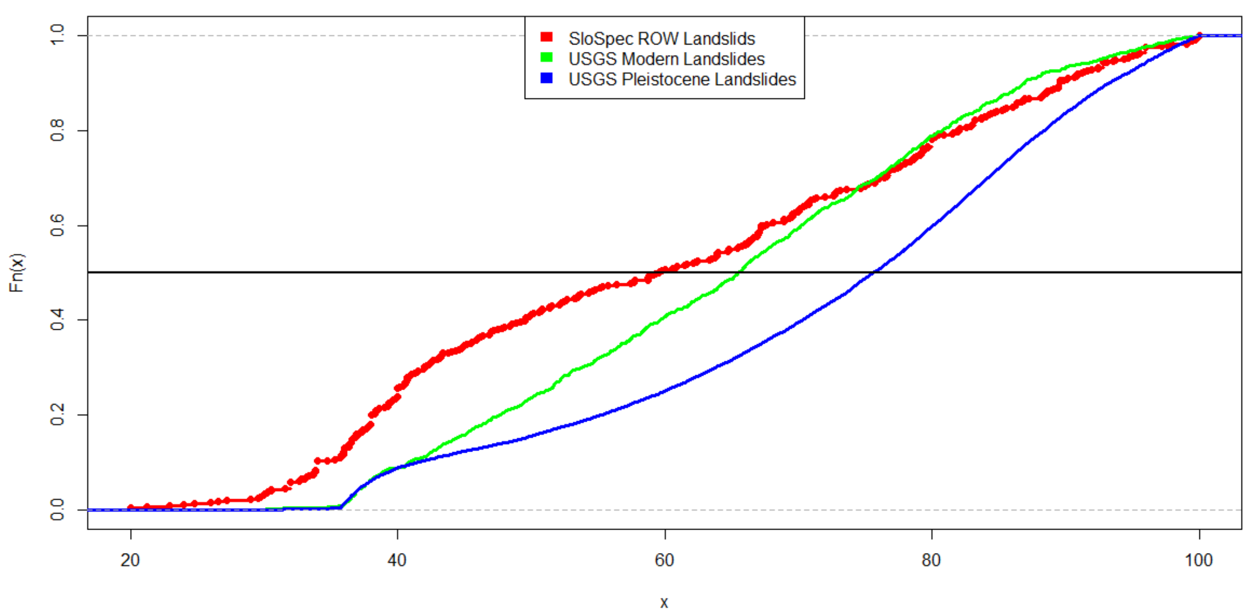

Figure 2. SolSpec research indicating that landslide events are occurring along pipeline corridors in the Marcellus region more frequently and at lower angles than predicted U.S. Geological Survey models for the area. Source: SolSpec (2019).

The combination of these factors makes oil and gas infrastructure in the Marcellus region especially vulnerable to environmental threats. As PHMSA-adopted standards point out, prevention and mitigation are the most effective methods for addressing risks posed by natural forces[20]. In order to prevent and mitigate environmental threats to pipeline integrity, operators must gather, evaluate, and integrate data to determine pipeline susceptibility to environmental hazards and allocate resources accordingly -- and they must do so quickly and frequently enough to respond to ever-changing environmental conditions. To achieve this, operators need efficient, comprehensive, data-driven methodologies for evaluating risk that go beyond the physical pipe to include its environmental context.

Just as ILI technology has revolutionized operators' ability to conduct internal pipe inspections, aerial analytics technology promises to transform external pipeline and environmental inspections to improve safety, sustainability, and efficiencies for Pennsylvania's oil and gas industry. However, ILI technology did not achieve commonplace use on its own. PHMSA now requires the use of an ILI device or comparable technology to ensure hazardous liquid pipeline integrity within HCAs[21]. For new best practices to become widely adopted, no matter how beneficial they are, support is often needed from regulatory authorities acknowledging that the new technology will be accepted as an approved method of compliance. Depending on market conditions and adoption barriers, the use of emergent best practices, such as aerial analytics technology, should be clearly identified in order to garner widespread use.

[20] American Society of Mechanical Engineers, 2018, "ASME B31.8S-2018: Managing System Integrity of Gas Pipelines" and American Petroleum Institute, 2018, "API Recommended Practice 1160: Managing System Integrity for Hazardous Liquid Pipelines"
[21] § 195.452(c)

Companies often look to agency interpretation and guidance regarding the suitability of new technologies for meeting compliance requirements. For instance, PHMSA explicitly allows for ROW patrol methods that include walking, driving, flying, or other appropriate means (§§ 192.705 and 195.412(a)). Remote sensing technologies typically fall under the category of "other appropriate means" whose ambiguity warrants agency clarification. PHMSA was recently asked to interpret if satellite imagery qualifies as a regulatory-compliant method for patrolling the ROW for potentially anomalous surface conditions that could threaten pipeline safety[22]. PHMSA responded that the satellite imagery presented in the interpretation request was of insufficient resolution to meet regulatory requirements for ROW patrol.

Another example of agency guidance regarding remote sensing for ROW patrol comes from PHMSA's previously mentioned May 2, 2019 advisory bulletin: "*Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Earth Movement and Other Geological Hazards*". The bulletin specifically allows for monitoring plans to include: "utilizing aerial mapping light detection and ranging or other technology to track changes in ground conditions."

Remote Sensing for Pipeline Safety

Remote sensing, or the science of obtaining information about the physical characteristics of an area from a distance, has dramatically changed the way that many sectors, including energy, agriculture, mining, infrastructure, and government, do business. For pipeline operators, aerial data collection improves upon traditional methods of ocular ROW inspection that can be inefficient, unsafe for personnel, and subject to human error. Additionally, ocular inspection often limits operators to reactive

[22] PHMSA, 7/29/2019, "Interpretation of §§ 192.705 and 195.412(a) for New Terrain Technologies" https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/standards-rulemaking/pipeline/interpretations/71916/new-terrain-technologies-pi-19-0005-07-29-2019-parts-192705-and-192412.pdf

measures that are non-conducive to preventing environmental threats to pipeline safety. Alternatively, operators and/or inspectors can fly UAVs or planes hosting a mounted camera or sensor over a pipeline corridor to **augment the field inspection process with increased safety, efficiency, and effectiveness.** The resulting aerial imagery can provide operators with an overwhelming amount of raw data that then requires processing and interpretation to discern information pertinent to management actions. To put aerial imagery to use for pipeline safety, big data collected in the field must be transformed into actionable intelligence capable of guiding decisions. Aerial analytics technology is a new best practice for pipeline safety that provides an efficient, scalable, and statistically robust method of converting huge amounts of aerial data into decision tools for proactively managing risk and resources.

SolSpec is among a growing handful of providers that serve the oil and gas sector with aerial data and analytics technology. Below is an outline of SolSpec's aerial analytics technology process summarized into six steps:

1. A UAV or plane captures data in the form of red, green, blue (RGB) aerial imagery or light ranging and detection (LiDAR) data.
    a. Camera takes photograph every 3 seconds capturing 8.5 megabytes of data.
    b. LiDAR sensor emits 1 million laser points per second capturing 34.2 megabytes of data.

    But data need analysis to drive decisions.
2. Imagery is uploaded to a secure cloud server.
3. SolSpec processes imagery and LiDAR data into digital surface and terrain models.
    a. Spectral data are processed at 2-cm resolution.
    b. Structural/terrain data are processed at 10-cm resolution.
4. SolSpec analyzes spectral and structural data using statistically validated predictive algorithms and modeling tools.

5. Summarized results are delivered to the User's desktop via SolSpec's secure, web-based platform.
6. Iterative machine learning processes constantly improve the predictive accuracy of SolSpec's aerial analytics tools.

Advancements in Remote Sensing for Pipeline Safety

In recent years, aerial imaging services have evolved tremendously. Now, thanks to remote sensing technologies such as UAVs and aerial sensors, it is easier than ever to get a bird's-eye view from above. The industries benefiting the most from the advancement of remote sensing services are those who rely on mapping solutions, such as the oil and gas pipeline industry or environmental consulting firms, for achieving compliance with pipeline design, construction, and operations requirements. High-resolution geospatial data collected throughout any or all stages of a project lifecycle empowers companies with precise models from which they can measure risk exposure and resource needs. Armed with this intelligence, companies can invest in proactive risk abatement and efficient resource allocation instead of being forced into reactive methods that demand higher levels of risk exposure and expenditures.

Remote Sensing with Unmanned Aerial Vehicles (UAVs)

When a UAV flies over a pipeline ROW for image data collection, it snaps a photograph every three seconds, thus capturing each surface feature multiple times from slightly different angles. During data processing, the photographs are stitched together in a process called photogrammetry to create a 2D map and 3D model of the surface for remote visualization and interpretation. Because all images captured are associated with a precise GPS reading from the UAV's onboard computer, these stitched maps and models contain geospatial data that serve to identify feature locations and analyze spatial interrelationships between different risk factors and the pipeline. When it comes to aerial imaging services, UAVs are much more flexible, responsive, and readily available than planes. UAV data collection can be completed by an internal employee, or a UAV aerial imaging services company can be contracted for the project. Some imaging companies also provide training for pilot certifications and assist with UAV program design and establishment.

Most UAVs are designed to complete a broad range of general mapping tasks. These UAV platforms are generally outfitted with high-quality red, green, blue (RGB) cameras very similar to what you might find in a camera or smartphone. For less than $2,000, the Phantom 4 Pro by DJI is one of the most capable and commonly used platforms for mapping. For more specialized tasks, different sensors can be utilized. These sensors range from near infrared to LiDAR. What was once cost-prohibitive or inaccessible a few years ago is now cheaper and easier to use than ever.

Unmanned Aerial Vehicle (UAV) Services Protect ***Personnel***

Increasingly, companies are using UAV mapping services to gain access to locations previously inaccessible without compromising resource integrity, human safety, or data quality. Job sites can often be hazardous environments, and inspections are especially necessary when environmental threats are at their peak, such as following significant precipitation events. Before UAV mapping services became available, company employees would have to perform inspections and surveys in hazardous areas manually, potentially putting themselves at risk. Now, personnel can stay out of harm's way by launching a UAV from a nearby safe location to inspect a potentially hazardous site. This not only improves personnel safety but also augments the inspection process with high-quality data collection capable of supporting statistical analysis that guides business-critical decisions.

Unmanned Aerial Vehicle (UAV) Services Protect ***Projects***

With efficiency as a core focus of most projects, finding novel ways to perform the same tasks at a lower cost while still achieving quality results is not easy. Because UAV mapping services are so efficient, it's much easier and far more cost effective for companies to utilize these mapping services rather than paying multiple employees to perform a surveying job. With minimal training, a UAV pilot can successfully map or survey 100 acres in roughly 20 minutes, while it takes employees numerous hours, if not days to survey the same size area.

UAV mapping services can be completed by either an internal employee or a UAV aerial imaging services company can be contracted for the project. Many believe that these services are expensive or that they will need to hire and train their own employees to operate the UAV, but this is not the case. With the number of third-party UAV mapping services companies growing by the day, businesses can take advantage of increasingly competitive pricing. What a company may not have once been able to afford is now quite reasonable.

Remote Sensing with LiDAR

In addition to UAV imagery, light detection and ranging – commonly known as LiDAR – allows for data collection at scale. LiDAR technology consists of emitting laser beams from a mounted sensor and measuring the time it takes for the laser to reflect from a service and return to the sensor. The resulting product of a LiDAR survey is a 3D point cloud model of the surveyed terrain. Unlike photogrammetry, LiDAR is typically conducted using planes and does not capture RGB data. The resulting dataset can be challenging to interpret without specialized visualization software.

The major advantage of LiDAR is the ability to map and model terrain through the tree canopy. LiDAR lasers can move through vegetation and water to map in-detail the forest/waterbody floor, which image-based methods such as photogrammetry are currently incapable of.

SolSpec will be offering LiDAR data capture, processing, and analysis services tailored to Appalachian Basin industries in the coming year.

3D Mapping and Modeling of Aerial Data

Remotely sensed data need processing, visualization, and interpretation to be actionable. As remote sensing technologies have advanced, so too has the software that transforms big data collected in the field into meaningful intelligence to guide decisions. Aerial mapping and modeling software technologies are becoming increasingly robust and their providers more numerous. Many industries are taking advantage of 3D mapping due to the ever-increasing number of use cases for this information. The following industries have adopted remote sensing and aerial imaging as a cornerstone of their project success:

- Construction
- Land Surveying
- Mining
- Inspection
- Land Development
- Forestry
- Agriculture
- Emergency Management

When paired with traditional survey ground control points, aerial imagery captured by UAVs can deliver sub-decimeter accuracy with robust 2D maps and 3D model (see Figure 3); LiDAR data can provide an even sharper level of accuracy without the need for ground control points. While traditional survey methods provide a singular snapshot of a particular place and time, 3D mapping and modeling offers the ability to obtain continuous information about the physical characteristics of an area across space and time. A major advantage of continuous information is the ability to conduct comprehensive measurement, analysis, and change detection to identify slow-moving but potentially problematic shifts in soils or hydrology.

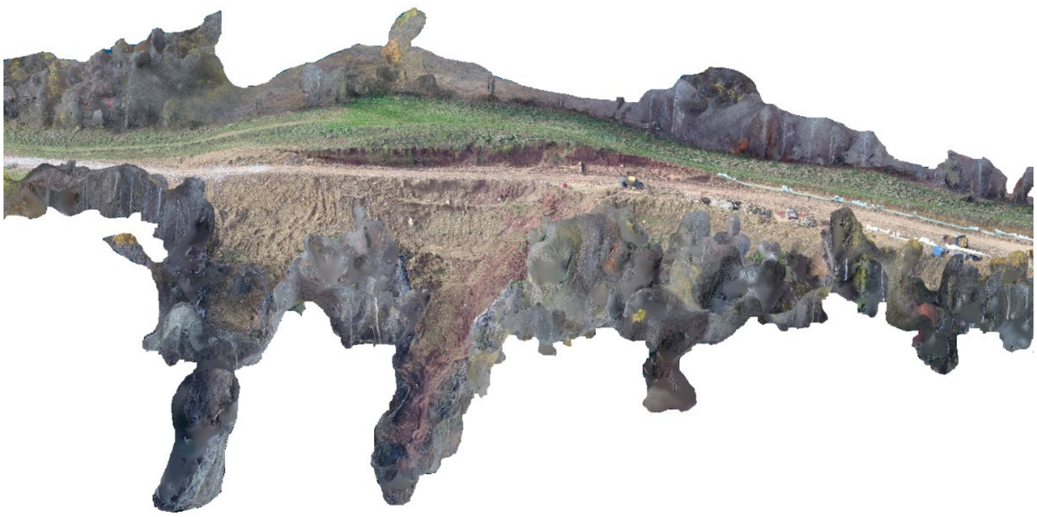

Figure 3. 3D model of pipeline ROW with slip. Source: SolSpec (2018).

Aerial Analytics for Pipeline Safety

Thanks to software like the SolSpec Aerial Analytics Platform, companies can now gain more information about their projects in an easy-to-understand manner. After a mapping mission is flown, the images are uploaded for processing which will output high-resolution maps in a matter of hours. These maps contain an incredible amount of information that is often difficult for humans to analyze without the aid of a computer. SolSpec has created software that uses high-tech algorithms to analyze the imagery and produce reports that solve specific problems. With all the legwork done and a report in-hand, companies can focus their efforts on what they do best: getting the job done on time and on budget.

With respect to the ANOPR, we offer the following comments for consideration by the Commission to selected subject areas of interest (i.e., right of way integrity management; planning, permitting and construction; monitoring and inspection; line marking; and leak detection) where the use of aerial inspection and analytics is applicable:

Right of Way Integrity Management (RIM)

The most effective and efficient means of addressing pipeline incidents is to prevent them from occurring in the first place. The transition from reactive disaster management to proactive disaster risk reduction saves costs for operators, communities, regulators, and investors. It's good for compliance, good for communities, and good for the bottom line. Pipelines are a relatively safe mode of transportation given the extremely large amounts of volatile energy products they move across great distances. Though the probability of a pipeline accident is low, the consequences when accidents do occur are often substantial. Therefore, as mentioned earlier, PHMSA requires operators to devote additional resources to anticipating, preventing, managing, and mitigating hazards to pipeline safety within HCAs, a process referred to as Integrity Management (IM).

Integrity Management is a performance-based, process-oriented program for managing the safety and environmental risks associated with oil/hazardous liquid and natural gas pipelines. PHMSA began requiring Integrity Management Programs for hazardous liquids pipelines in 2001[23] and gas transmission pipelines in 2004.[24] The performance-based Integrity Management approach has facilitated the identification and mitigation of thousands of pipeline anomalies and defects. Yet evidence suggests that the programs may not improve safety outcomes to the extent anticipated. A 2013 study from the U.S. Department of Transportation (DOT) examined the effectiveness of Integrity

[23] PHMSA, "Transportation of Hazardous Liquid by Pipeline," 49 CFR Part 195 Pipeline Safety: Pipeline Integrity Management in High Consequence Areas (Hazardous Liquid Operators with 500 or More Miles of Pipeline), Final Rule (Federal Register December 1, 2000). This rule was effective as of March 31, 2001

[24] PHMSA "Transportation of Natural and Other Gas by Pipeline," 49 CFR Part 192 Pipeline Safety: Pipeline Integrity Management in High Consequence Areas (Gas Transmission Pipelines); Final Rule (Research and Special Programs Administration, December 15, 2003). This rule was effective as of January 14, 2004

Management programs in achieving pipeline safety objectives within the country. The evaluation found that safety risks may be increasing rather than decreasing, and that the six highest-consequence pipeline accidents on record occurred after PHMSA's mandate for Integrity Management programs.[25] Several impediments to the efficacy of Integrity Management programs were identified:

- A significant portion of risk occurs outside of HCAs targeted by traditional Integrity Management programs;
- Risk models do not incorporate the best science for risk analysis;
- The quality of the data used for risk analysis is unknown;
- Risk evaluations have not kept pace with changing conditions on the ground; and
- Preventative and mitigative actions have not occurred to the extent expected.

In consideration of these findings, increased oil and gas infrastructure construction in variable terrain, and expanding urban footprints, operators must go above and beyond typical Integrity Management program requirements to comprehensively and successfully abate risk, achieve compliance, and protect profits.

Just as ILI technology is changing the way operators conduct internal pipe inspections, aerial analytics technology promises to transform external pipeline and environmental inspections through Right of Way Integrity Management (RIM).

RIM is a holistic approach that empowers oil and gas pipeline owners and operators to programmatically and proactively address landslide hazards, stormwater, encroachment, and other threats. Routinely scheduled flyovers with manned aircraft or Unmanned Aerial Systems (UAS) provide

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[25] Rick Kowalewski, "A Report to the Secretary of Transportation Pipeline Integrity Management An Evaluation to Help Improve PHMSA's Oversight of Performance-Based Pipeline Safety Programs," Pipeline Safety Trust, published October 31, 2013, http://pstrust.org/wp-content/uploads/2015/10/Kowalewski-IM-PE_Report.pdf

accurate, reliable, and up-to-date data on any section of a pipeline ROW, thus addressing gaps identified in traditional Integrity Management programs. Repeated monitoring enables operators to better detect potential hazards and subtle or large changes on the ROW surface. Operators can then efficiently allocate resources and prioritize monitoring and mitigation efforts for the zones where they are needed most, thereby preventing the escalation of cost and consequence.[26]

SolSpec developed the RIM methodology described in the following sections as a comprehensive, statistically validated means of managing existing and potential hazards to the health of pipeline ROWs. Increased use of UAVs by many industries has allowed for the production of massive amounts of data. The quantity, however, is meaningless without the ability to transform big data collected from the field into actionable intelligence at the desktop. For pipeline operators, the transformation process requires efficient, scalable, and statistically robust analytic methods that complement and build upon traditional inspection and Integrity Management program protocols, and that is precisely what SolSpec's RIM program accomplishes.

SolSpec offers a RIM program tailored for different applications in pipeline construction and operations that address, respectively: the planning, permitting, and construction of pipelines through new or existing easements; Right of Way Hazard Assessment (ROWHA) for existing pipelines; routine monitoring and impact patrolling after significant weather events; and depth of cover assessment using aerial analytics and ILI technologies.

RIM for Pipeline Construction

Pipeline construction projects often plague owners and operators with unforeseen costs, delayed timelines, and unknown liabilities. Many of these inefficiencies are preventable with the right

[26] Chiara Belvederesi, Megan Thompson, and Petr E. Komers, "Statistical Analysis of Environmental Consequences of Hazardous Liquid Pipeline Accidents," Heliyon 11, no. 4 (2018): 16

information. Geospatial aerial analytics are effective from the outset of pipeline construction projects through the project lifetime, from informing route selection and bidding to developing a contractor punch-list and closing out permits. Each stage of the planning and construction process requires specific types of flights and analysis, detailed in the following section.

During project planning and prior to construction, geospatial aerial analytics of the corridor(s) of interest inform route selection, minimize exposure to hazards, guide bidding, and facilitate permitting. For potential or newly acquired easements, baseline flights capture high-resolution imagery and topography of the project area that are analyzed to identify and rank the geologic formations and soil conditions that may pose hazards to the project or surrounding environment or have the potential to cause or contribute to pollution of regulated bodies of water.

At the commencement of construction, survey flights are performed immediately following clearing when survey crews are staking the centerline. Survey flights leverage ground control points set by survey teams to establish a topographic surface model that can be leveraged with subsequent flights to discern pre-existing conditions from project liabilities. The survey flight and associated analytics document pre-disturbed conditions to inform contract management, identify potential hazards, and optimize routing. New construction within existing easements allows for the combination of the baseline and survey flights into a single flight.

Regardless of whether the construction takes place on new or existing easements, progress report flights and analytics monitor each phase of construction and the linear progress made on each spread since the previous flight. Flights can be performed weekly, bi-weekly, or monthly, and each flight is accompanied by a progress report detailing the phases of construction and the progress made on each spread since the previous flight. Depending on the frequency of flights, the following phases are reported: clearing, trenching, backfilling, and restoration. **Immediately following restoration**, as-built flights are performed to capture and evaluate the detailed topographic surface of the ROW, which can be compared to subsequent flights throughout project operations for change detection, monitoring, and contract management.

Between as-built and close-out stages, above-average precipitation events trigger significant event response monitoring flights that feed imagery into SolSpec's Right-of-Way Hazard Assessment (ROWHA) model (see below section) to inventory and assess existing and potential slips and soil conditions that may pose hazards to the pipeline, adjacent landowners, or sensitive ecological resources.

At the end of the project and prior to the expiration of a contractors' warranty, close-out monitoring flight is executed and compared to the as-built analysis for change detection. SolSpec's ROWHA Model inventories and assesses the conditions of both existing and potential slips, as well as the status of erosion and stormwater best management practices (BMPs). Additionally, SolSpec's Vegetative Cover Model analyzes the spectral reflectance of living biomass and bare ground to measure the percent of vegetative cover within the ROW. Results from these analytics can be used to develop a contractor punch list, fulfill permit requirements, and close out the project.

RIM for Pipeline Operations: Right of Way Hazard Assessment (ROWHA)

SolSpec data analytics can be used throughout the active pipeline lifetime to identify and prioritize zones according to the level of threats posed to ROW integrity, public health, and the environment. Prioritization of existing and potential hazards empowers decision makers to proactively allocate resources to zones where they are needed most to manage risk, ensure pipeline integrity, and fulfill compliance objectives.

Infrastructure that cuts through mountainous terrain is especially vulnerable to threats posed by mass soil movement. For example, the Appalachian Mountains of the eastern U.S. host pipelines systems in which 40-67% of the lines are buried within landslide-prone slopes. With potentially hundreds of miles to monitor and manage, pipeline operators are challenged to identify the highest-priority areas within large segments already considered at-risk.[27]

The Right of Way Hazard Assessment (ROWHA) is a cumulative model consisting of two sub-models: SolSpec's Slip Potential Model and BMP Condition Assessment. The Slip Potential Model measures and forecasts soil and land features most prone to slippage and predicts how active and potential slips might intersect with and impact the pipeline, adjacent landowners, and sensitive ecological resources. The information for this model is used to proactively plan and prioritize mitigation actions that prevent incident and impact occurrence.

The BMP Condition Assessment examines the flow direction and accumulation of water on the ROW surface to assess the effectiveness of existing and potential stormwater erosion and sediment control BMPs. The information is used to assess if and where excessive surface drainage may result in mass soil movement that intersects with and impacts the pipeline, adjacent landowners, and sensitive ecological resources. The two sub-models are executed individually to determine the condition and potential of earth movement to impact the pipeline, adjacent landowners, and sensitive ecological resources.

Next, the outputs of the Slip Potential Model and the BMP Condition Assessment sub-models described above are aggregated, summarized, and weighted to produce the cumulative ROWHA model. The ROWHA inventories and ranks where slips are most likely to form throughout the pipeline system and where erosion and sedimentation may be problematic due to ineffective stormwater BMPs. Existing and potential slips and faulty erosion control devices are weighted according to their proximal and directional connectivity to the pipeline, sensitive ecological resources, and adjacent properties. These

[27] Mike Soraghan, "Landslides, explosions spark fear in pipeline country," E&E News, June 4, 2019, https://www.eenews.net/stories/1060472727

data inform the delineation of critical Slip Management Zones and Erosion Management Zones that, if unmanaged, could directly jeopardize the safety and integrity of the pipeline, sensitive ecological resources, and adjacent properties.

Slip and Erosion Management Zones identify, respectively, areas with existing or high likelihood of slips and areas with ineffective or failing erosion and sediment control BMPs. Both Slip and Erosion Management Zones are prioritized for proactive mitigation and monitoring in order to prevent potential or further slope destabilization, water quality pollution, subsidence, and cost escalation. To ensure project success and promote public health, areas within the Potential Impact Radius (PIR) with residences, no matter the number, are treated as high-priority zones, and prioritized alongside the Slip and Erosion Management Zones. The data produced from the ROWHA allow operators to clearly understand the specific areas in need of immediate action and those that may soon become bigger challenges if unattended (see Appendix A).

RIM for Pipeline Operations: Routine Monitoring and Surveillance

Aerial imagery used in the ROWHA analytics process described above establishes the baseline for routine flyovers captured during a once-annually system-wide flyover of the entire pipeline that helps fulfill minimum patrol interval requirements and provides updated data for Slip and Erosion Management Zones, and residential areas within the PIR. The annual surveillance flight inventories previously undetected slip and erosion activity and incorporates new results into the pipeline's ROWHA prioritization metrics. Additionally, monitoring flyovers following implementation of slip mitigation, slope stabilization efforts, and BMP rectifications capture imagery for comparison against pre-treatment conditions, enabling operators to track, measure, and report on both the effectiveness of mitigation efforts and the reduction of hazardous slips and high-slip-potential areas within and adjacent to the ROW.

Flyovers based on the prioritized list of Slip and Erosion Management Zones, along with the residence and PIR information, makes it possible to detect early warning signs and inform mitigation response efforts immediately following significant precipitation, severe freeze-thaw cycles, flooding, or other significant weather events.

ROW for Pipeline Operations: Depth of Cover

In-Line Inspection (ILI) axial strain measurement technology has traditionally been used to detect longitudinal strain on the pipe due to natural forces, such as slope instability or subsidence. Combined with SolSpec's analytic tools, ILI becomes the foundation for a depth of cover analysis that allows for identification of areas prone to exposure and greater risk of incidents. The smart pigs used in ILI are georeferenced, and their locations can be compared to the surface data collected by SolSpec to identify the exact depth of cover on any point in the pipeline.

Depth of cover is a serious issue that plagues operators in every region and is of concern for pipelines crossing under waterways, where they are subject to higher risks and erosion is difficult to identify because it's happening away from view.[28] Erosion under waterways can be exacerbated by horizontal drilling and river scouring, leading to exposed pipe that can rupture during flooding or increased flow. With increased occurrence and severity of precipitation, depth of cover becomes an even larger concern for all operators, no matter the location.[29]

SolSpec measures the depth of cover on buried pipelines by combining ground elevation data collected using LiDAR with high-resolution inertial measurement unit (IMU) data collected during the

[28] Chiara Belvederesi, Megan Thompson, and Petr E. Komers, "Statistical Analysis of Environmental Consequences of Hazardous Liquid Pipeline Accidents," Heliyon 11, no. 4 (2018): 3

[29] "Changes in precipitation," Government of Canada, modified 9 April 2019, https://www.canada.ca/en/environment-climate-change/services/climate-change/canadian-centre-climateservices/basics/trends-projections/changes-precipitation.html

inspection. This analysis provides accurate information and raw data points of depth of the pipeline at established intervals, and map books are generated to show areas of concern.

Depth of cover is distinct from the ROHWA analysis, in which erosion potential and slip potential are identified and analyzed. Depth of cover does not show where a pipeline is likely to fail; rather, it identifies exact segments where there the pipeline is less protected and more exposed to further hazards.

Line Markers/Valves

UAVs are incredible tools capable of capturing high-resolution images from the air. Because all images captured are associated with a precise GPS reading from the UAV's onboard computer, mains, valves, crossings and other assets can be easily identified, marked and mapped through GPS coordinates.

Moreover, UAV mapping services can be used to identify and gain access to locations previously inaccessible (i.e., around a sensitive wetland or body of water). Therefore, companies can make more precise measurements using photogrammetry tools, saving them both time and money. With highly accurate maps and the ability to make precise measurements, companies can invest in preventative measures as opposed to reactionary ones.

Leak Detection

While leak detection is not currently a SolSpec product; conceptually, it shows a lot of promise. The most effective and efficient means of addressing pipeline incidents is to prevent them from occurring in the first place, particularly where a pipeline failure could have the most significant adverse consequence. SolSpec's Slip Potential Model and BMP Condition Assessment are used to proactively plan and prioritize mitigation actions that prevent incident and impact occurrences which can lead to leaks.

Flyovers based on the prioritized list of Slip and Erosion Management Zones makes it possible to detect early warning signs and inform mitigation response efforts immediately following significant precipitation, severe freeze-thaw cycles, flooding, or other significant weather events which can cause leaks.

Conclusion

Timely, accurate data is critical for effective decision making and ensuring pipeline integrity. Inspections conducted by people physically walking the ROW are subject to human error and put the individuals in potentially hazardous conditions. A RIM program informed by aerial analytics increases the efficiency of pipeline technicians, facilitates emergency response, and identifies key areas for focused resources and efforts in hazard mitigation. SolSpec provides data for scalable solutions overnight, instead of over weeks, so operators and decision makers have the information they need to make crucial decisions to protect our environment and industries.

The cost of unmanaged ROW integrity is high and continues to increase: landslides, destruction of property, lost lives, contaminated water, environmental degradation, lawsuits, damaged reputations, irrecoverable revenues, bankruptcies, loss of public approval. Aerial mapping and analytics are a solution for improved and efficient resource allocation, public safety, regulatory compliance, and pipeline integrity. The approach to environmental hazards has historically been reactive, responding to incidents and patching them up as best as possible. We promote and advocate strongly for a proactive approach based on our RIM program, with the goal of ensuring ROW integrity that protects the safety of personnel, communities, and resources for generations to come.

However, the use of emergent best practices, such as aerial analytics technology, needs to be clearly identified in the Commission's regulations as a tool for achieving compliance with pipeline design, construction, and operations requirements; specifically, in the Marcellus shale region and other areas vulnerable to environmental threats.

Again, thank you for the opportunity to comment on this Advance Notice of Proposed Rulemaking. If you have any questions or need any additional information, please do not hesitate to contact me.

Respectfully,

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SolSpec
AERIAL ANALYTICS

Appendix A

The following exhibits demonstrate the ability of aerial mapping and analytics such as SolSpec's ROW Hazard Assessment (ROWHA) to support pipeline operators in clearly identifying priority areas needing managing action that, if left unattended, may soon increase in cost and consequence.

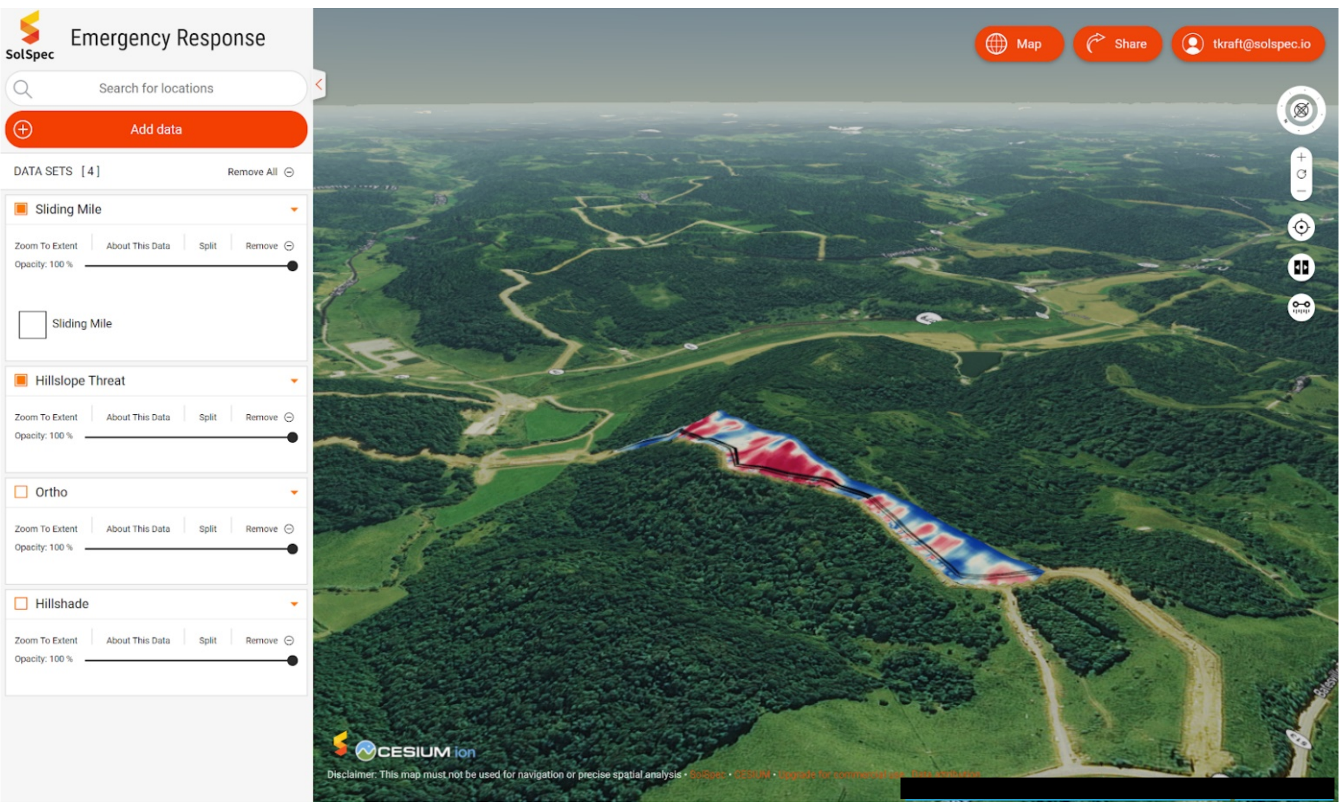

Figure 4. The SolSpec ROW Hazard Assessment model applied to a section of pipeline located in the Appalachian Basin outside of Pennsylvania. Source: SolSpec.

SolSpec
AERIAL ANALYTICS

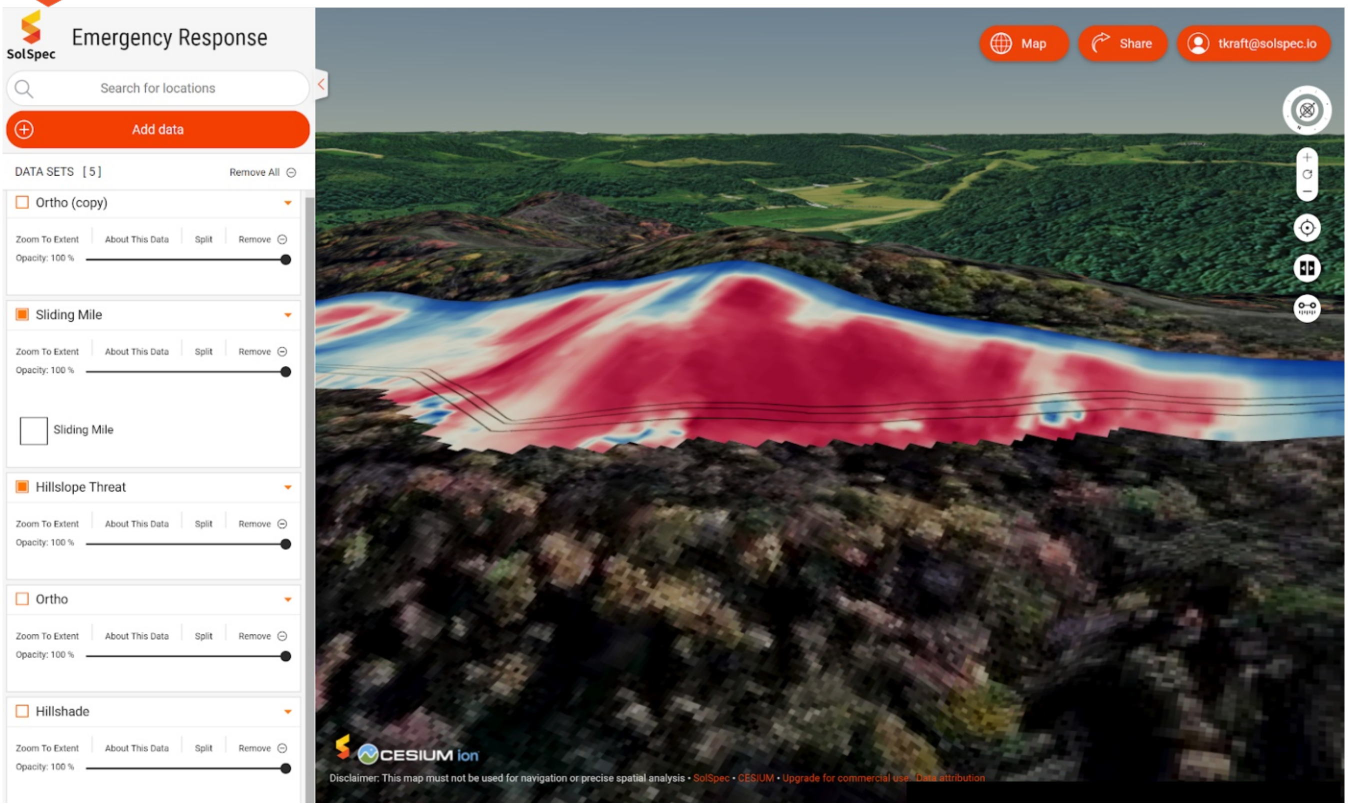

Figure 5. Close-up of area from Figure 4 that ranked in top 95th percentile for being at risk of slope failure according to the ROW Hazard Assessment. Source: SolSpec.

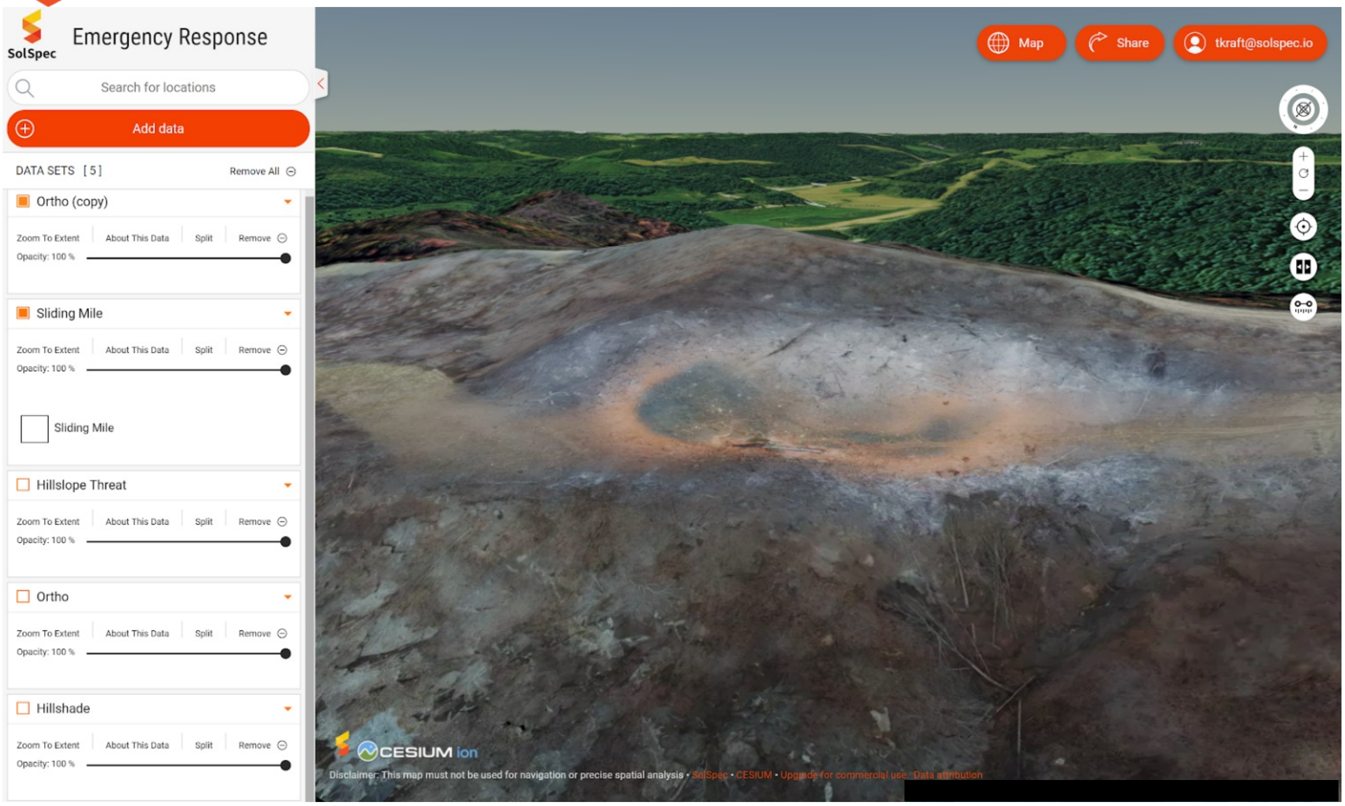

Figure 5. The major company operating the pipeline took no action to mitigate the area ranked in the top 95th percentile for slope failure. Following a significant rain event, the site experienced a landslide that caused the pipeline to fail. The company now employs SolSpec's ROW Integrity Management (RIM) program to manage environmental risk. Source: SolSpec.

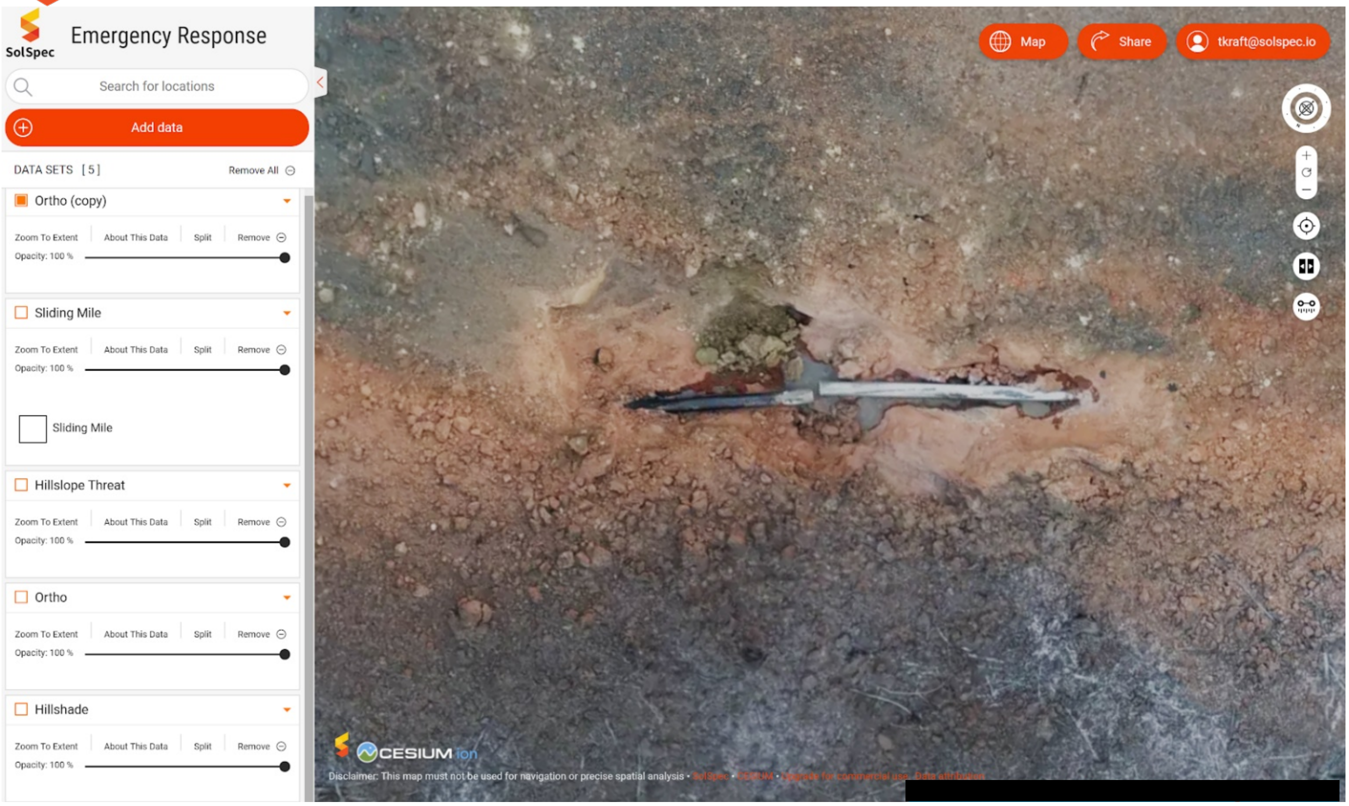

Figure 6. Close-up of 3D model of the failed pipe. Source: SolSpec.