Slope Stability and Erosion Control Challenges on Mega Projects Rules, Methodology, New Technology, and Vulnerability on Construction Phases

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Abstract *– All Big Project has big challenges on the amounts of sediments that need to be controlled on daily basis. It is one of the big challenges that need to take into consideration on Owner side and de PM on the construction process. Even the technology today has many resources that can be used at the time that the project needs to be built, things can be changed quickly. Sediments controls always need to be included in the design, take all consideration for the specific area of the development and the special characteristics for each location. Retention ponds, swells, rip rap and other systems to maintain controls of the areas need to be implemented. But What's happened if the site changes daily with the construction process? Changes like heavy traffic equipment, road that change for better access, earth work, site logistic for walkways and pedestrian areas, big excavations and site utilities installation. What's happens if things change quickly, and decisions need to be implemented. Mega Project presents a big challenge for engineers and contractors, complying with all regulations, protecting the environmental, time commitment and quality products at the end make always a challenge.*

Key Terms *– AI Programs, Big Development, DEM, Sediment Control.*

INTRODUCTION

Description: Impacted Area 3,754 acres, construction of 7 retention ponds. See (**Figure 2)**, 7 Buildings one level Data Center. Each building Approx. 1,000,000 sq. ft. Each building. All utilities excavation and soil restoration. Time of Construction 12 years. Site Work contemplates more than 1,44 million cubic meters of soil that need to be storage, moved and used for filling again. See (**Figure 1 and Figure 4).** All those areas are classified as agricultural areas that need to be evaluated on all impacts on the construction process. The focus of this project is to make the evaluation and establish the control for soil stabilization and sediment control on projects that change continuously and need to comply with all regulations closer to sensitive areas, including wets lands and lakes.

Figure 1
Aerial View of the Project – Location Boydton, VA

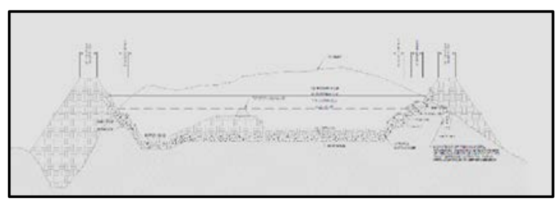

Figure 2
Proposed Pond #7 – Regulations and DDQ Restriction for Development of Areas in Virginia State

DDQ required a very specific analysis, and plans established for the type of development including inspections daily, monthly and annual permit. Erosion control is crucial for maintaining the stability of construction sites and natural landscapes [1]. Here are some steps and considerations you can take to address erosion control effectively amid project changes:

Assess the Current Status: Begin by evaluating the current state of erosion control measures on your project site. Identify areas where erosion is occurring or where existing control measures may be insufficient due to project changes.

Review Project Changes: Understand how recent changes in the project scope, design, or timeline might impact erosion control needs. Changes such as increased excavation, altered drainage patterns, or extended project duration can significantly affect erosion risks.

Update Erosion Control Plans: Based on your assessment and understanding of project changes, revise or update the erosion control plans. This may involve:

a) Modifying sediment control measures (e.g., installing silt fences, sediment basins) to address new areas of concern. Adjusting slope stabilization techniques (e.g., hydroseeding, erosion control blankets) based on updated site conditions. Implementing additional erosion control measures in areas prone to increased erosion risk due to project changes.

Engage Stakeholders: Communicate with project stakeholders including engineers, environmental specialists, and construction managers to ensure everyone is aware of erosion control needs resulting from project changes. Collaboration is essential for effective erosion control management.

Monitor and Adapt: Implement a robust monitoring program to regularly assess erosion control effectiveness. Adjustments may be needed as the project progresses and site conditions continue to evolve [2].

Comply with Regulations: Ensure that all erosion control measures comply with local environmental regulations and permit requirements. Stay informed about any regulatory updates that may impact erosion control practices.

Training and Awareness: Provide training and awareness sessions for project staff regarding erosion control best practices. Encourage a proactive approach to identifying and addressing erosion issues.

Emergency Preparedness: Develop contingency plans for responding to unexpected erosion events or severe weather conditions. Quick action can minimize potential damage and environmental impacts.

Document Changes: Keep detailed records of erosion control activities, modifications, and outcomes resulting from project changes. This documentation can be valuable for future reference and compliance reporting.

Regular Inspections: Conduct regular inspections of erosion control measures to ensure they are properly installed and maintained throughout the project lifecycle. See **Figure 3**.

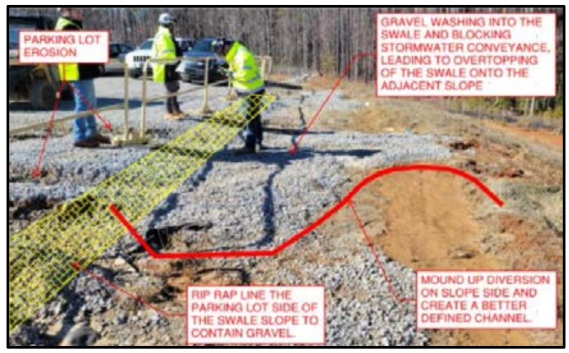

Figure 3
Erosion Control Inspection

By following these steps, you can adapt your erosion control strategies to effectively manage changing project conditions and minimize environmental impacts. Regular communication and proactive planning are key to successful erosion control in dynamic project environments.

Figure 4
Sediment Retention Ponds – AI Develop Programs Technologies

AI can provide advanced tools and techniques to analyze data, predict the impacts of changes, and optimize decisions in real time. See **Figure 5** and **Figure 6**. Here are some ways AI can be applied in this context:

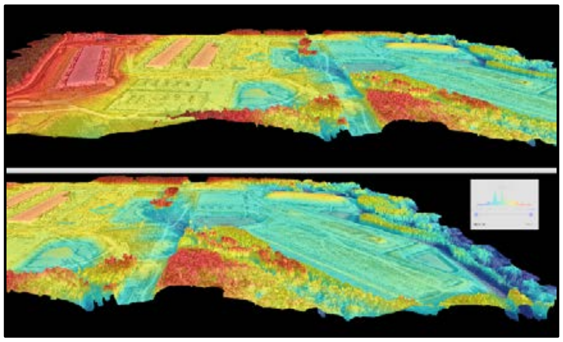

Figure 5
DEM Created By Drone

Predictive Analytics: AI can use machine learning models to analyze historical and current project data, identifying patterns and trends that help predict potential future changes. This can include changes in schedule, budget, resources needed, or erosion risks in your specific project case.

Risk Management: AI systems can constantly assess project risks and suggest actions to mitigate them. For example, by identifying areas prior to erosion due to design changes or weather conditions, AI can recommend specific erosion control measures.See (**Figure 6).**

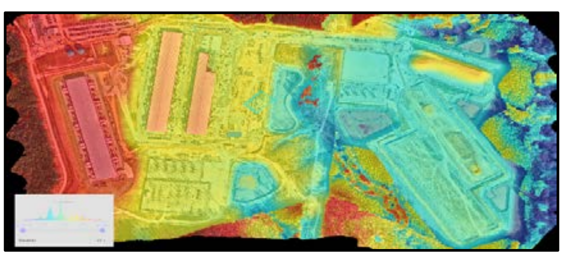

Figure 6
DEM of the Project

Resource Optimization: AI can optimize the allocation of resources, such as labor and machinery, considering changes in the project. This ensures efficient distribution of resources to address new tasks or needs generated by the changes.

Dynamic Planning: Using AI algorithms, dynamic project plans can be developed that automatically adjust as circumstances change. This includes automatically rescheduling activities and updating the critical path based on detected changes. See (**Figure 7).**

Figure 7
Site Evaluation Layout By Drone

Natural Language Processing (NLP): NLP systems can analyze project-related documents and communications to identify potential changes or requests. This helps keep the team informed and proactively respond to proposed changes.

Recommendation Systems: AI can offer intelligent, data-driven recommendations to adapt to specific changes in the project. See (**Figure 8).** For example, I recommend appropriate erosion control solutions based on new site conditions [1].

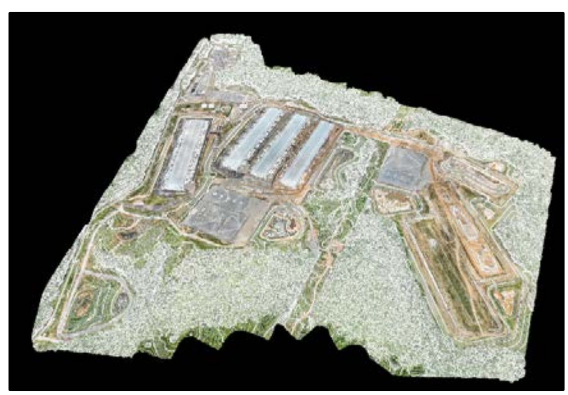

Figure 8
Contour Evaluation Using AI on Google Earth

Automated Monitoring: Using sensors and IOT (Internet of Things) technologies, AI can continuously monitor the status of the construction site, including erosion and other environmental impacts. This allows for a rapid response to unforeseen changes. See (**Figure 9 and Figure 10).**

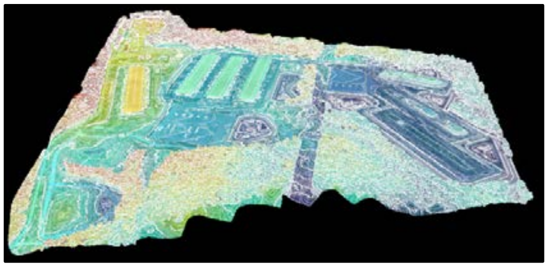

Figure 9
DEM and Contuor Elevation Analisis

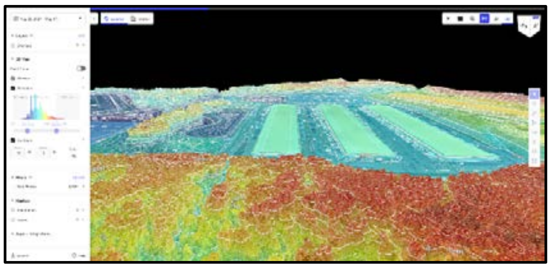

Figure 10
Lateral Site View

Simulation and Modeling: AI-based simulation models can predict the impact of proposed changes to the project, including effects on erosion and soil stability. This helps to make informed decisions before implementing changes on the ground. In short, artificial intelligence offers several powerful tools to manage and adapt to changes in construction projects, including erosion management. See (**Figure 11)** By integrating AI into project management, organizations can improve agility, efficiency, and responsiveness to dynamic change, while ensuring project success and sustainability. See (**Figure 12).**

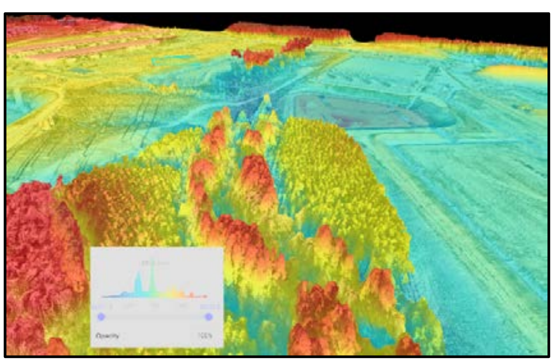

Figure 11
Site Depression Analysis

Figure 12
North Site View

Slope Stabilization Process

It is critical in construction projects to prevent erosion, landslides, and other stability-related issues. Here is an overview of key approaches and practices for effective slope stabilization:

1. **Assessment and Planning:**
   a) Site Analysis: Conduct a geological survey to understand soil types, drainage patterns, and potential risks associated with slope failure. See (**Figure 13).**
   b) Risk Assessment: Identify high-risk areas prone to erosion, landslides, or destabilization before beginning construction.

Figure 13
Areas Evaluated for Possibles Erosion Control Changes

2. **Design Considerations**
   a) Slope Gradient Reduction: Where possible, design slopes with gentler gradients. Steeper slopes are inherently more unstable.

b) Retaining Structures: Use retaining walls, gabions, or other structures to hold back soil and reduce slope angles where necessary.

c) Vegetation Planning: Incorporate vegetation into the design to help bind soil, increase water absorption, and reduce erosion.

3. Erosion Control Techniques

a) Terracing: Create terraces on steep slopes to break the slope into smaller, more manageable areas, which slows down water runoff and reduces erosion.

b) Laying Erosion Control Mats: Use geotextiles or erosion control mats to stabilize soil and promote grass growth. See (**Figure 14).**

c) Mulching: Apply a layer of organic or inorganic mulch to protect soil from erosion and enhance moisture retention.

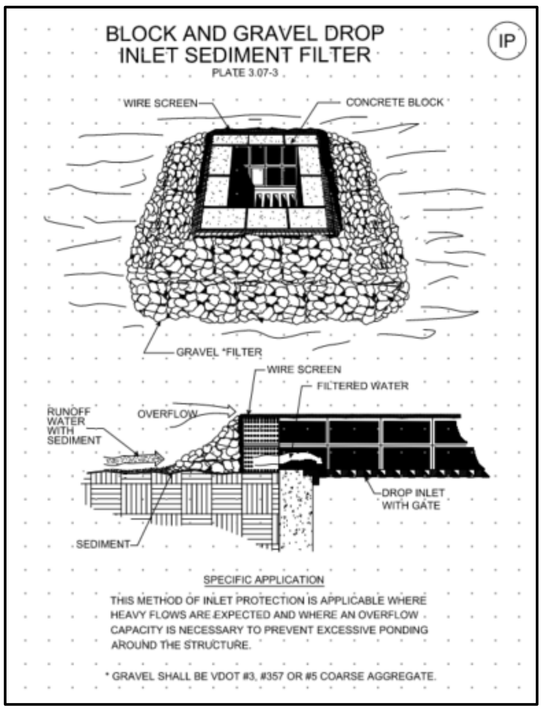

Figure 14
Erosion Control Systems

4. Drainage Management

a) Surface Drainage: Ensure adequate surface drainage through grading, curbs, and ditches to channel water away from vulnerable slopes.

b) Subsurface Drainage: Install drainage pipes or trenches to prevent water from accumulating on the slope, which can lead to destabilization.

c) Drainage as an Integrated Approach: Combine surface and subsurface drainage solutions for broader effectiveness.

5. Soil Reinforcement Techniques

a) Rock Anchors: Use rock anchors to stabilize slopes by anchoring structures to the bedrock below.

b) Soil Nails: Implement soil nailing with steel rods driven into the slope to reinforce soil and provide resistance against sliding.

c) Geogrids: Use geogrids for soil reinforcement in embankments, improving the load-bearing capacity of the slope.

6. Monitoring and Maintenance

a) Regular Inspections: Conduct regular monitoring for signs of erosion, movement, or instability on slopes during and after construction. See (**Figure 15).**

Figure 15
Erosion After Rain Event

b) Data Collection: Use instruments such as inclinometers or piezometers to measure slope movements and water levels to find potential landslide risks**.**

c) Maintenance Plans:

Develop and implement maintenance strategies to ensure that drainage systems and stabilization measures remain effective over time.

7. **Responding to Changes**
   a) Adaptation to Site Conditions: Be prepared to change stabilization techniques based on ongoing observations and changing site conditions, including weather events or construction activities. See (**Figure 16 and Figure 17)** [3].

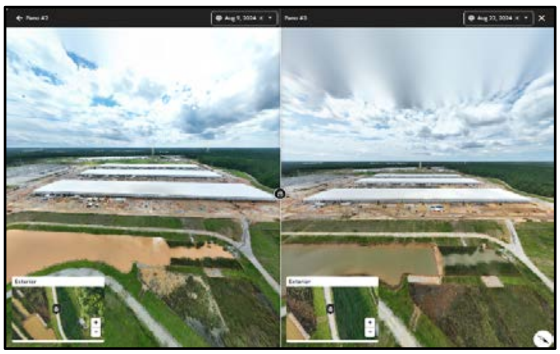

Figure 16
Rain Event Evaluation

Figure 17
Pictures Locations Aerial Layout

Development and Construction Phases

1. **Planning and Design Phase**
   - Site Assessment: Conduct thorough assessments to identify potential erosion and sedimentation risks.
   - Best Management Practices (BMPs): Design BMPs tailored to the specific conditions of the site, including silt fences, sediment basins, and erosion control blankets.

2. **Pre-Construction Phase**
   - Erosion Control Measures: Implement measures like temporary seeding and mulching to stabilize exposed soil before construction begins.
   - Construction Schedule: Plan construction activities in a manner that minimizes land disturbance and allows for sediment control measures to be implemented quickly.

3. **Construction Phase**
   - Regular Inspections: Conduct daily inspections to monitor the effectiveness of sediment control measures and adjust as necessary [4].
   - Installation of Control Devices: Use silt fences, sediment traps, and check dams to capture sediment runoff. See (**Figure 18).**

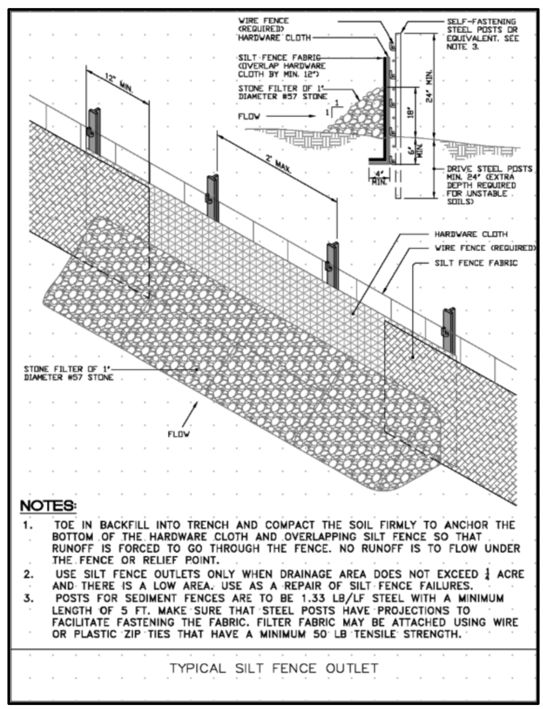

Figure 18
Typical Silt Fence Installation

- Water Management: Implement practices to manage stormwater runoff, such as diversion ditches and temporary retention ponds, to reduce erosion and sediment transport. See (**Figure 19).**

Figure 19
Run Off After Rain Event

4. **Operational Phase**
   - Consistency in Practices: Keep ongoing practices to control sediment throughout the operational life of the project. This may include continuous monitoring and adjustment of BMPs.
   - Training: Regular training for personnel on sediment control measures and their importance can help maintain compliance and effectiveness.

5. **Post-Construction Phase**
   - Site Restoration: Once construction is complete, restore disturbed areas through re-seeding and adding vegetation to help stabilize soil.
   - Long-term Monitoring: Post-construction monitoring should be conducted to ensure that sediment control measures remain effective over time, especially during rainfall events.

6. **Adaptability**
   - Given that the conditions of mega projects can change daily, having a flexible sediment control plan that allows for quick adaptation to changing site conditions is essential.

7. **Compliance and Reporting**
   - Ensure compliance with local, state, and federal regulations regarding sediment control. Regularly document sediment control practices and effectiveness.

Effective sediment control in mega projects requires a proactive, adaptive approach to manage the risks of erosion and sedimentation. See (**Figure 20 and Figure 21).** By implementing these practices consistently across all phases of the project and remaining responsive to changing conditions, you can significantly minimize environmental impacts.

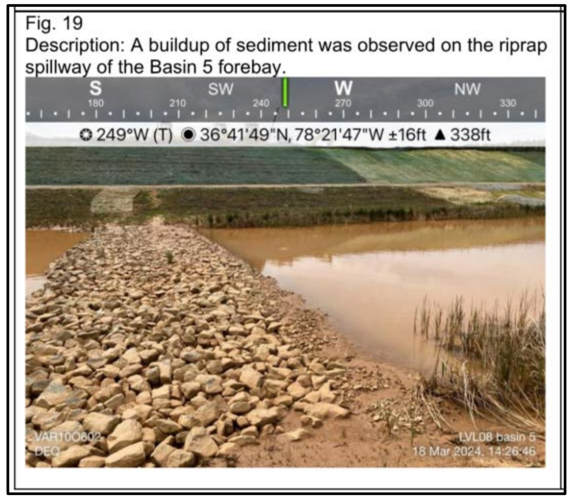

Figure 20
Run-Off Evaluation Inspection

Figure 21
Run-Off Erosion

Traps and Basins

Sediment traps and sediment basins will be designed and constructed based on the total drainage area to be served by the trap or basin. Sediment traps should not be used for more than 18 months unless they are designed as permanent impoundments.

The minimum storage capacity of a sediment trap will be 134 cubic yards per acre of drainage area (134 cubic yards per acre is equivalent to 1 inch of runoff), and the trap will only control drainage areas less than 3 acres. Provide a combination of man-made stormwater conveyance system improvement, stormwater detention, or other measures that is satisfactory to the VESMP or VESCP authority. Surface runoff from disturbed areas that is composed of flow from drainage areas greater than or equal to 3 acres will be controlled by a sediment basin. Temporary sediment basins should be designed and constructed based on the total drainage area to be served by the sediment basin. The maximum total drainage area to be served by a temporary sediment basin should be 100 acres. The outfall system will, at a minimum, maintain the structural integrity of the basin during a 25-year storm of 24-hour duration. Runoff coefficients used in runoff calculations will correspond to a bare earth condition or those conditions expected to exist while the sediment basin is used. See (**Figure 22).** Remaining half should be in the form of a drawdown or dry storage to provide extended settling time during less frequent, larger storm events. Concentrated stormwater flow from a temporary sediment basin should be released into an adequate stormwater conveyance system. Demonstrate that the total drainage area at the point of discharge within the stormwater conveyance system is at least 100 times greater than the drainage area served by the temporary sediment basin in question.

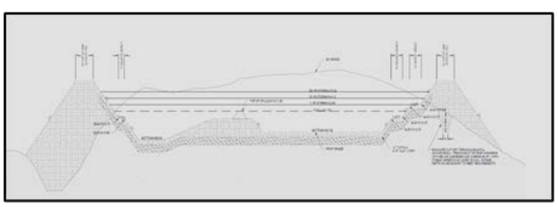

Figure 22
Sediment Basing

Cut and fill slopes will be designed and constructed in a manner that will minimize erosion. Slopes that are found to be eroding excessively within 1 year of permanent stabilization will be provided with additional slope stabilizing measures until the problem is corrected. Cut and fill slopes are susceptible to erosion due to increased runoff flow velocity, so they must be constructed in the best way possible to decrease erosion by reducing slope length and grade. See (**Figure 23).**

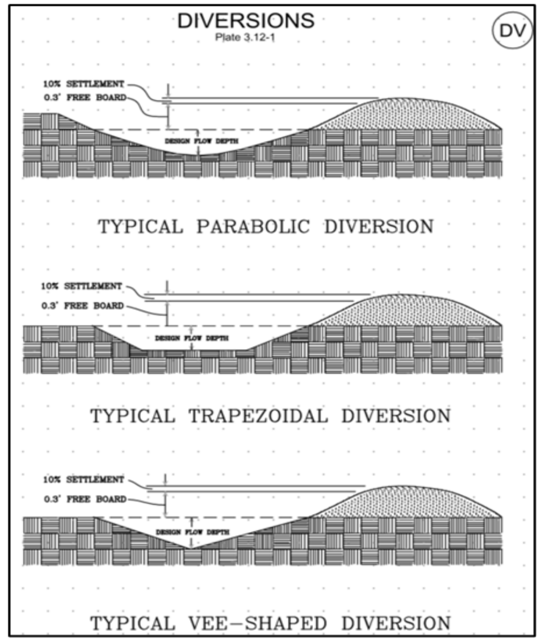

Figure 23
Typical Erosion Detail

Plans must clearly show slope length and grades that will remain stable. It is important that slopes are properly seeded and mulched to set up permanent vegetation so erosion by concentrated flow does not occur. Roughening the surface of the slope can also help decrease runoff by lowering the velocity of flow and increasing water retention, which leads to better seed germination. This practice should generally be implemented unless the slope requires a high degree of maintenance mowing after vegetative establishment.

The Evolution of Minimum Standard 19 Channel Protection Criteria MS-19 (9VAC25-875-560) requires designers to evaluate the adequacy of the downstream man-made and/or natural channels to safely convey the developed condition runoff and to verify the adequacy of all channels and pipes in the following manner:

1. If not using energy balance methodology (see Section 5.3.2.3 Channel Protection if you are unfamiliar with this method), demonstrate that

the total drainage area to the point of analysis within the channel is 100 times greater than the contributing drainage area of the project (in which case, the channel or pipe system is assumed to be adequate based on the correspondingly small impact of the project's runoff to the larger stream or channel system).

2. Natural channels will be analyzed using a 2-year storm to verify that stormwater will not overtop channel banks or cause erosion of channel beds or banks. See (**Figure 24 and Figure 25).**
3. All man-made channels will be analyzed using a 10-year storm to verify that stormwater will not overtop its banks and use a 2-year storm to prove that stormwater will not cause erosion of channel bed or banks; and
4. Pipes and storm sewer systems will be analyzed using a 10-year storm to verify that stormwater will be contained within the pipe or system.
5. If the existing or man-made channels or pipes are not adequate, the applicant will:

   5.1 Improve the channel to a condition that meets the artificial channel criteria previously described. Improve the pipe or pipe system so that the 10-year storm is contained within the system.

   5.2 Develop a site design that:

   a. Will not cause the pre-development peak runoff rate from a 2-year storm to increase when runoff outfalls into a natural channel; or
   b. Will not cause the pre-development peak runoff rate from a 10-year storm to increase when runoff outfalls into a man-made channel.
   c. Provide a combination of channel improvement, stormwater detention, or other satisfactory measures to the VESMP authority to prevent downstream erosion.

Table 5-1 Allowable Sheet Flow Velocities by Slope and Cover

Land Slope	Land Cover	Velocity (ft/sec)*
0% - 5%	Bermudagrass	6
0% - 5%	Reed canarygrass Tall fescue Kentucky bluegrass	5
0% - 5%	Grass-legume mixture	4

Figure 24
Flow Velocities Table

Table 5-1 Allowable Sheet Flow Velocities by Slope and Cover

Land Slope	Land Cover	Velocity (ft/sec)*
0% - 5%	Red fescue Redtop Annual lespedeza Small grains Temporary vegetation	2.5
5% - 10%	Bermudagrass	5
5% - 10%	Reed canarygrass Tall fescue Kentucky bluegrass	4
5% - 10%	Grass-legume mixture	3
Greater than 10%	Bermudagrass	4
Greater than 10%	Reed canarygrass Tall fescue Kentucky bluegrass	3
Any	Earth, sandy silt	2
Any	Earth, silt clay	3.5
Any	Earth, clay	6
Any	Rock, sedimentary	10
Any	Rock, sandstone	8
Any	Rock, shale	3.5
Any	Rock, igneous or metamorphic	20

Sources: Virginia Erosion & Sediment Control Handbook, Table 5-14; NRCS National Engineering Handbook, Part 654, Chapter 8, Table 8-4)

*For highly erodible soils (i.e., soils with an erodibility factor [K factor] greater than 0.35), permissible velocities should be decreased by 25%.

Figure 25
Flow Velocities by Slope and Cover

CONCLUSION

Big Developments need a lot of coordination to prevent inconvenient situations and possible violations of codes and laws. Over a prolonged period, weather, design changes, or other conditions create a big challenge for these developments. To comply, evaluate, and make rapid changes to make the project stay on track and stay with the same commitment as the design requires it's a daily challenge. Logistics and new actions need to be implemented in advance of the construction process. Implementing effective slope stabilization and erosion control techniques during construction projects is vital for safety, environmental protection, and long-term sustainability. A combination of proper planning, engineering solutions, and ongoing maintenance can significantly reduce the risk of slope failure, and excess sediment control can incur additional costs for administrative penalties for environmental violations. AI is one of the big tools for helping in all situations that need to be addressed in advance in all phases of construction projects.

REFERENCES

[1] Virginia Department of Environmental Quality. (n. d.). *Virginia Stormwater Management Handbook* [Online]. Available: https://online.encodeplus.com/regs/deq-va/doc-viewer.aspx#secid--1.

[2] Virginia Department of Environmental Quality. (n. d.). *Virginia Stormwater Management Handbook, C-SCM-08*

Rock Filter Outlet [Online]. Available: https://online.encodeplus.com/regs/deq-va/doc-viewer.aspx#secid-616.

[3] Exact Stormwater Management. (n. d.). *Stormwater Facility Inspection & Maintenance* [Online]. Available: https://www.exactstorm.com/bmp-maintenance/?gad_source=1&gclid=CjwKCAjw1NK4BhAwEiwAVUHPUKfmCZYfkxhaVHHymuWLJk5QBtnGbklQ6SbhH9rPATIMEgGse-d95RoC0AEQAvD_BwE.

[4] J. Harbor, “Engineering geomorphology at the cutting edge of land disturbance: erosion and sediment control on construction sites,” in *Geomorphology*, vol. 31, no. 1-4, pp. 247-263, Dec. 1999. DOI: 10.1016/s0169-555x(99)00107-5.