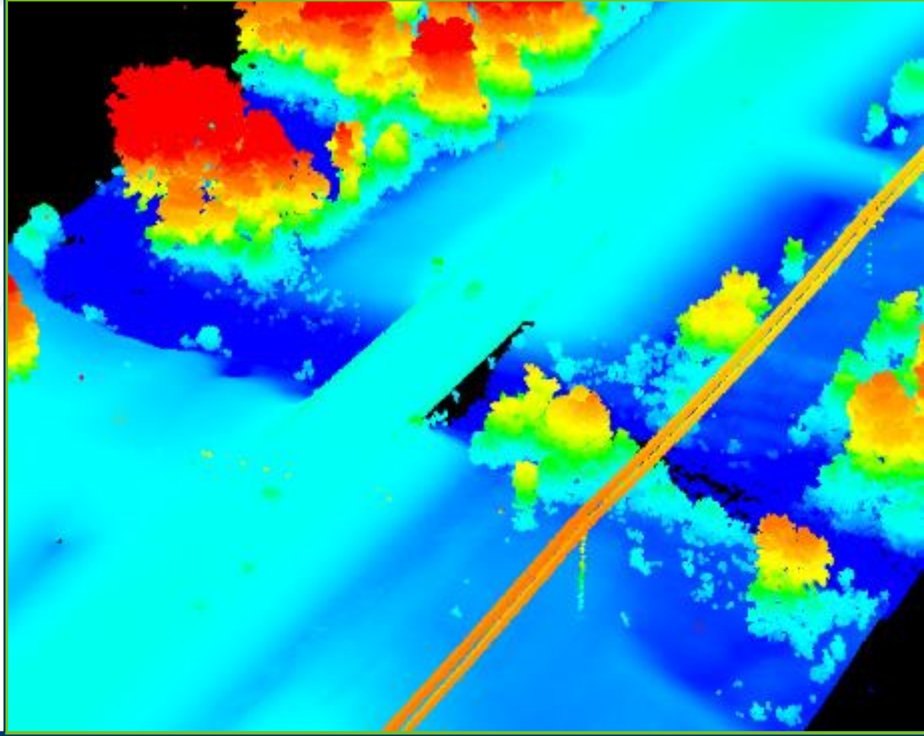

Mapping Hydrologic Connectivity and Wetlands with LiDAR Processes and Techniques from Minnesota and Wisconsin

Sean Vaughn, MNIT@DNR

3D Geomatics Committee Chair

GIS hydrologist – Watershed & LiDAR data steward

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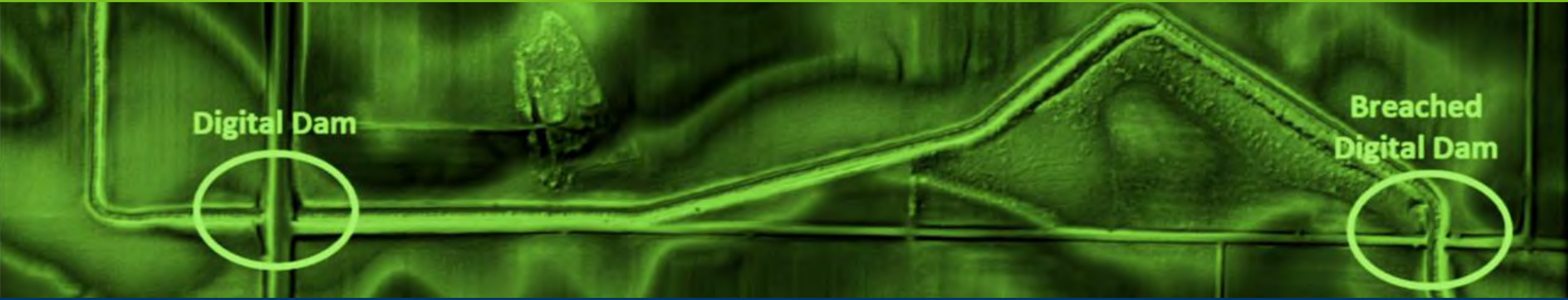
DEM Hydro-mod Subgroup Chair

GIS Analyst – Watershed & LiDAR Data Steward

rick.moore@state.mn.us

Tuesday, January 19, 2021
2:00 PM (central time)
Online

Digital Elevation Model (DEM) HYDRO-MODIFICATION



An Introduction to Minnesota's Perspective

Note: DEM **Hydro-modification** = DEM **Conditioning**

DEM Hydro-modification: is a digital depression examination process that uses terrain analysis tools in a geographic information system (GIS) to modify lidar-derived, raster-cell elevation values (Z-values) in digital elevation models (DEM) resulting in a hydro-modified DEM (hDEM).

Introduction

Topics/Agenda...

Agenda

Mapping Hydrologic Connectivity and Wetlands with LiDAR
Processes and Techniques from Minnesota and Wisconsin

Key Topics from Sean and Rick

- **Awareness:** Lidar does not replicate hydrologic connectivity of the landscape.
- Lidar-derived DEMs: **Mapping and Establishing Hydrologic Connectivity**
- **Coordination:** Establishing Collaborative Community of Practice
- hDEM – Special digital surfaces

LiDAR does its job, lack of flow in DEMs is not a flaw of lidar
Proper replication of landscape hydrology in DEMs is required
hDEMs are foundational data (Point Cloud, DEMs)
Establish Coordination to ensure hDEM development is conducted to a level of completes and accuracy that serves all hydraulic and hydrologic business.
Culvert Database supports culvert data sharing for DEM hydro-modification

Building Connections to Lidar and Wetland Management

- I started modifying Digital Elevation Models (DEMs) in 1997
  - Rick has been modifying DEMs for the last decade
- My career started in Wetland Delineation and mapping the hydrologic connectivity of wetlands (surface water)
- I was part of bringing lidar to Minnesota starting in 2002, our statewide collection was completed between 2008 – 2012.
- I’m serving as a lead to bring Minnesota its second state lidar collection.

- Field Inspection – **Roadside Mapping** (1992)

Depressions & Impressions

Drainage Discoveries

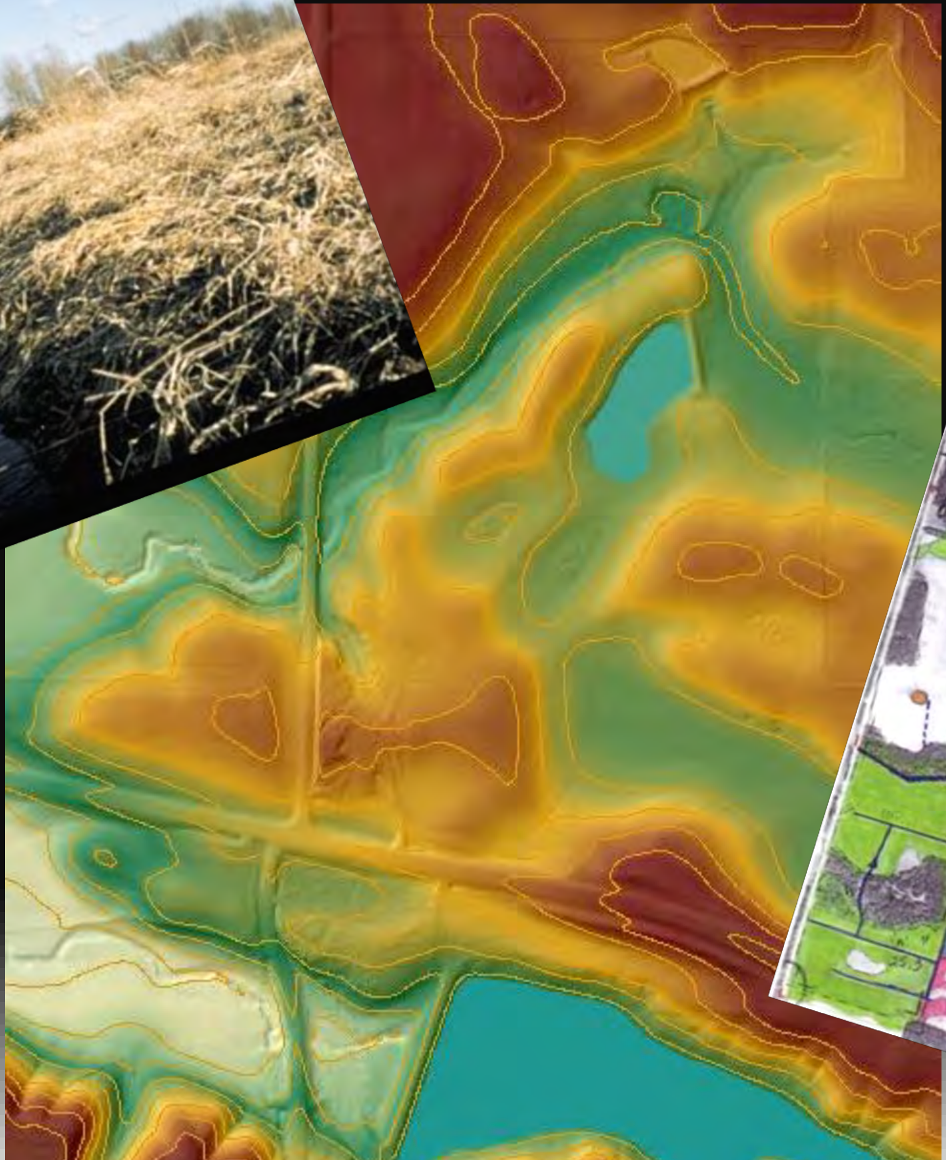
- Field Inspection – **Aerial Mapping** (1992)

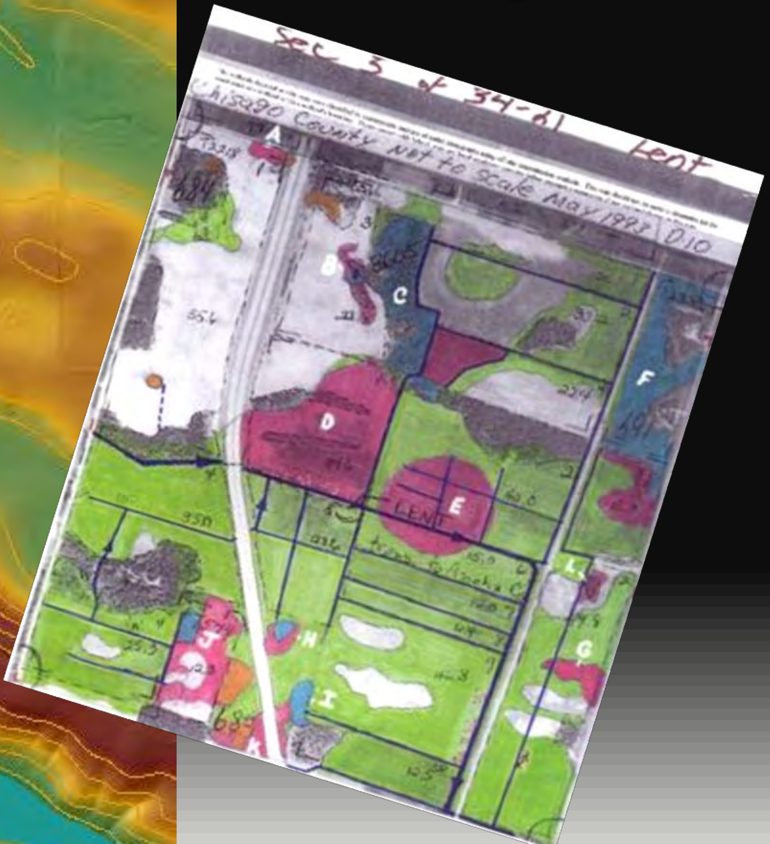
- Oblique Photos Indicate Linear Signatures of Ditching/water routing
- LiDAR Captures this Detail

- One Dimensional Planar View – **Manual GIS** (1992 - 1994)
  - Manual Interpretation

  - Manual Illustration

Hydro Background | Manual Hydrography → Lidar-DEM Hydrography





- LiDAR products allow us to identify all of those hydrography features from one high accuracy data set.

3DGeo Workgroups

Sectors of Expertise

- **Multidiscipline** committee organized by workgroups
- Each discipline sector is comprised of **subject matter experts**
- **Five** workgroup-sectors now established with **work plans**
- **Today** we will share the successes of the **DEM Hydro-modification** Subgroup
  - Rick Moore – Chair
  - Sean Vaughn – Committee Liaison

3DGeo - Data Acquisition Workgroup

Mission:

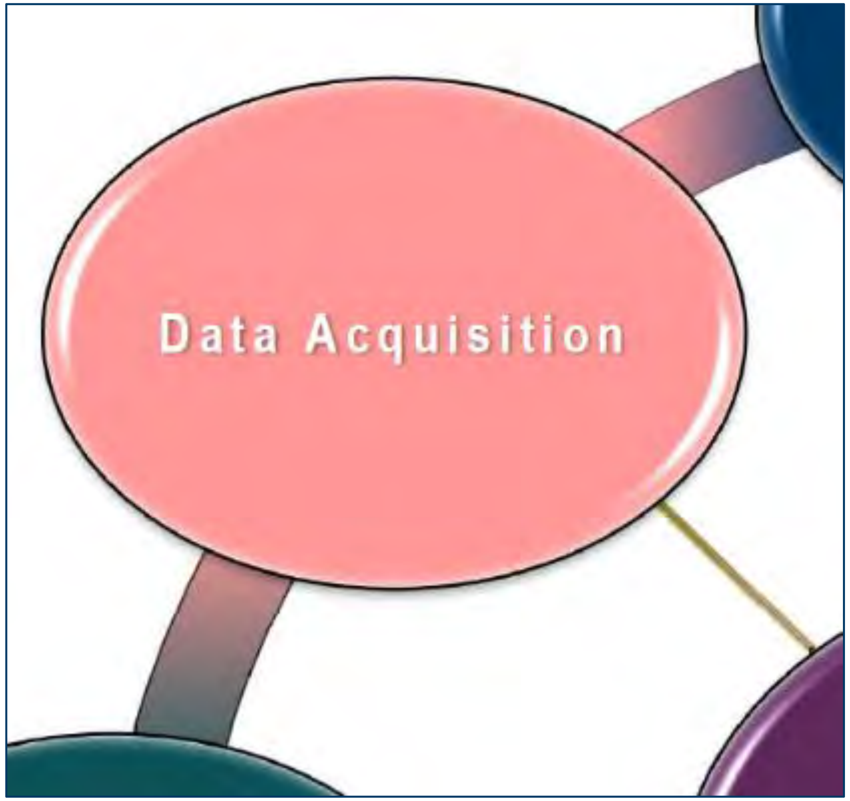
- Promotes **procurement** of foundational **3D data** for Minnesota.

Co-Chairs

- Sean Vaughn, Alison Slaats, and Gerry Sjerven

Lidar Acquisition Subgroup:

- Alison Slaats (MnGeo), Dan Ross (MnGeo), Jennifer Corcoran (DNR), Colin Lee (MnDOT), Sean Vaughn (MNIT DNR), Gerry Sjerven (MN Power), Matt Baltes (NRCS), Joel Nelson (U of MN), Joe Sapletal (Dakota Co), Andra Mathews (MnDOT), and Brandon Krumwiede (NOAA)



3DGeo – Hydrogeomorphology Workgroup

Mission

- Promotes the consistent development of Minnesota's **hydrography data** and to enable data exchange through coordination, cooperation and **standards development**

Co-chairs

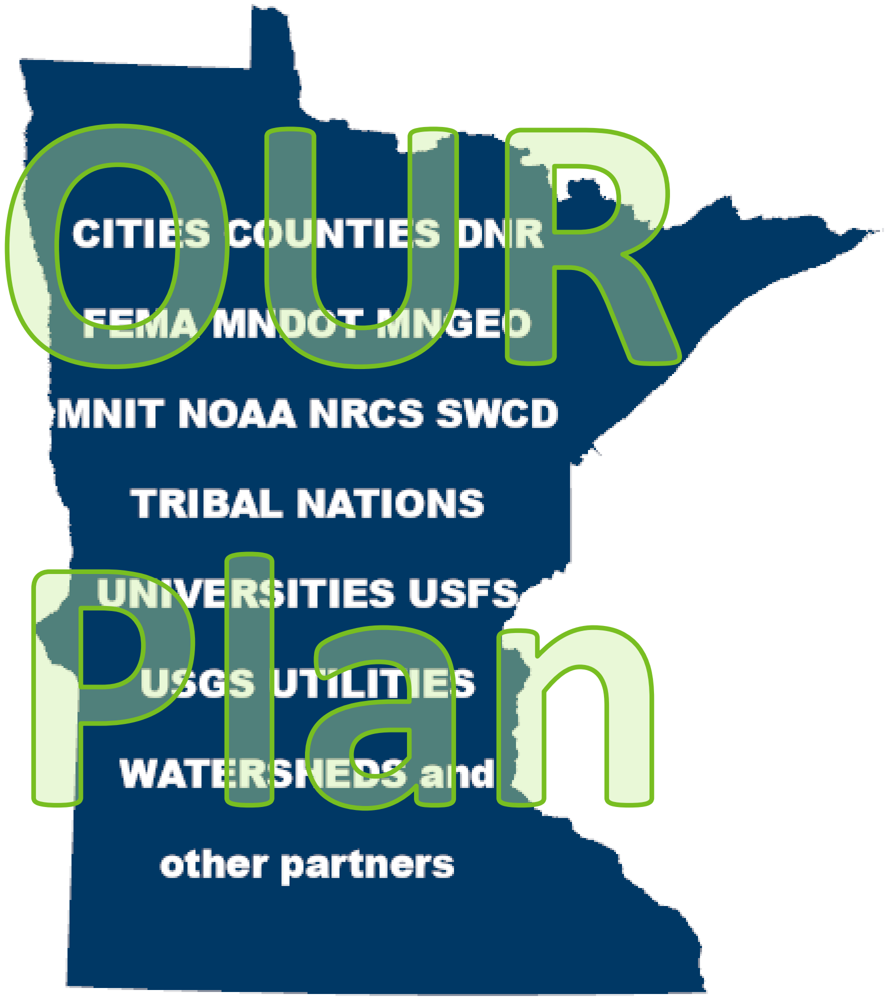
- **Rick Moore**, **Jamie Schulz** and **Andrea Bergman**

Liaison

- **Sean Vaughn**

Minnesota State Lidar Plan

Minnesota Lidar Plan - Our Plan – Your Plan – ONE PLAN

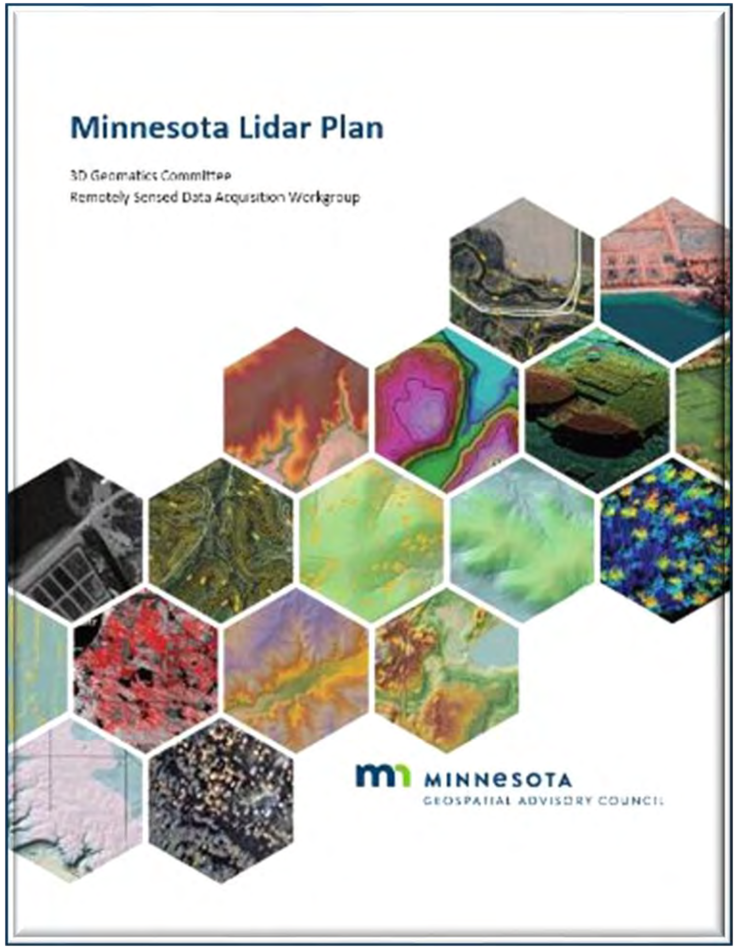


The Minnesota Lidar Plan

- **One** plan for Minnesota
- **Committee** led plan, not a state agency plan
- **Collaboration** of the geospatial community
- **Coordination** of lidar acquisition in Minnesota leverages federal match dollars

Lidar acquisition success is built on a guiding plan that pulls the community together to foster collaboration and coordinate funding to achieve the common goal of new high density lidar across Minnesota

Minnesota State Lidar Plan and Story Map



https://www.mngeo.state.mn.us/committee/3dgeo/acquisition/Minnesota_State_Lidar_Plan.pdf

http://bit.ly/MnLidarPlanStoryMap

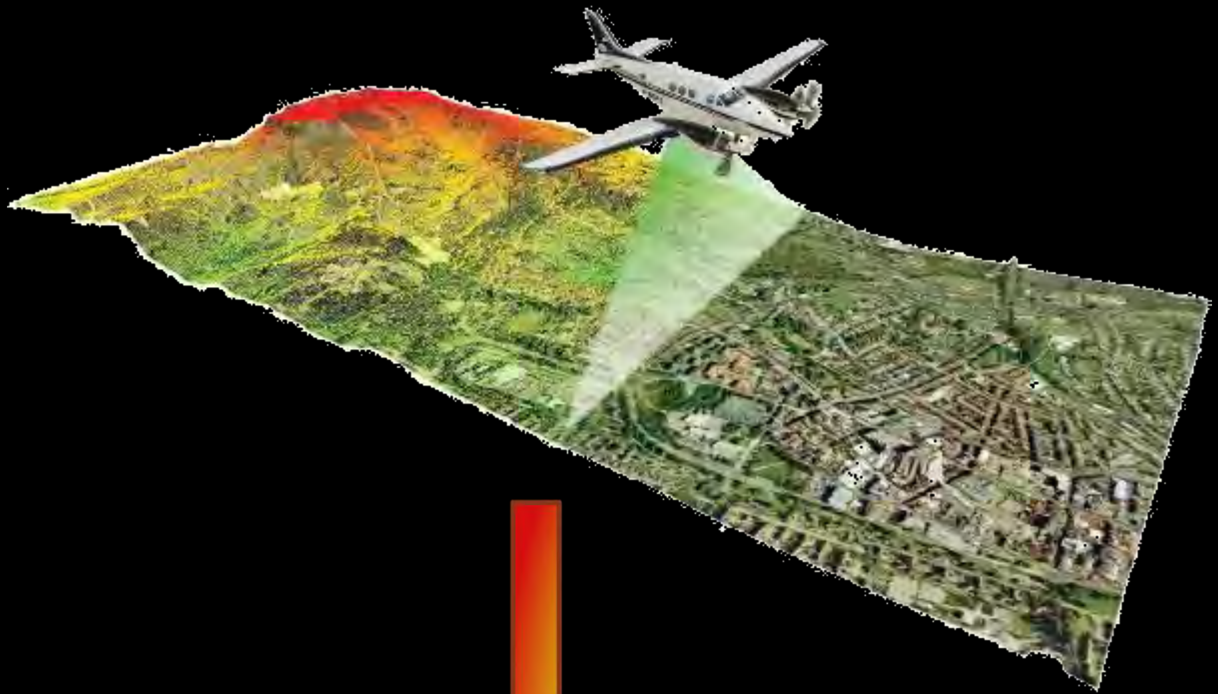
Next

Lidar & DEMs

LiDAR Acquisition → Point Cloud

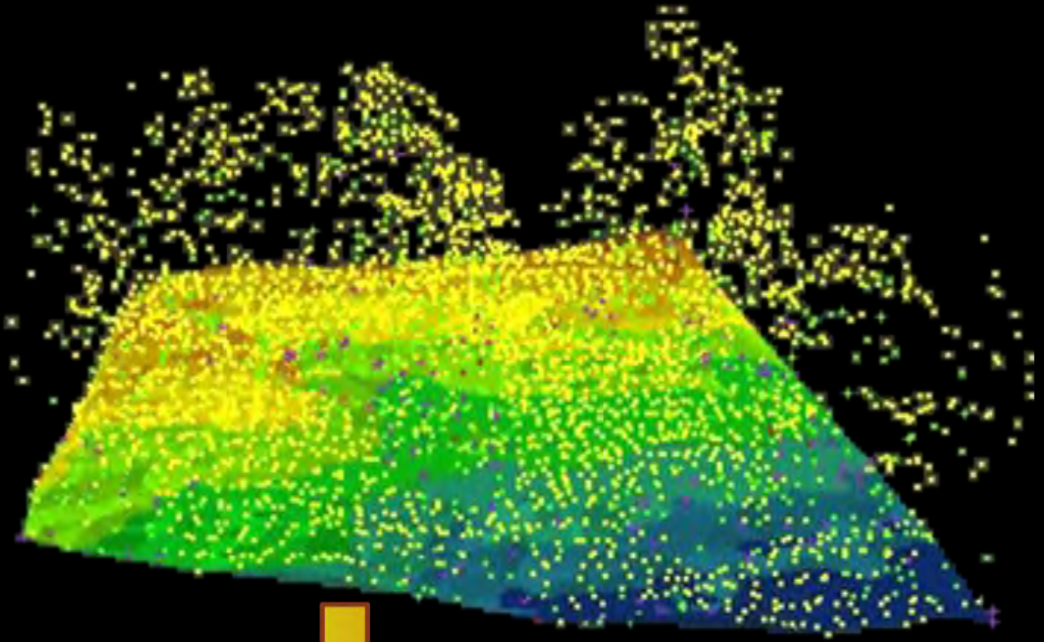
LiDAR Acquisition → Point Cloud

Lidar Acquisition



Lidar Point Cloud

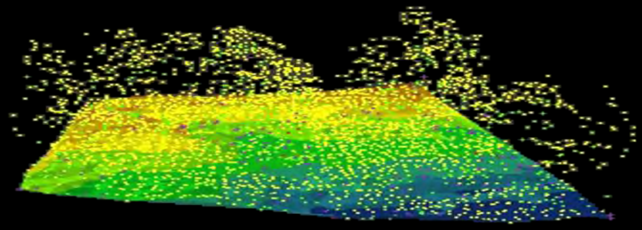
3D Rendition of Natural and Built Environments



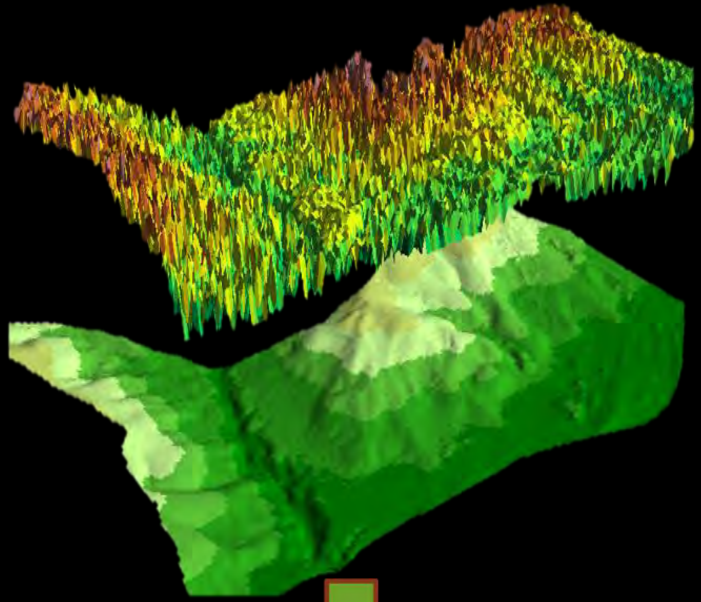
Painting Points

Lidar Point Cloud Classification

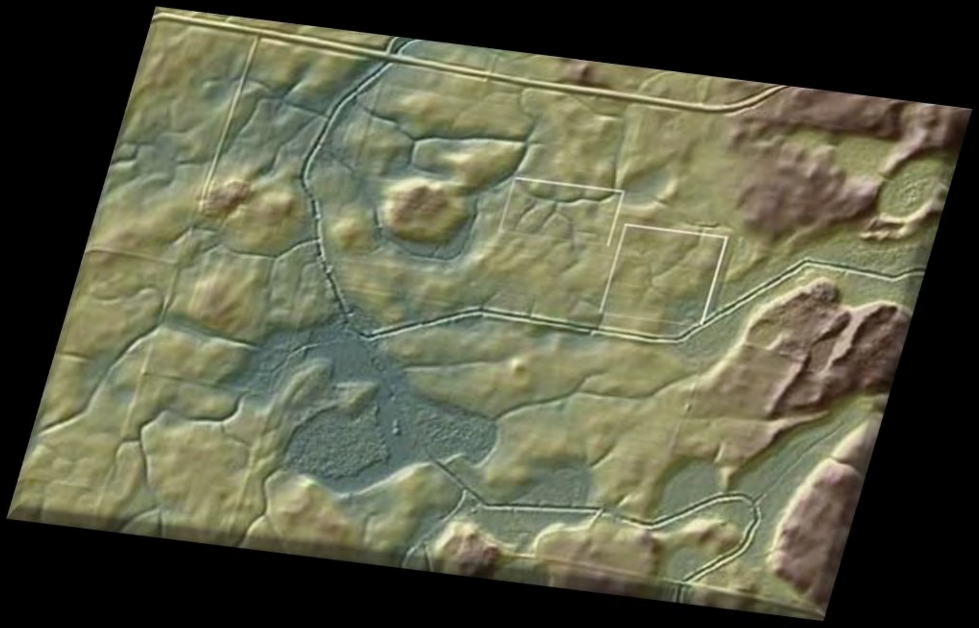
- Modeled water does not "flow" within the DEM without DEM Hydro-modification



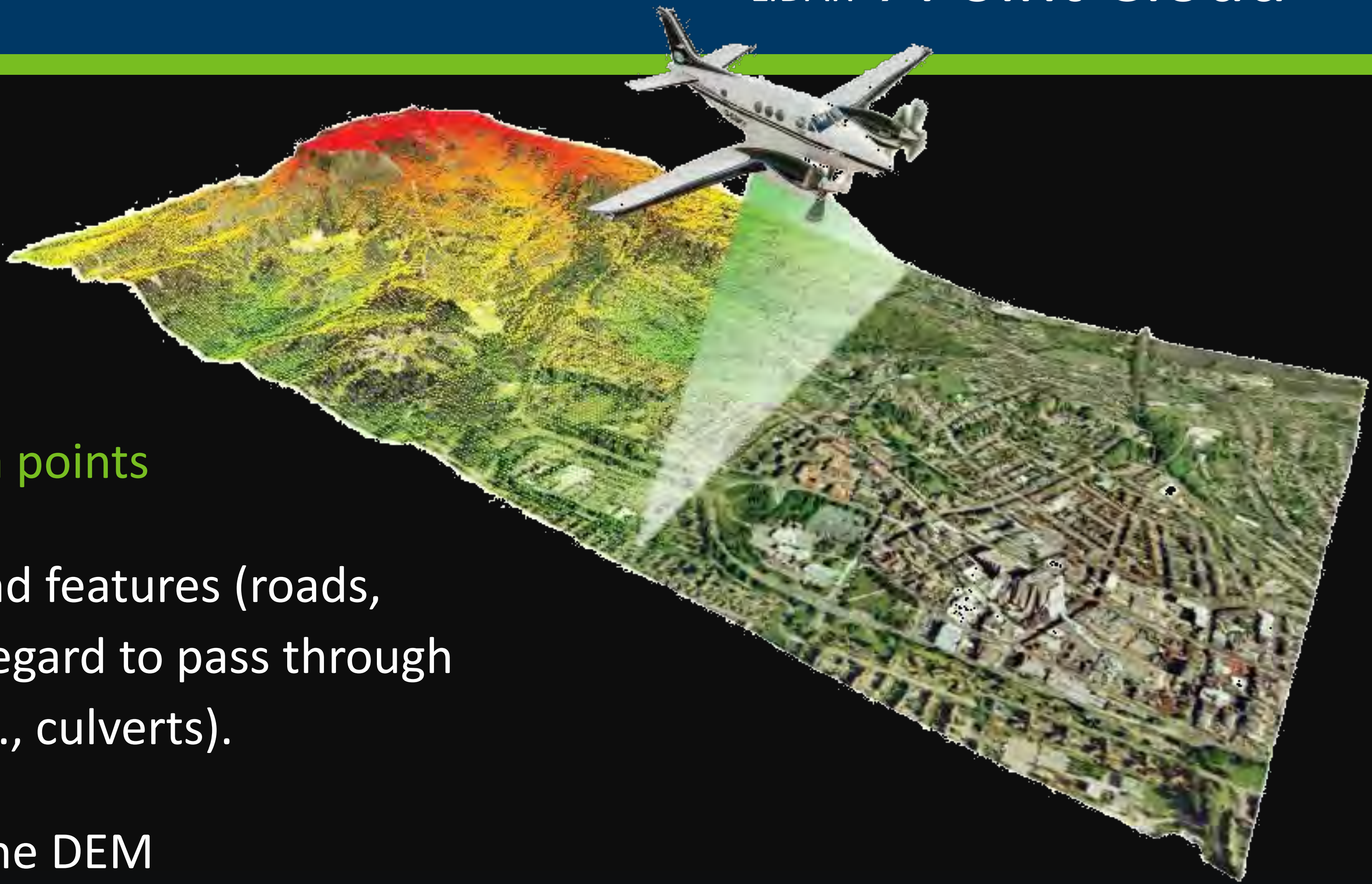
LiDAR 3D Point Cloud



LiDAR-derived 3D Digital Elevation Model (DEM)



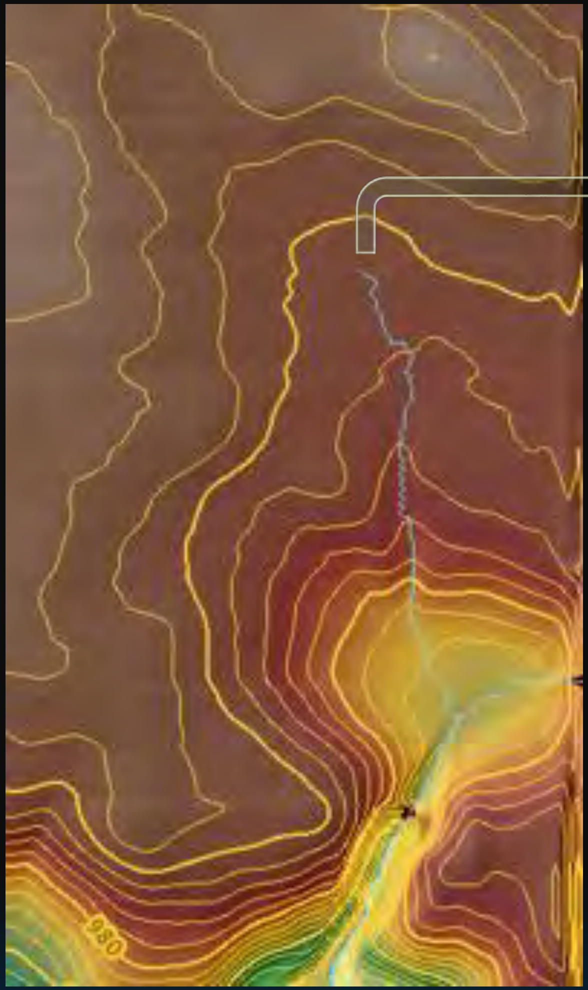
LiDAR does its job



- Millions of elevation data points
- LiDAR captures terrain and features (roads, dams, bridges) without regard to pass through conveyance of water (e.g., culverts).
- Creates Digital Dams in the DEM
- Not unique to Minnesota

- Features of hydrologic Significance.
  - Nickpoint
  - Fluvial Processes
  - Soil Degradation
- Where does the watercourse begin ?
  - Where concentrated flow begins.
  - LiDAR captures these landforms.

We Model this with DEMs



- Features of hydrologic Significance.
  - Nickpoint
  - Water Conveyance Landform
- Where does the watercourse begin ?
  - Where concentrated flow begins. LiDAR captures these landforms.

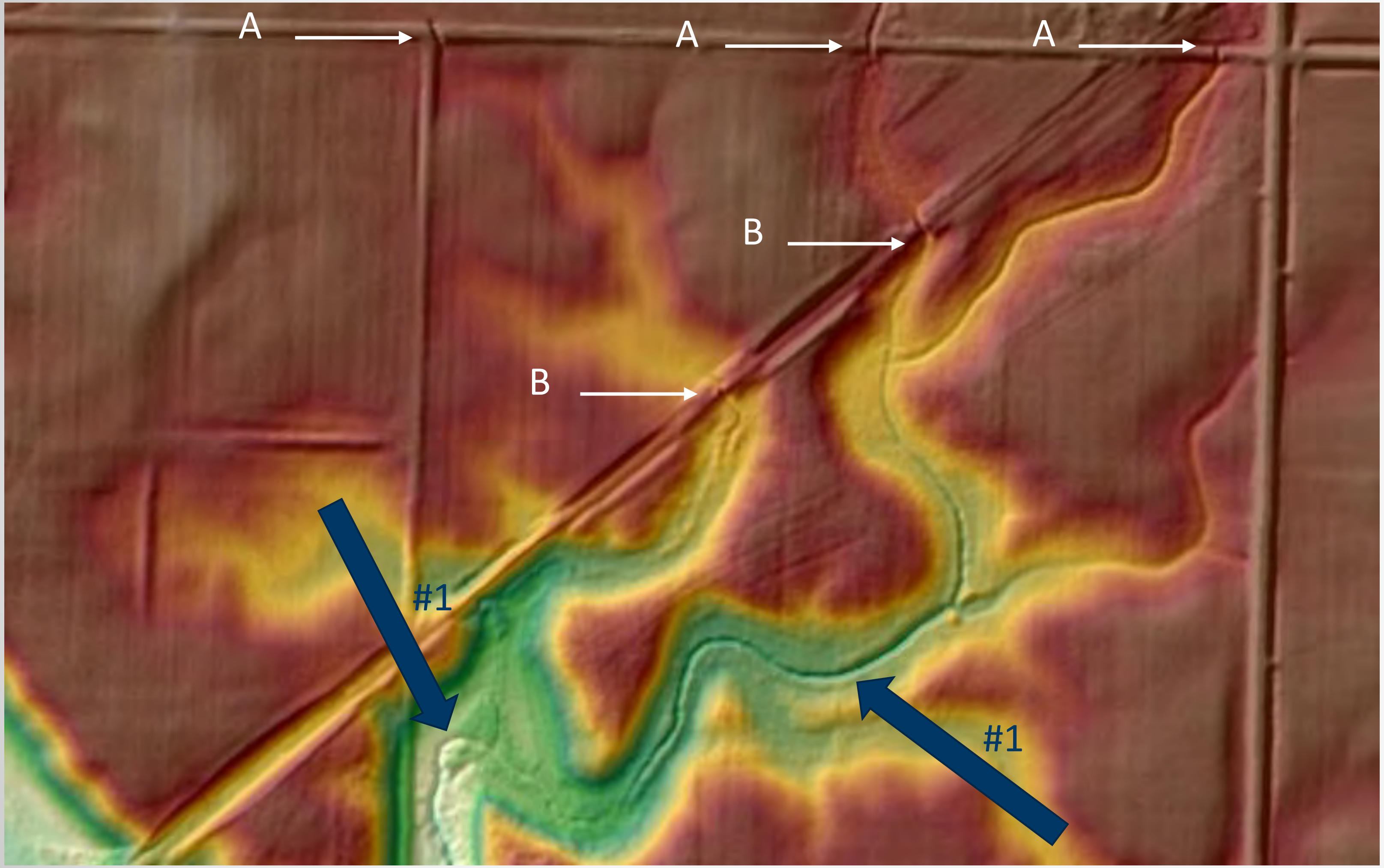
We Do this with Digital Elevation Models (DEM)

What is DEM Hydro-modification...

DEM HYDRO-MODIFICATION

- is -

DIGITAL DAM REMOVAL



Hydro-modified Digital Elevation Model (hDEM)

- Digital Dams in this DEM have been breached to allow water to flow in the model

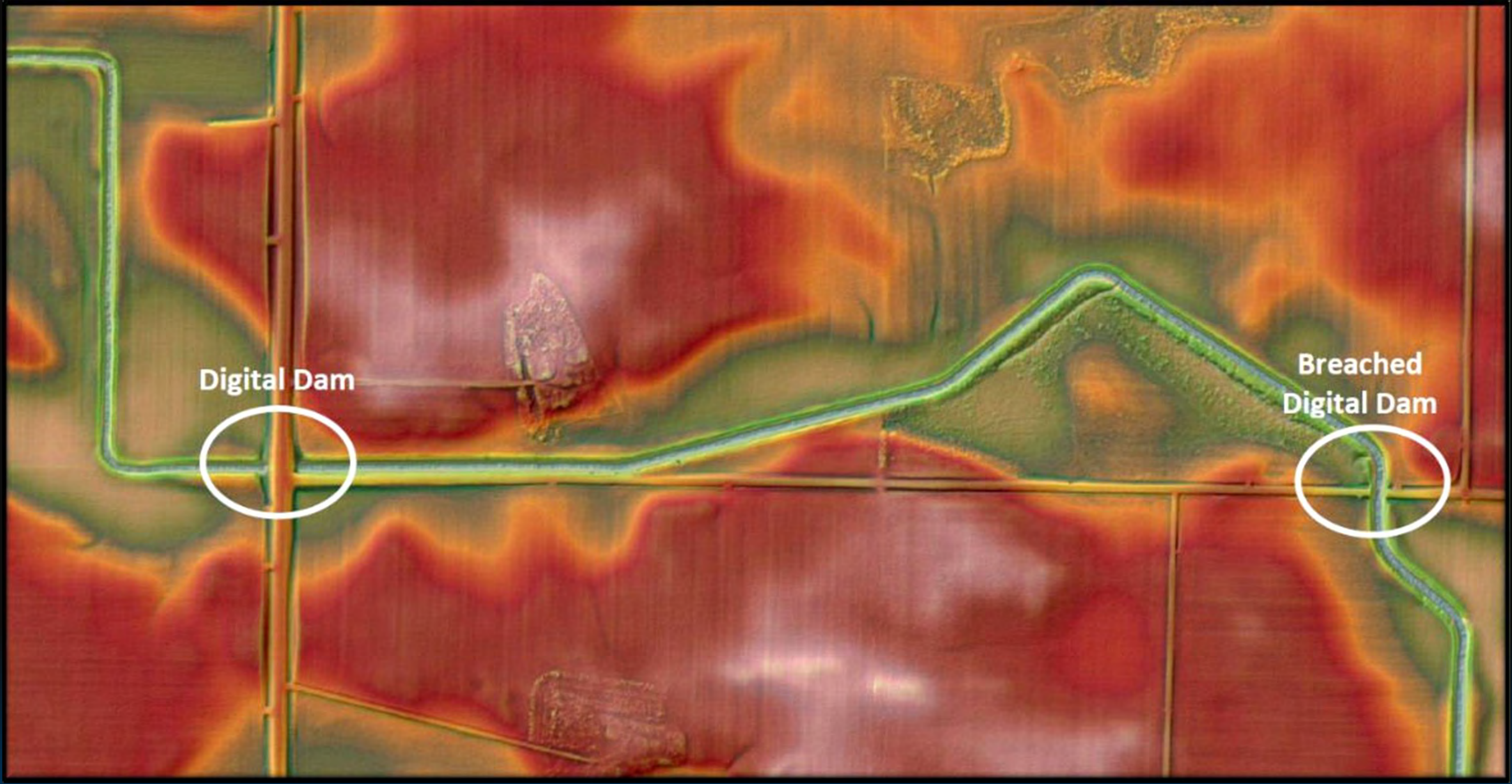
  (A) - Roads

  (B) - Railroad

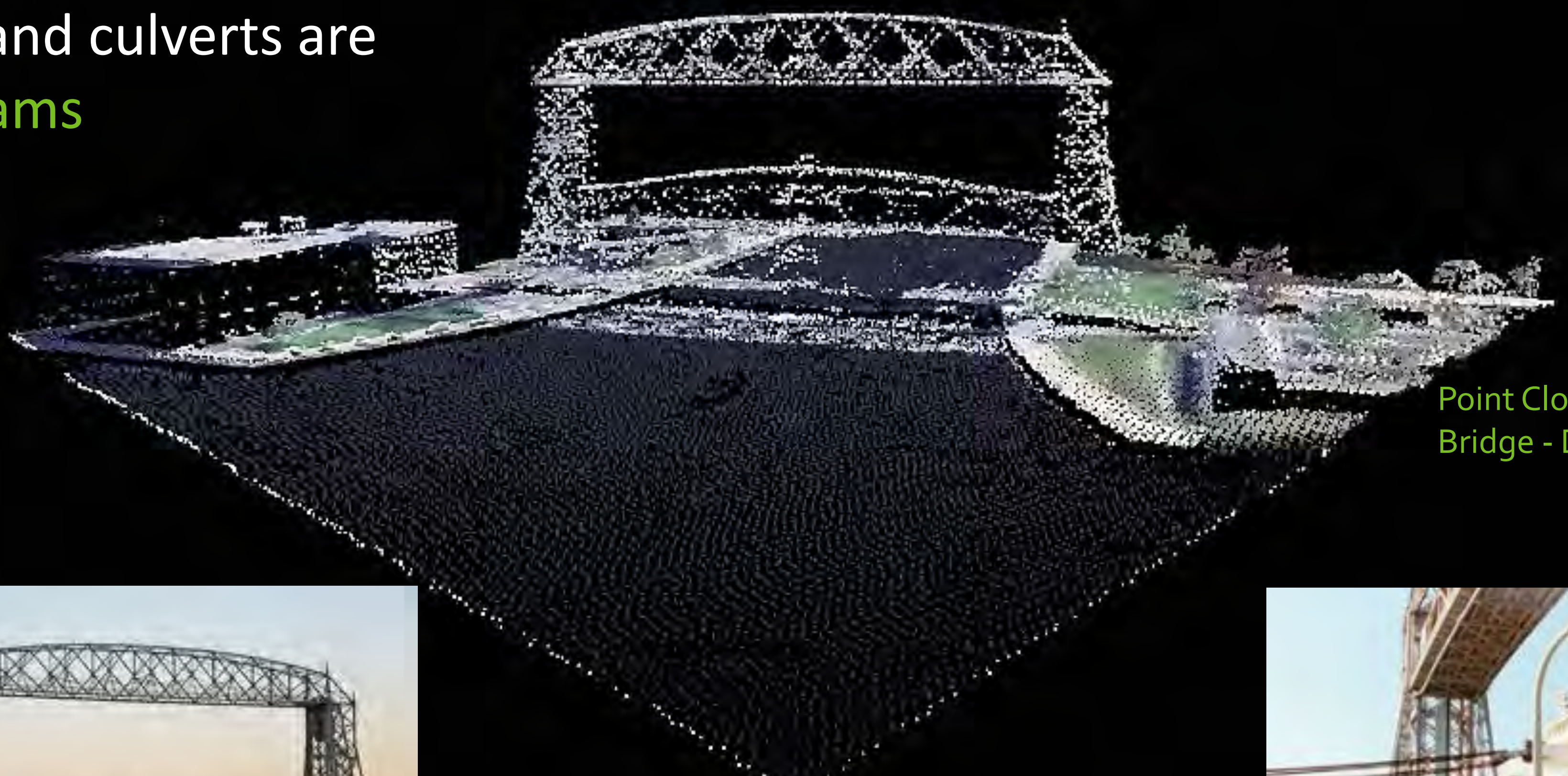
  (#1) - Watercourse

  - Receives water from these “breached” locations (A) and (B)

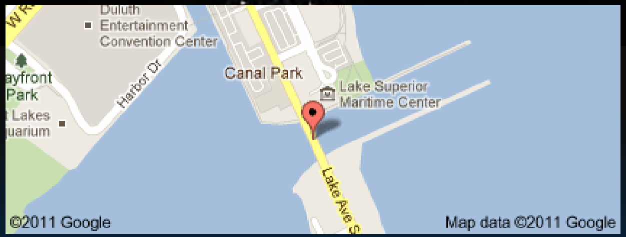
LiDAR → Point Cloud → DEM → Digital Dams



- Bridges and culverts are digital dams



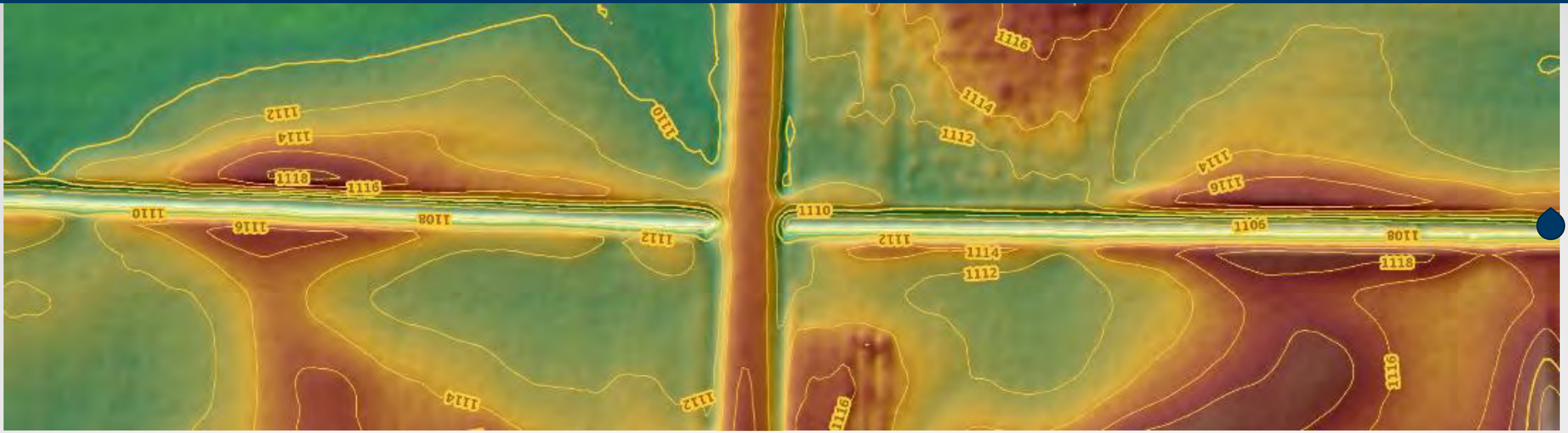
Point Cloud of the Aerial Lift Bridge - Duluth, MN



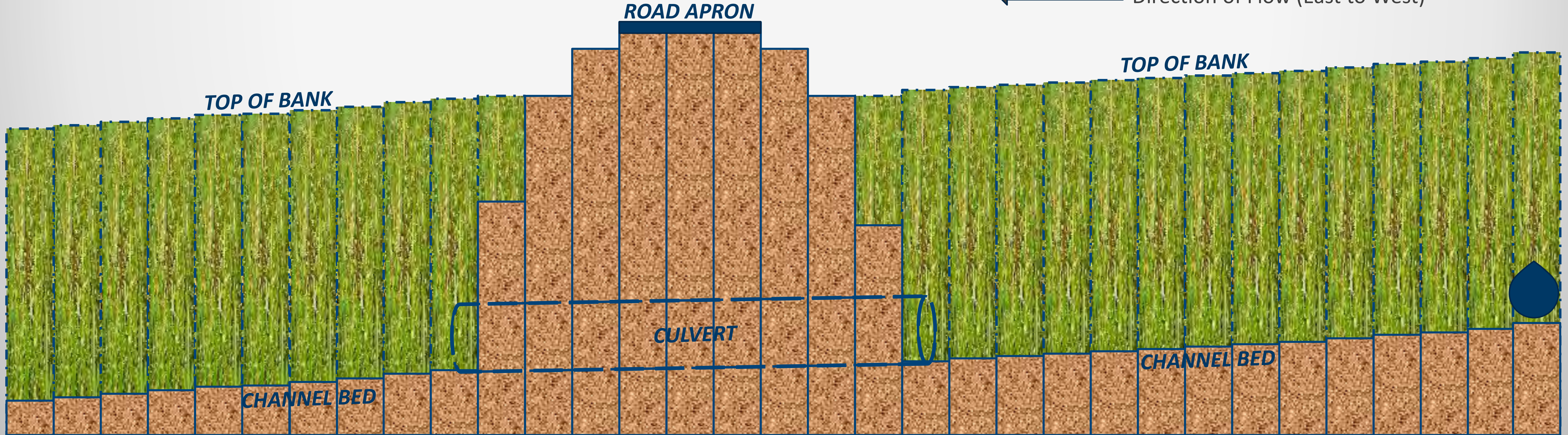
Next

DEM Hydro-modification Animation...

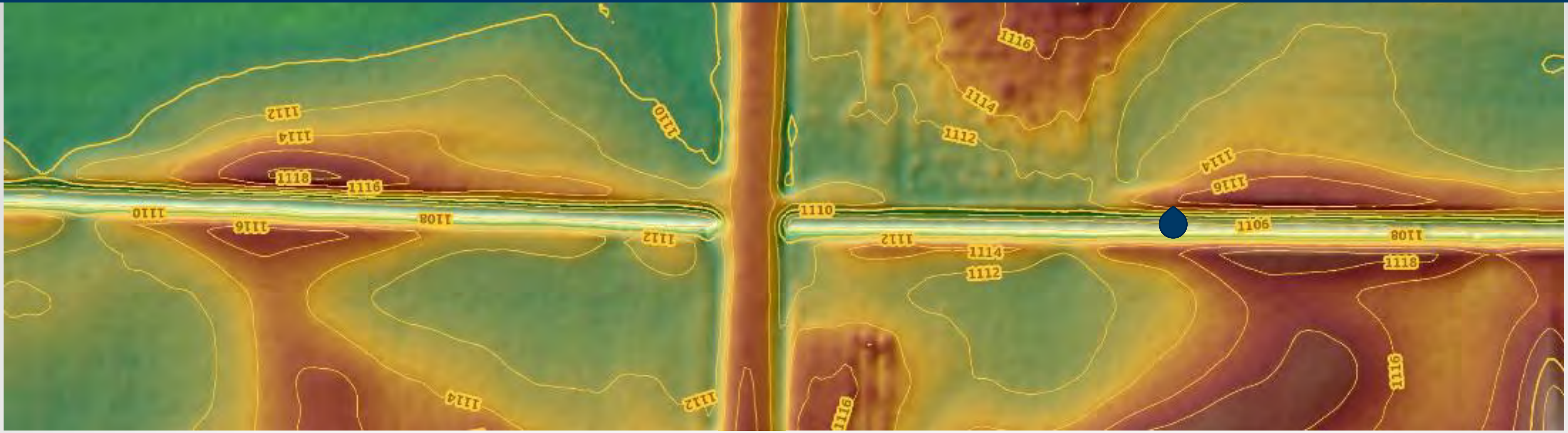
1.) Replicating a real-world scenario, water (raindrop) flows within the channel starting from the east (right)



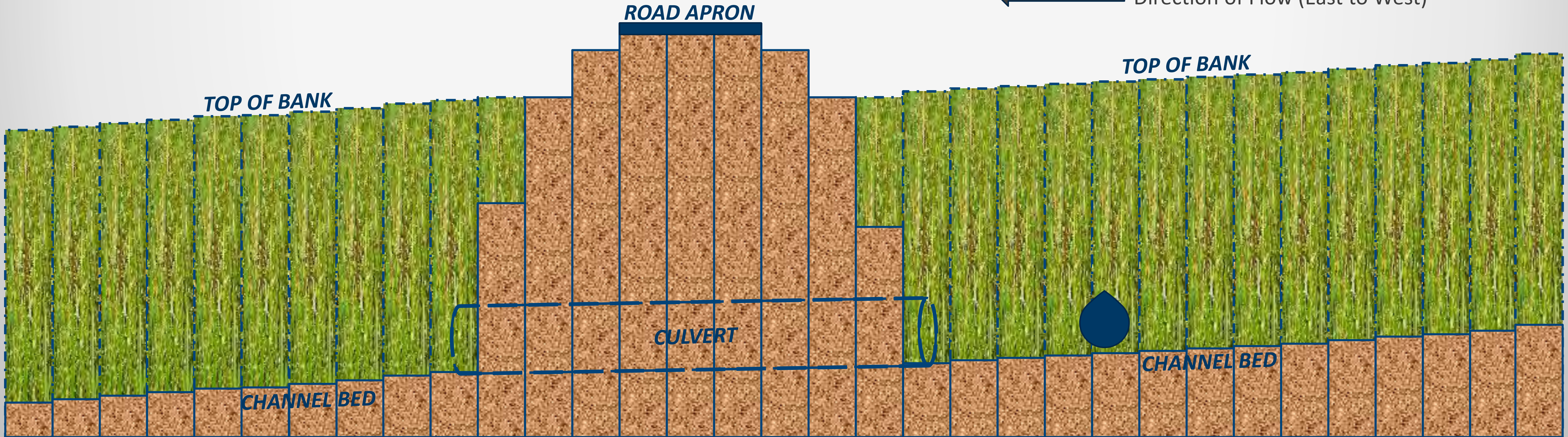
Direction of Flow (East to West)



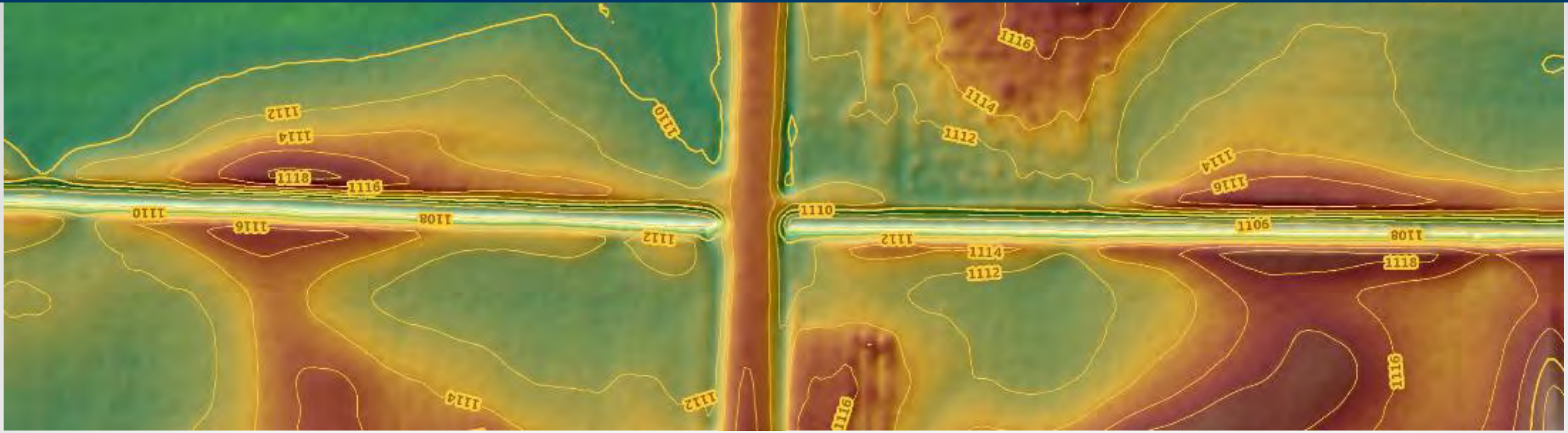
2.) Simulated raindrop continues its path following the downward slope of the channel



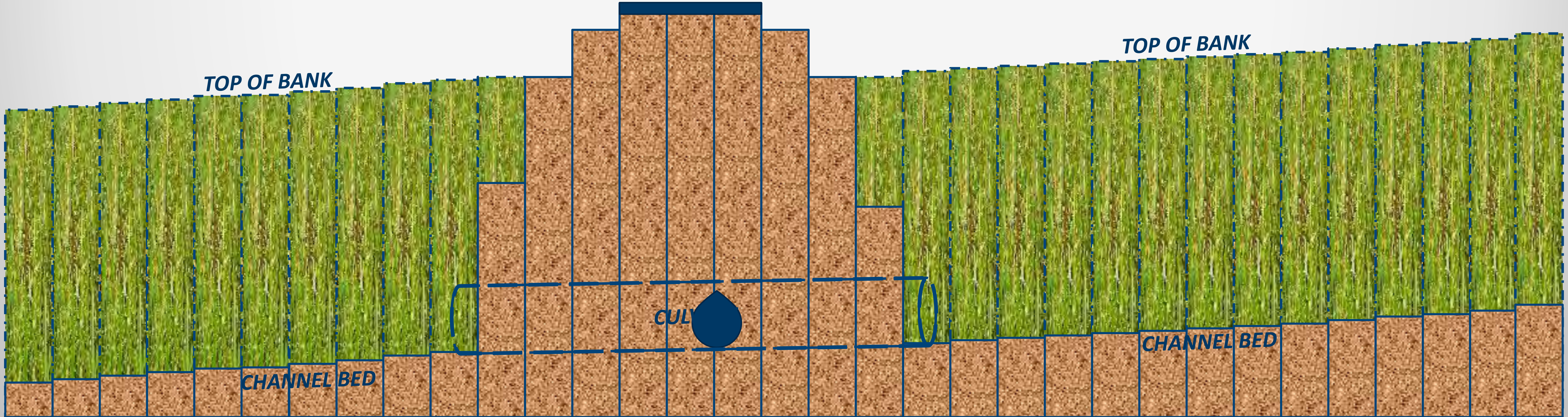
Direction of Flow (East to West)



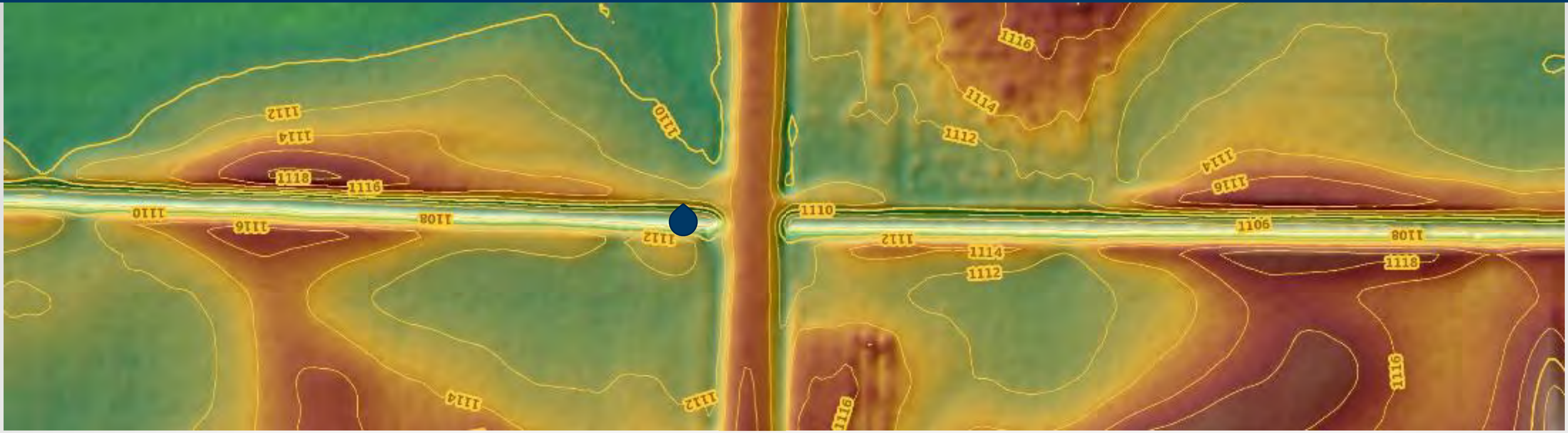
3.) Water passes through the culvert underneath the road



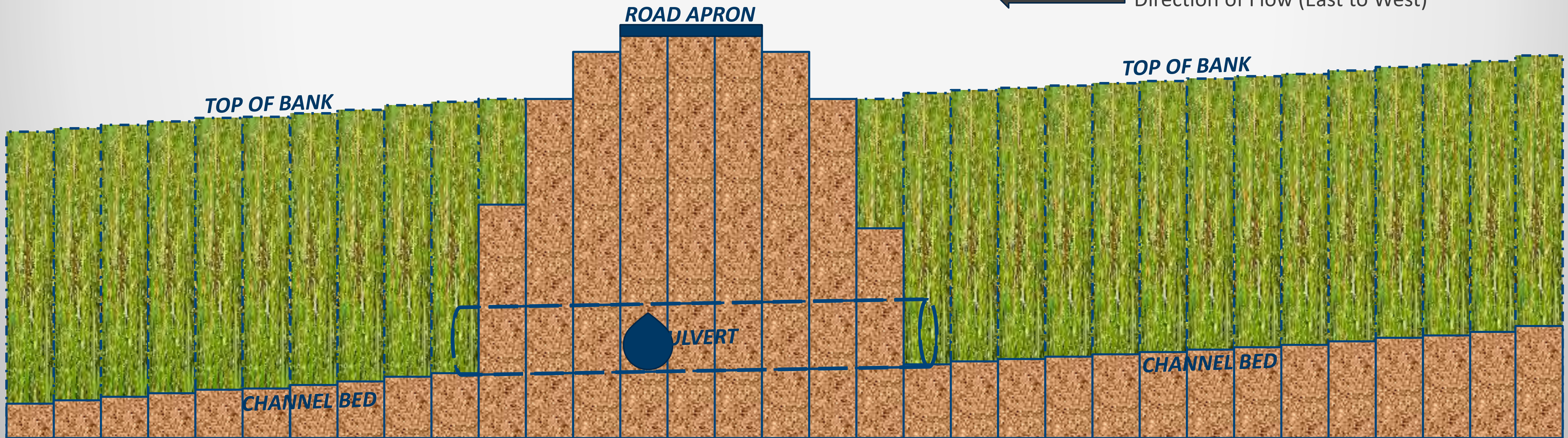
Direction of Flow (East to West)



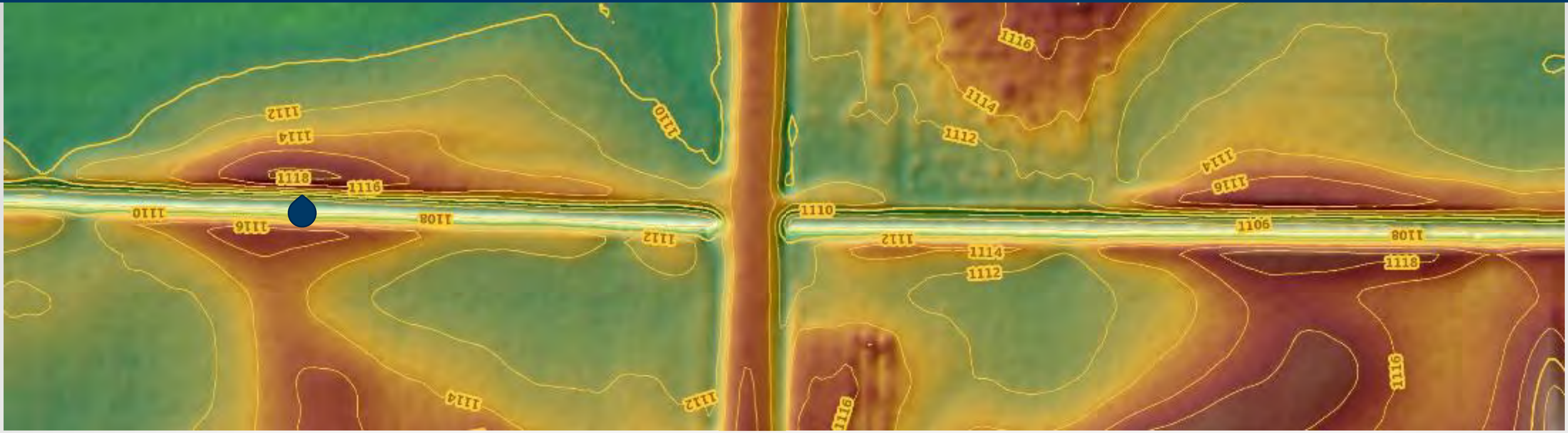
4.) Sloping channel bed continues to pull the simulated raindrop downstream within the channel



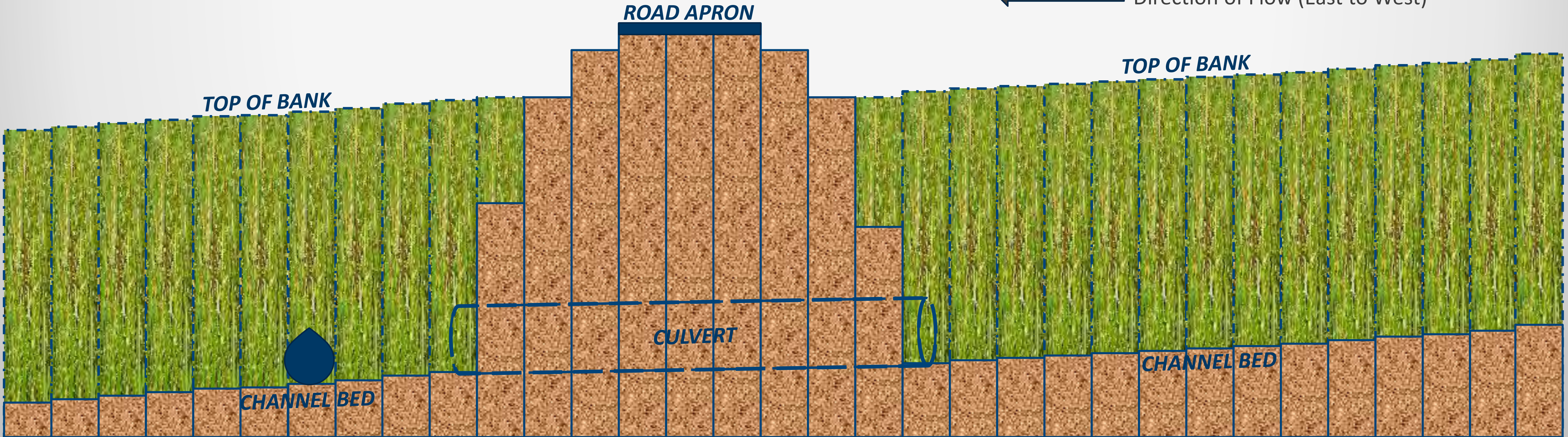
Direction of Flow (East to West)



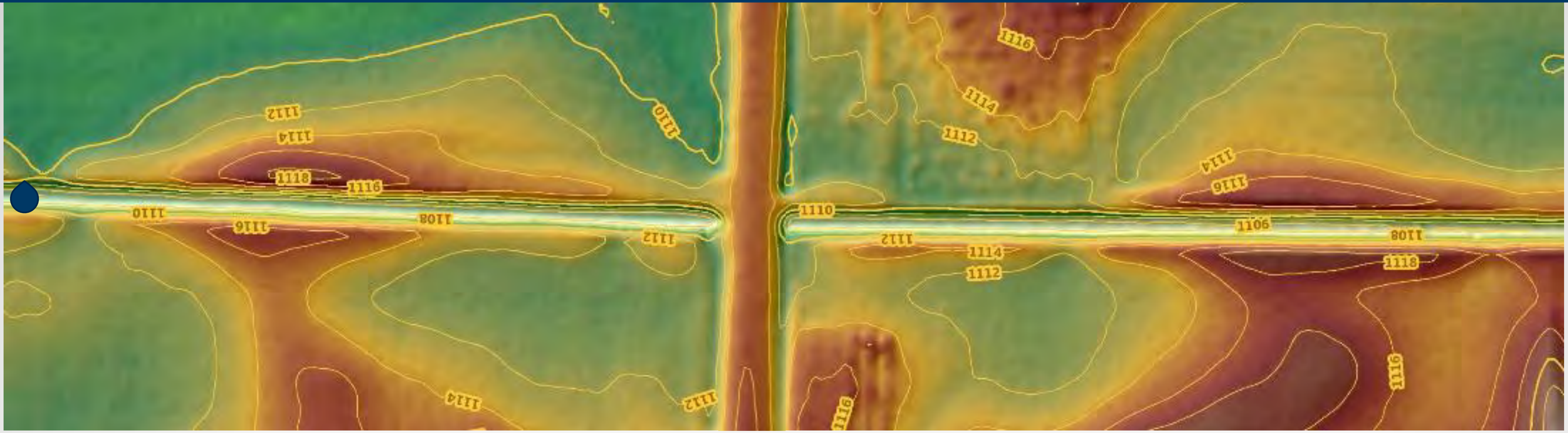
5.) Simulated raindrop continues downstream within the channel based on the sloping channel bed



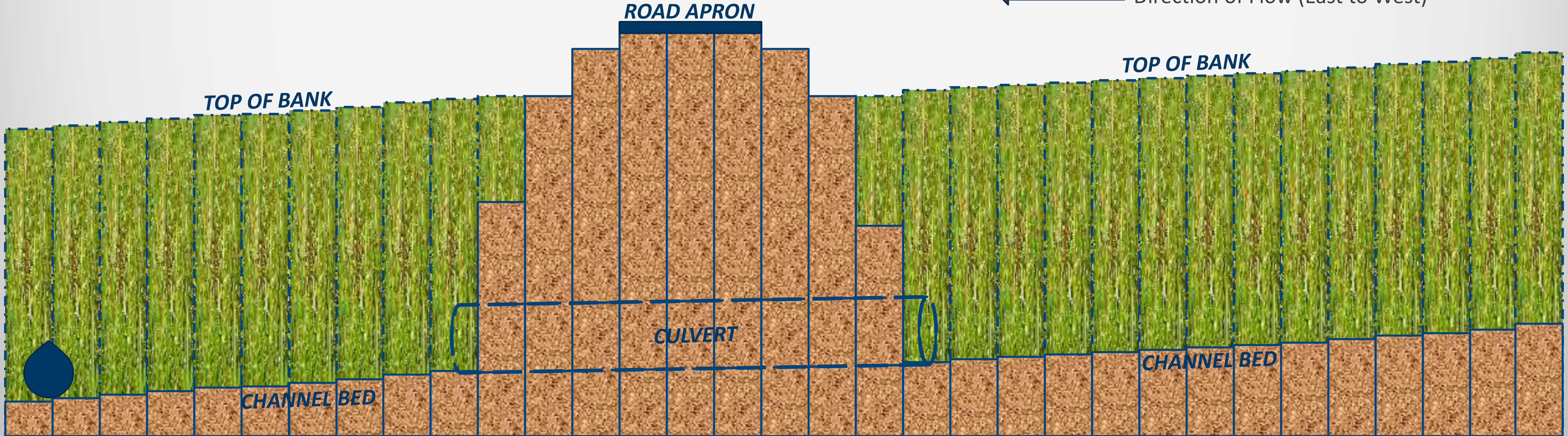
Direction of Flow (East to West)



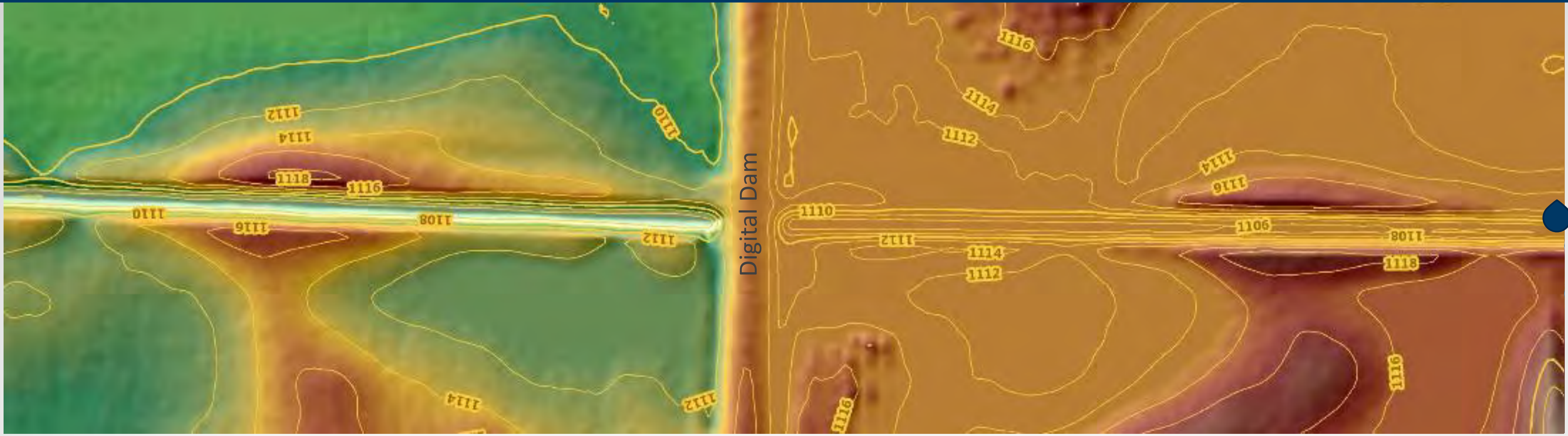
...And continues downstream within the channel based on the sloping channel bed



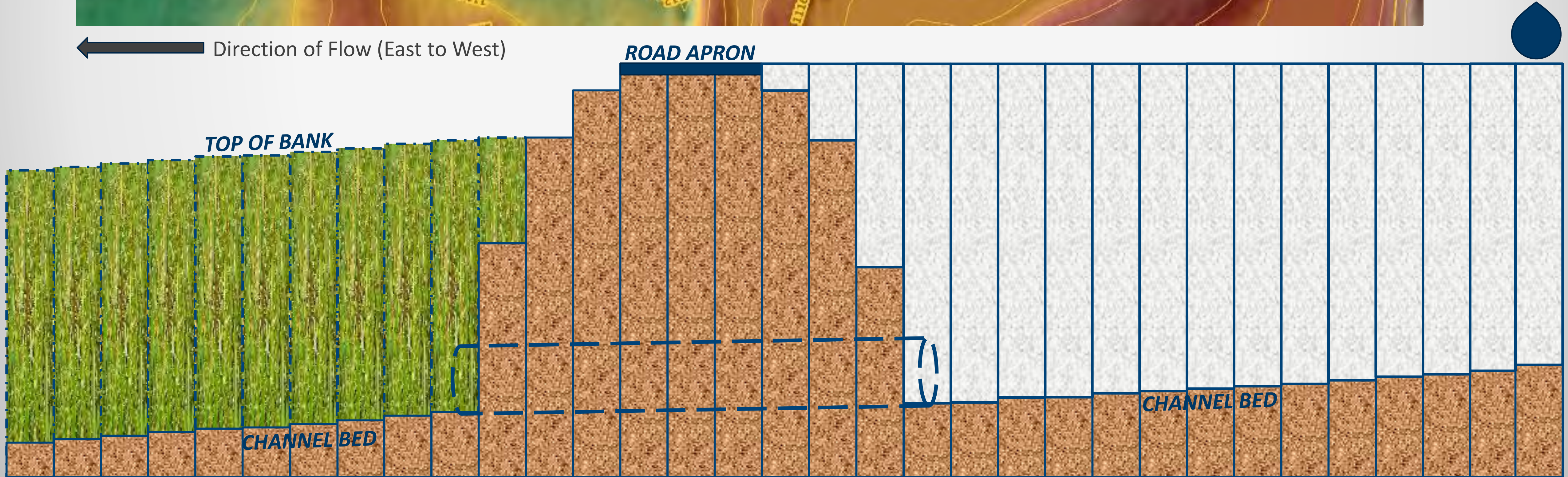
Direction of Flow (East to West)



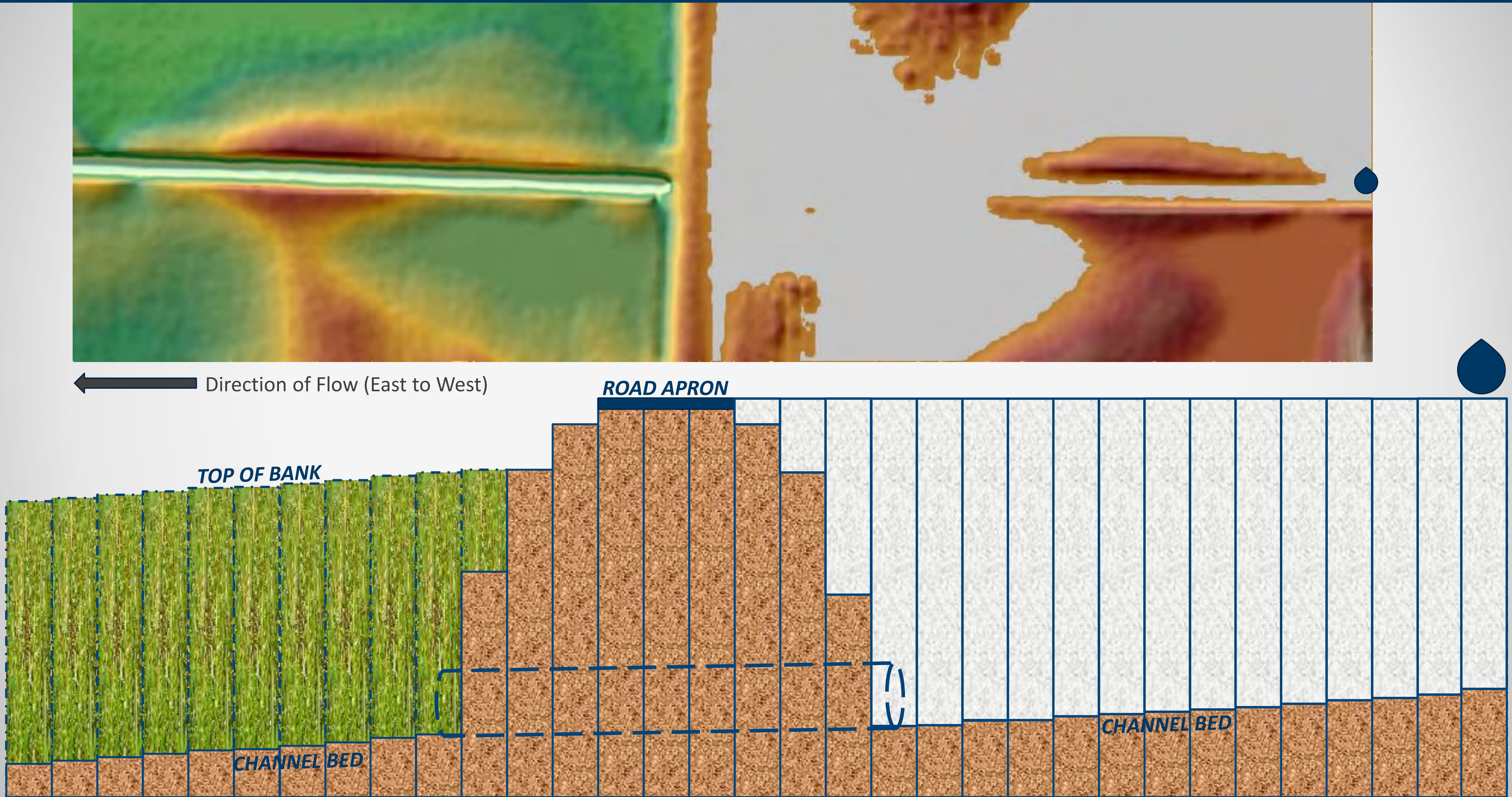
6.) In the Terrain Analysis Model, the road acts as a Digital Dam



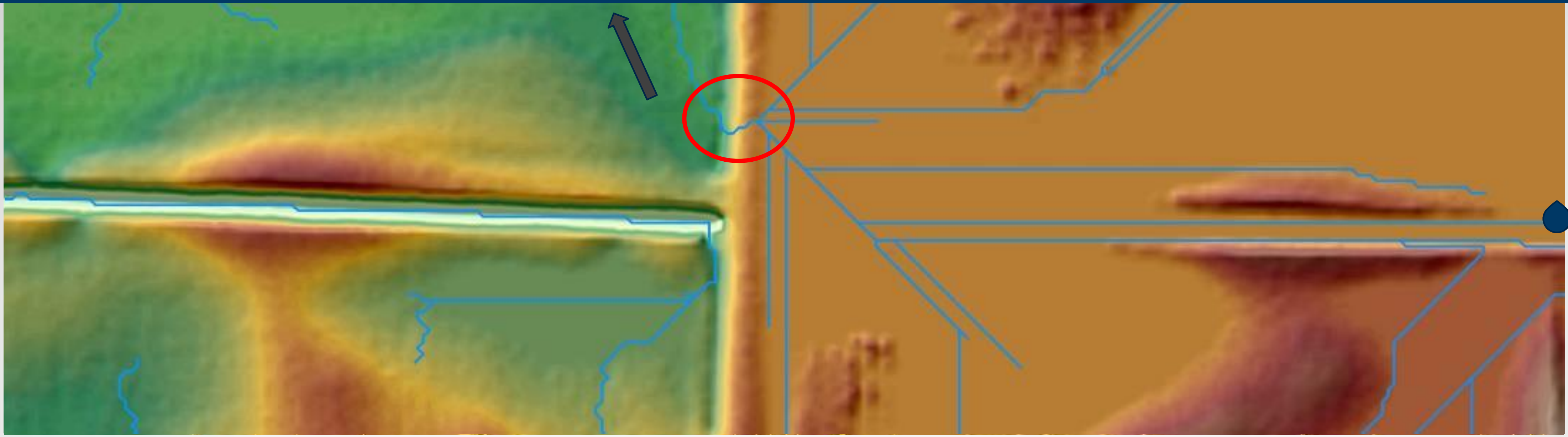
Direction of Flow (East to West)

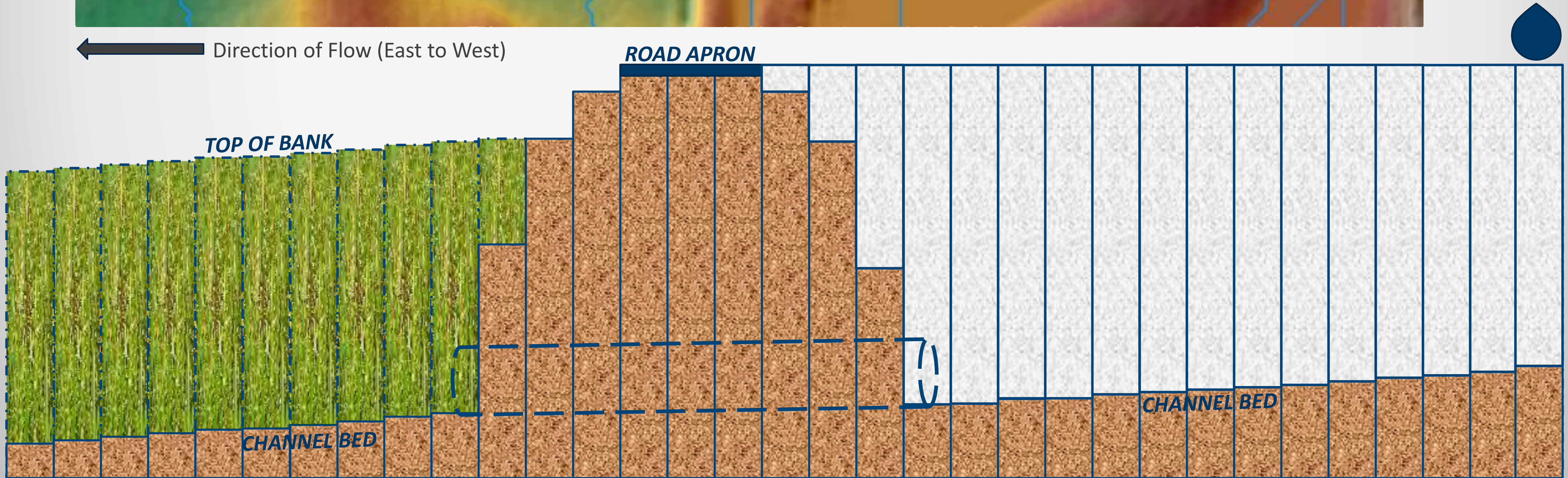


7.) In the Model, all cells must "flow" to the outlet, therefore depressions are filled to a discharge (spill) elevation

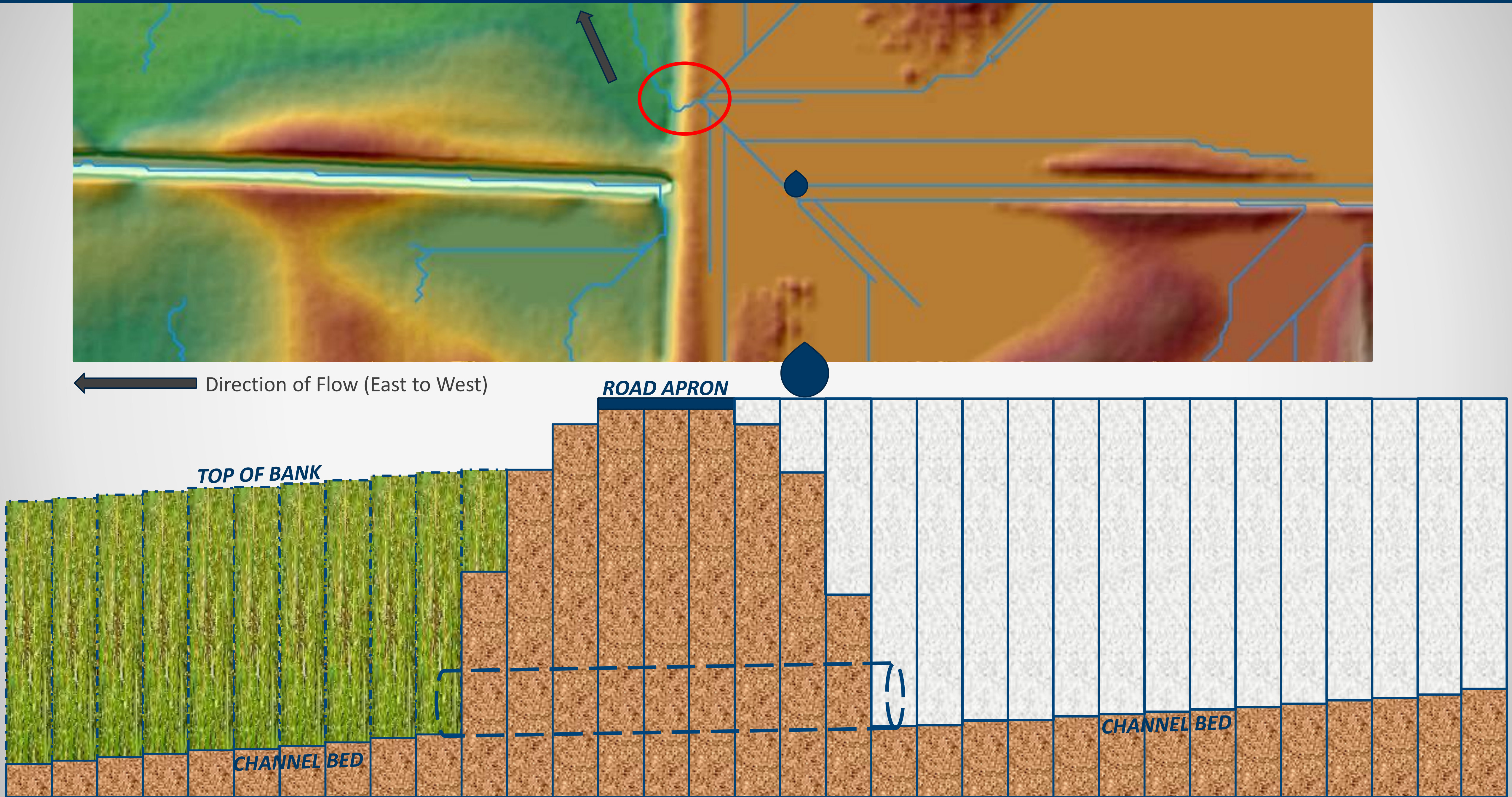


8.) The flow pathways are derived and the filled area now outlets to the north at the lowest elevation

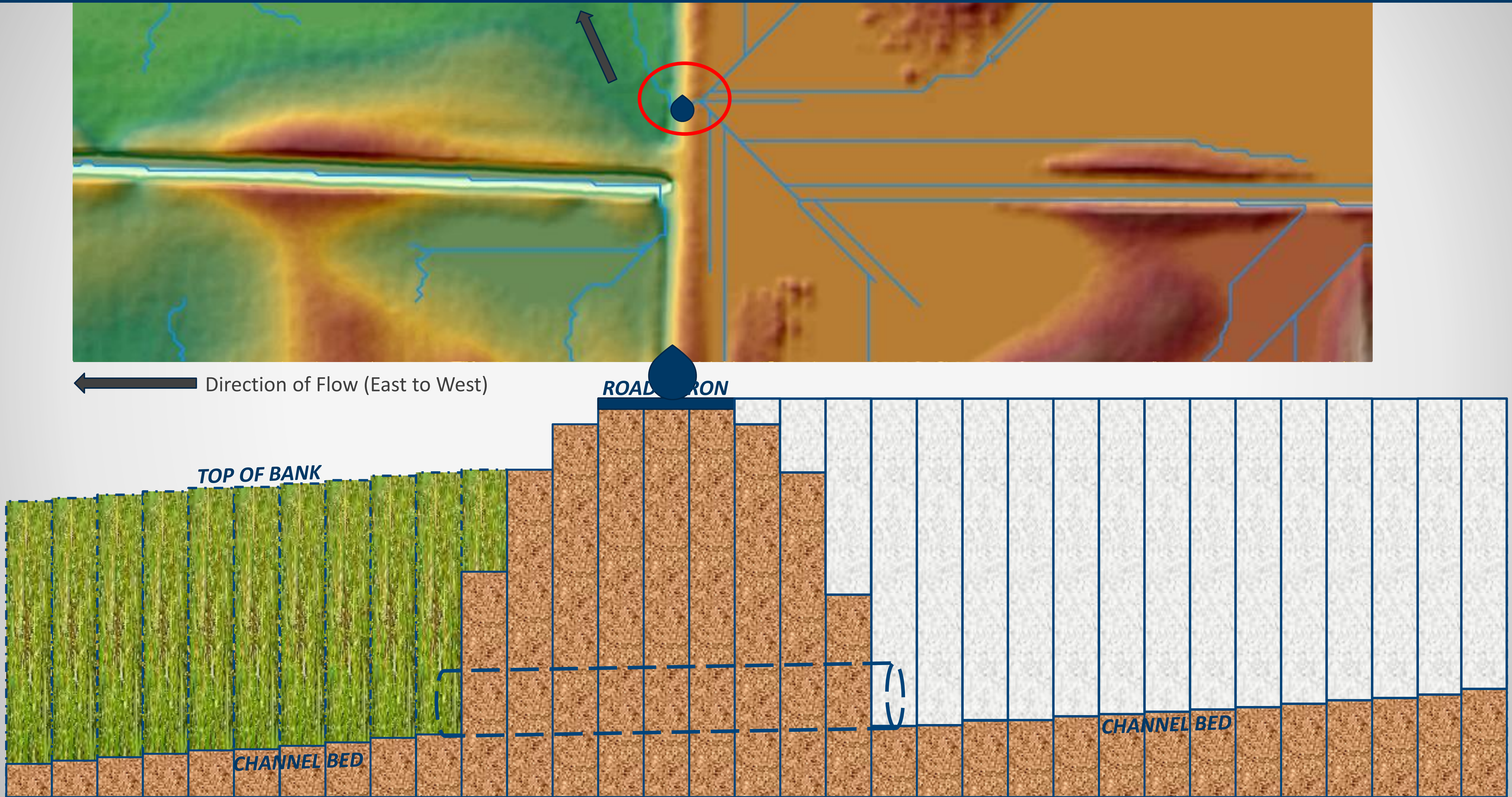




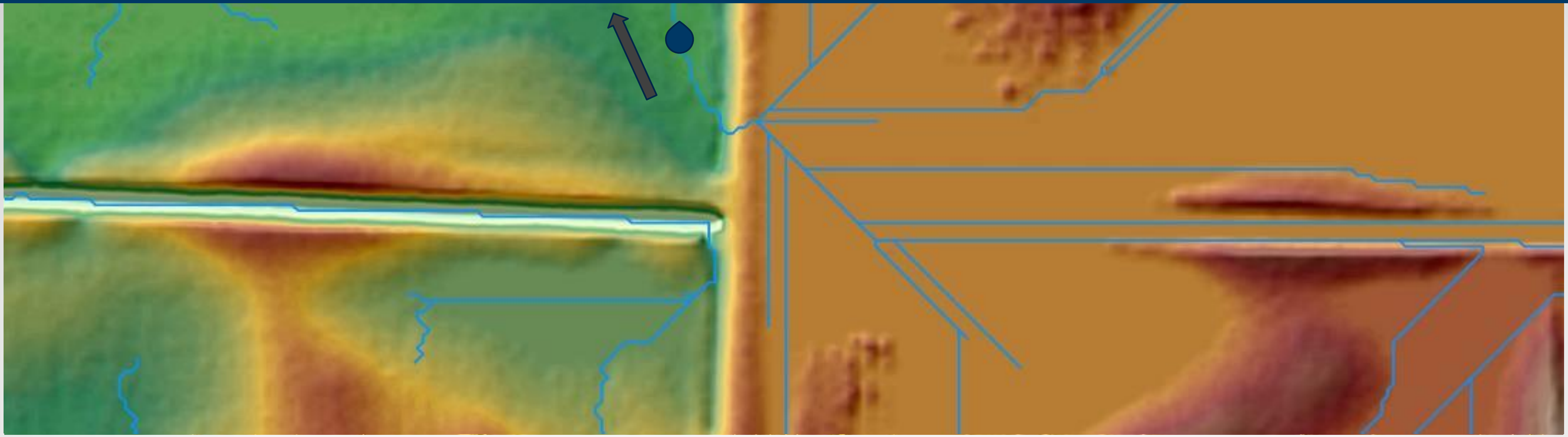
9.) The modeled water droplet now flows along the new flow pathways across the filled region

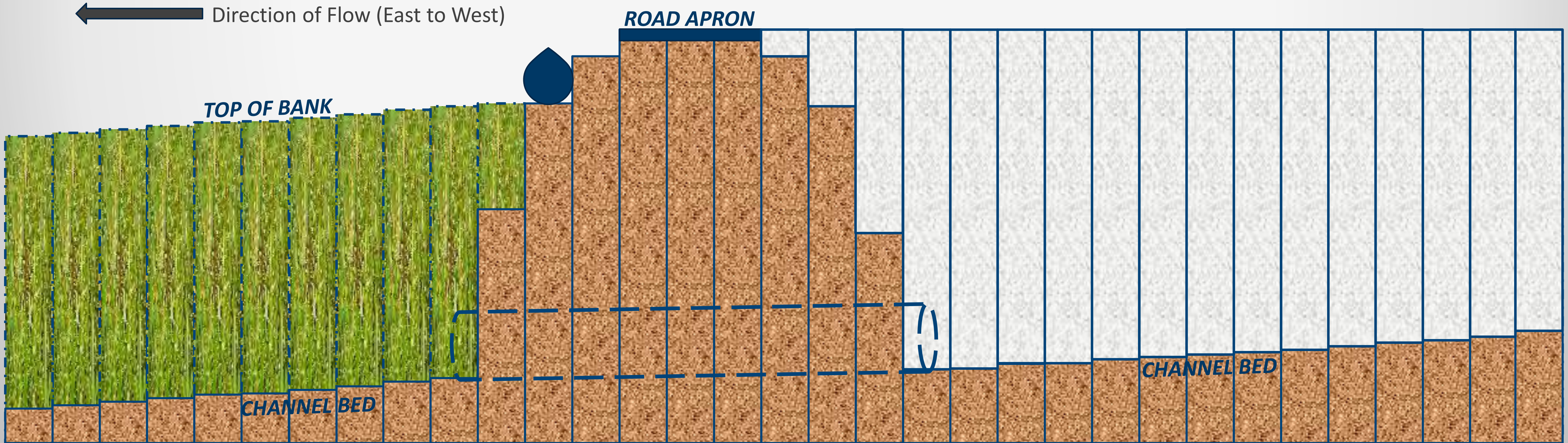


10.) The modeled water droplet crosses the road at its lowest elevation and continues along flow pathway

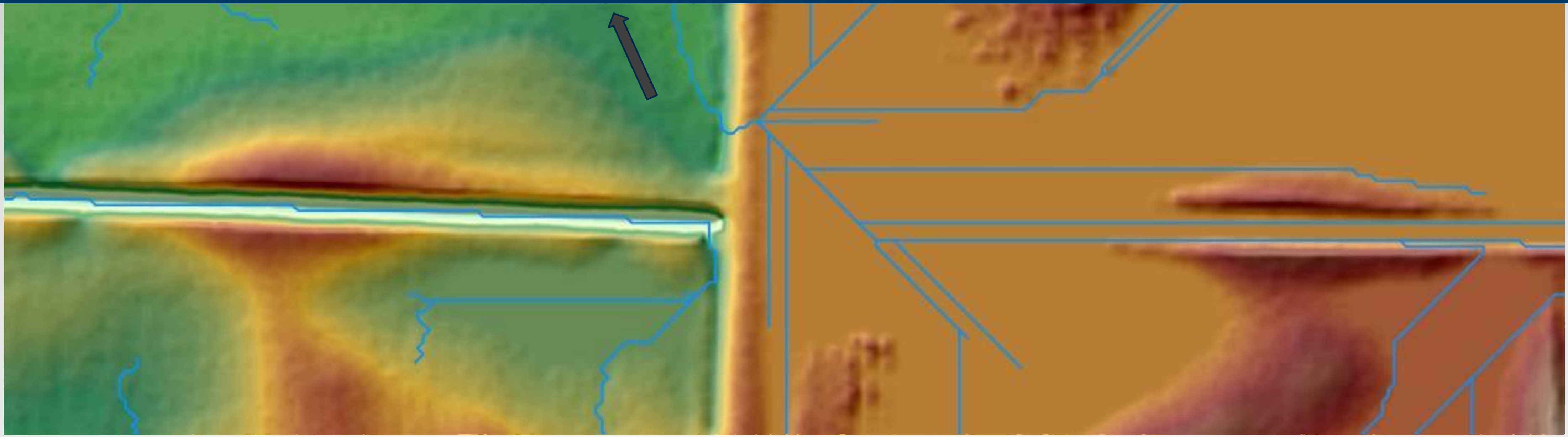


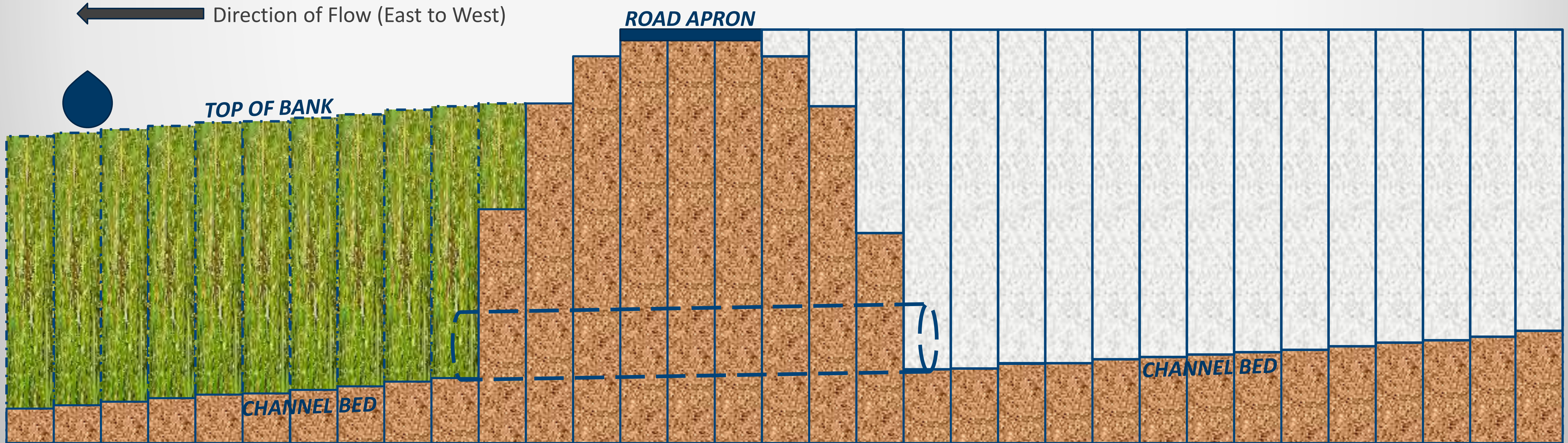
11.) The modeled water droplet drops off the road embankment and continues along flow pathway



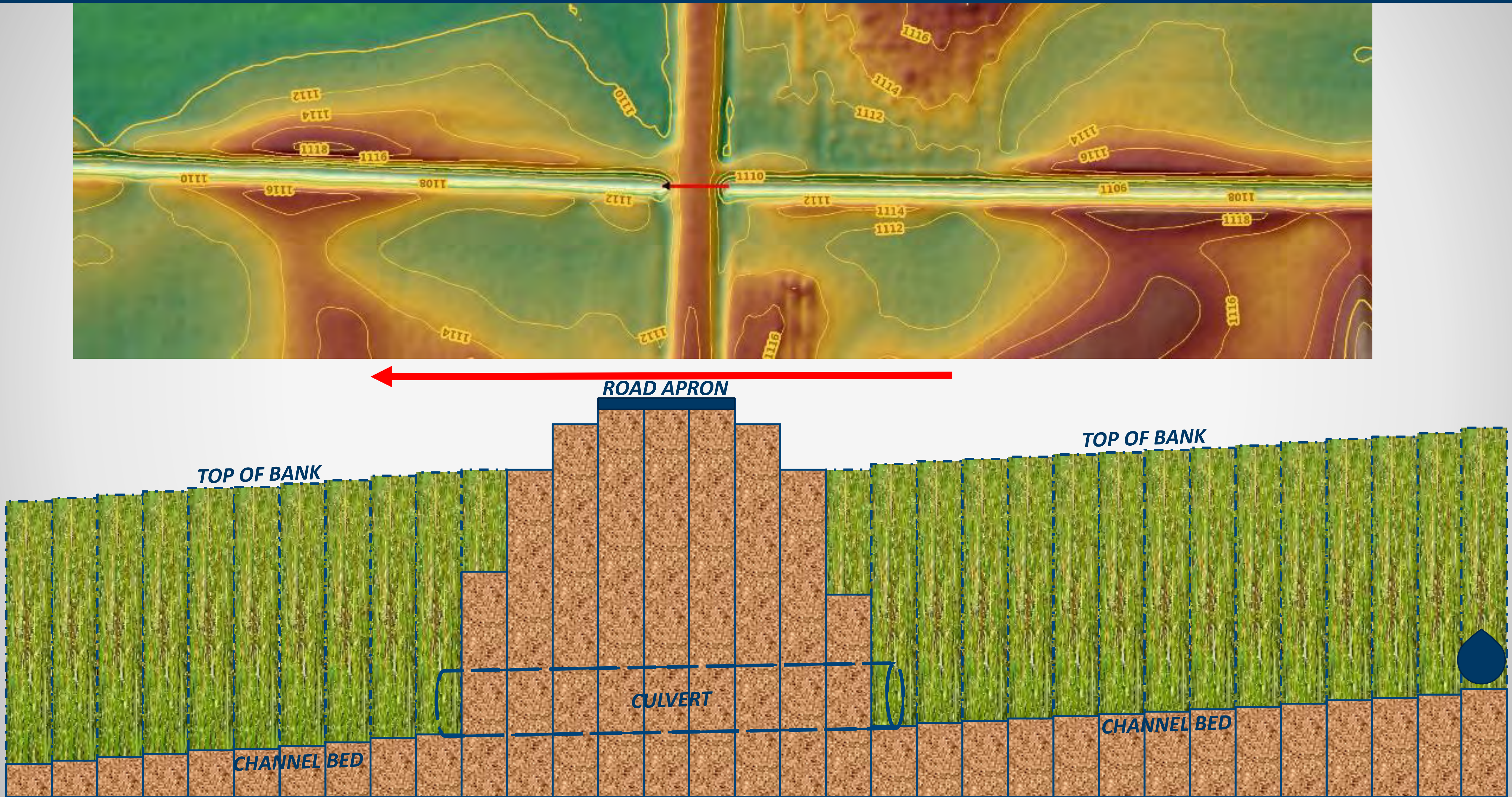


12.) The modeled water droplet continues along the flow pathway and never re-enters the channel

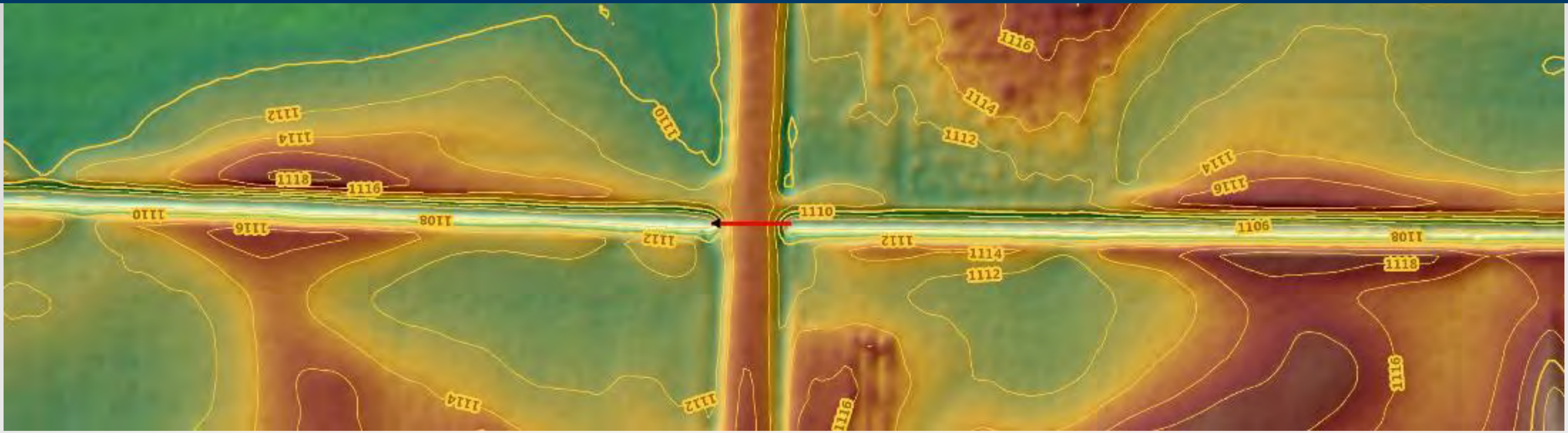


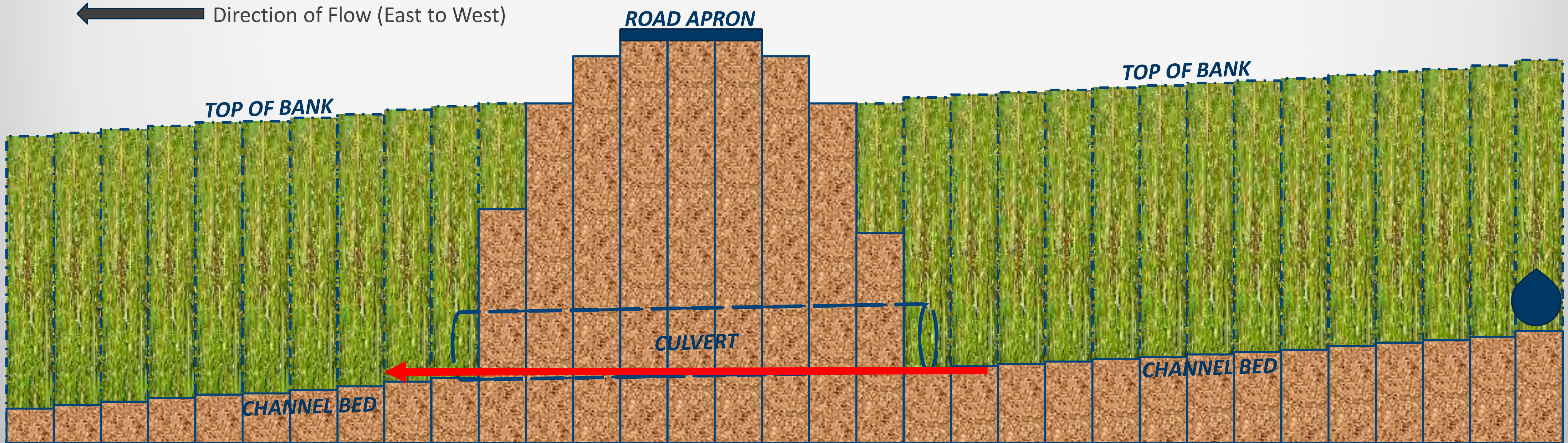


1.) In DEM Hydro-modification, a breachline (red arrow) is digitized at the location of the culvert

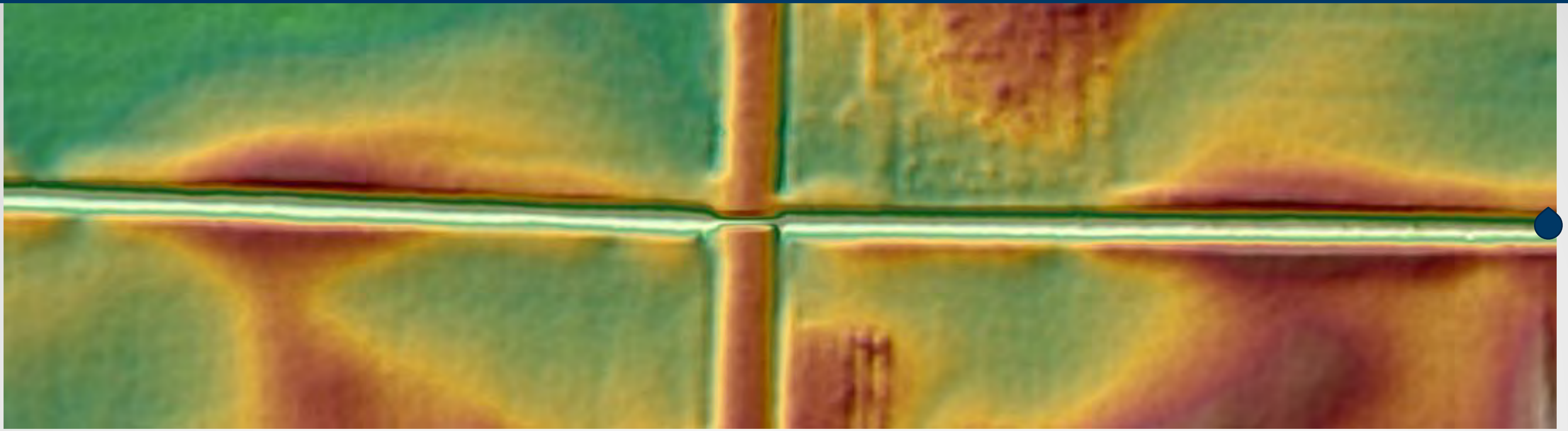


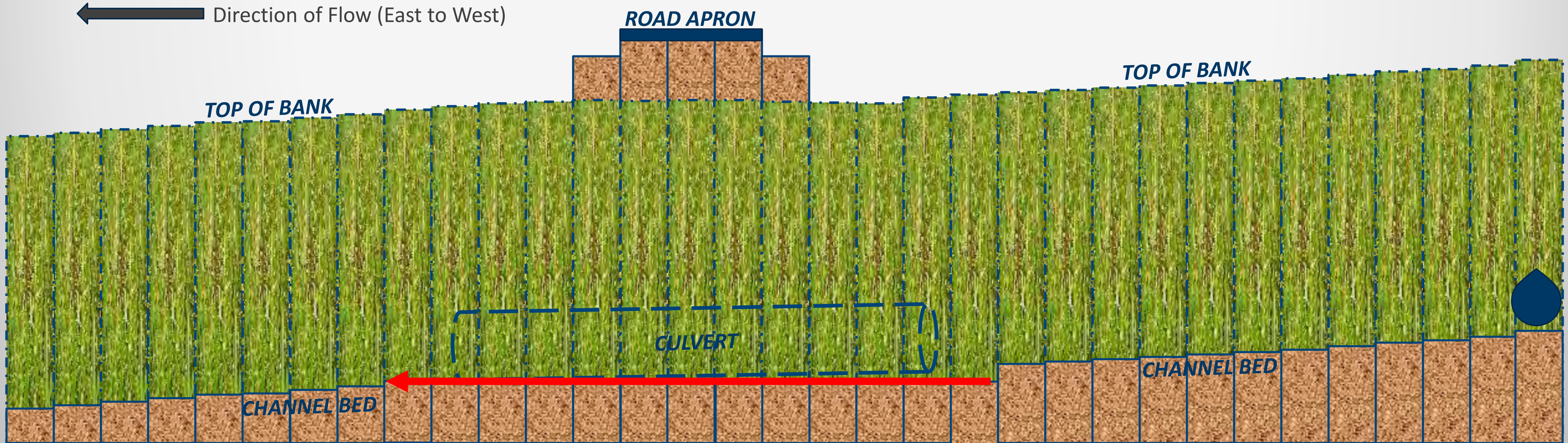
2.) In the hydro-modification process, the lowest elevation along the breachline is determined and



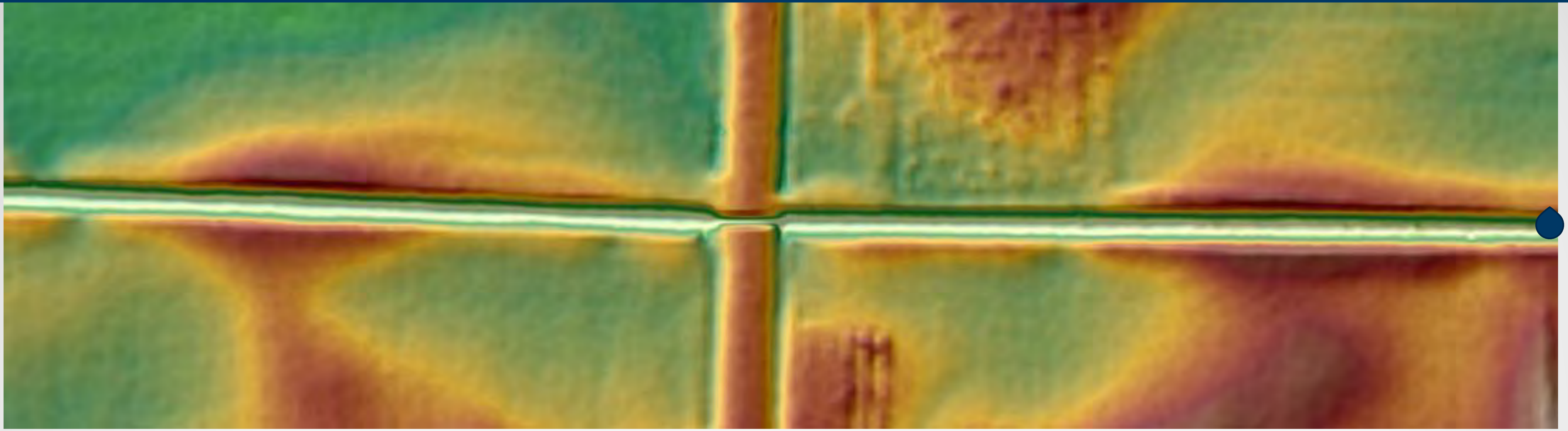


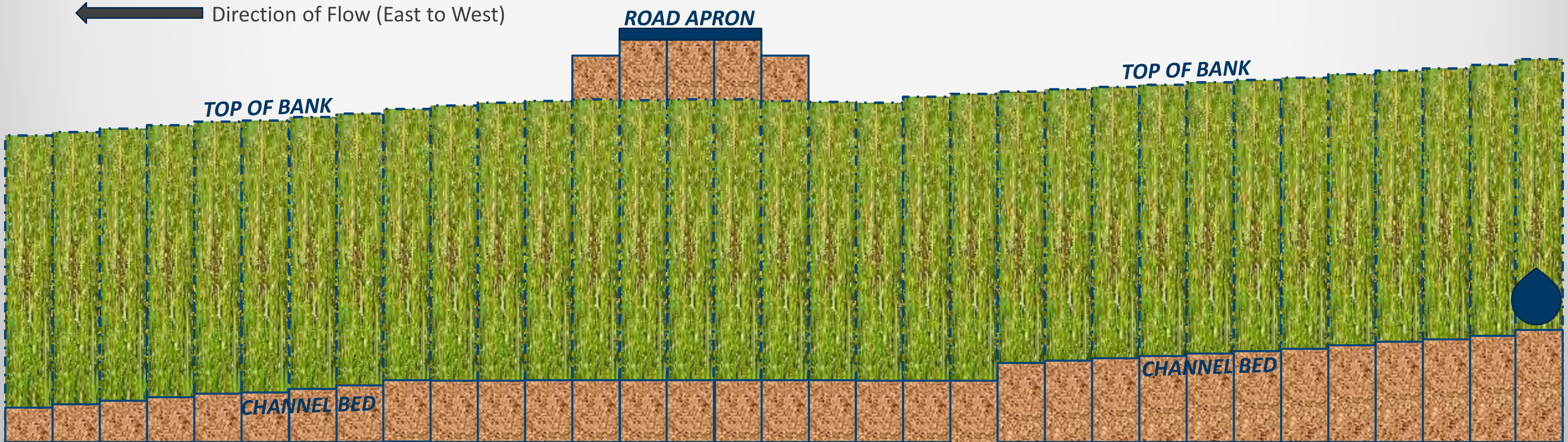
…all cells coincident with the breachline are assigned a value equal to the lowest elevation value.



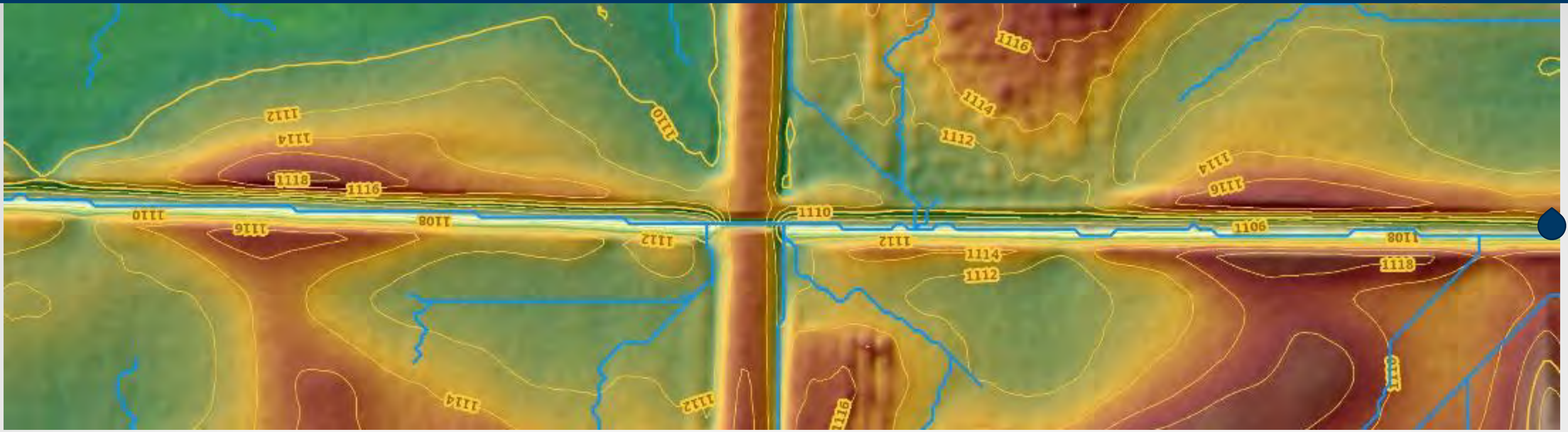


3.) The new hydro-modified Digital Elevation Model is analyzed

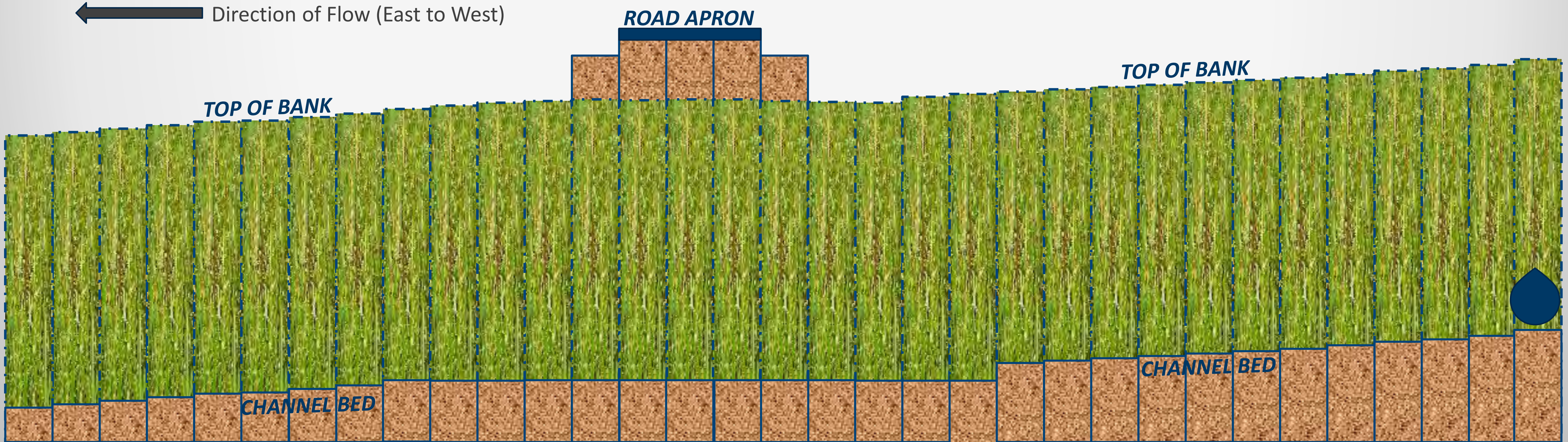




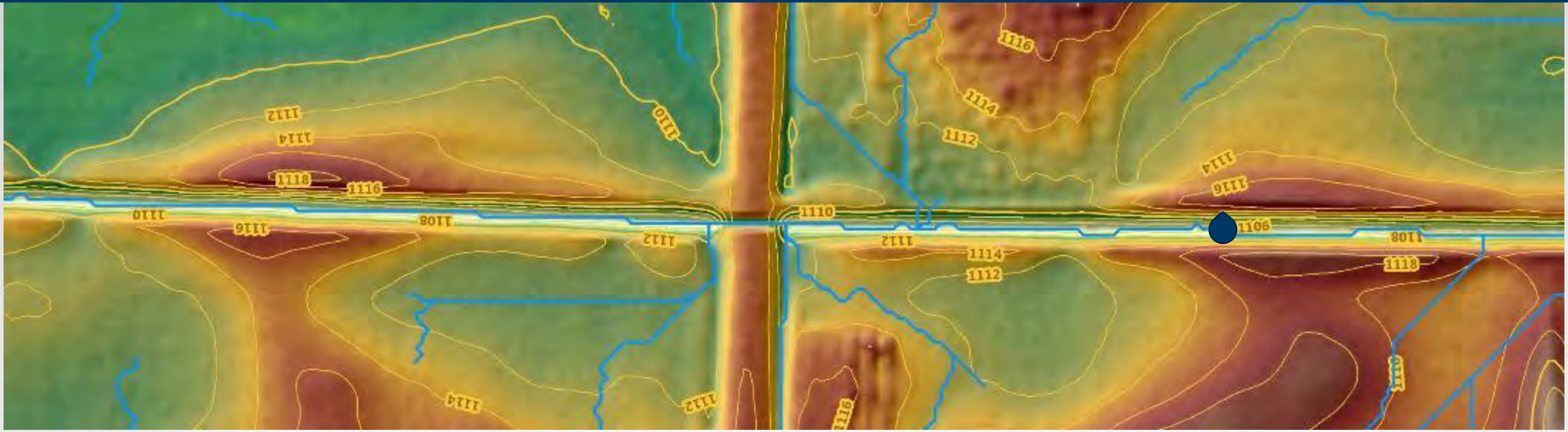
…and new flow pathways are developed for the new hDEM



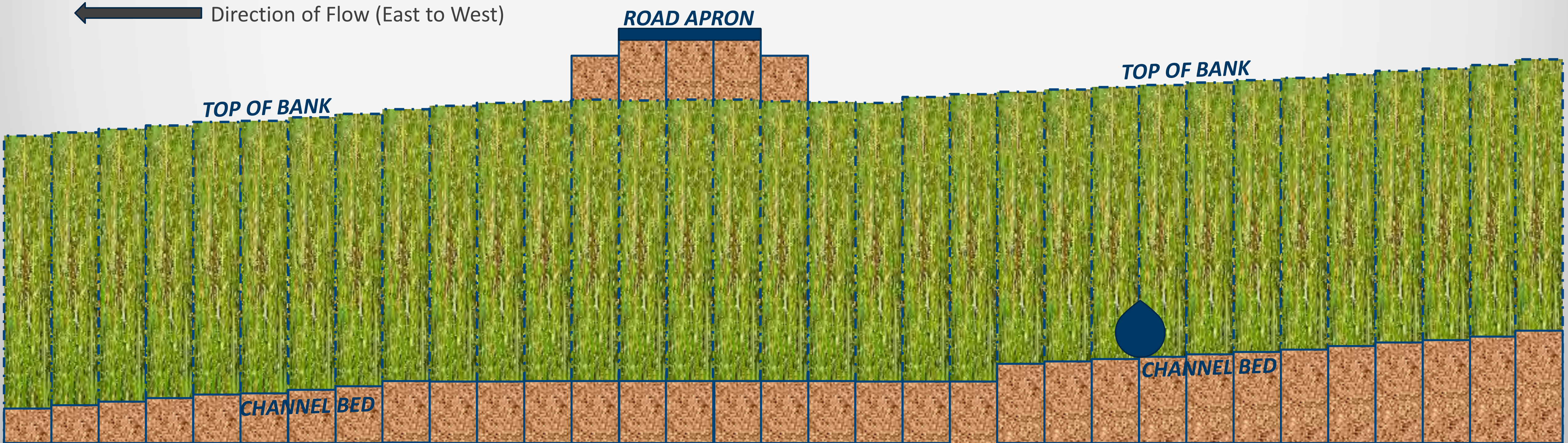
Direction of Flow (East to West)



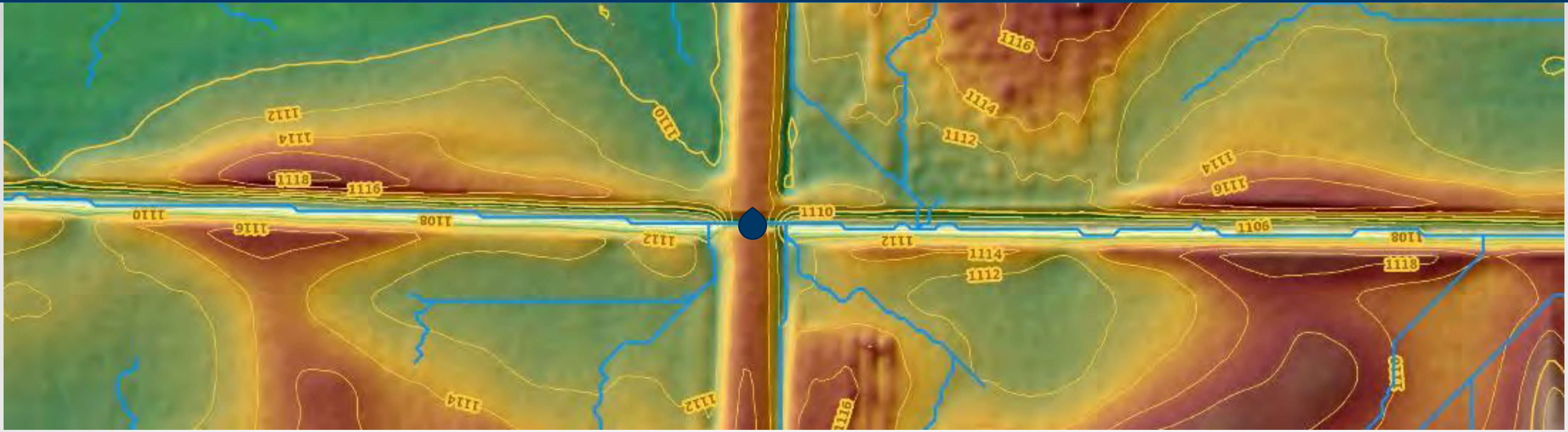
4.) The modeled water droplet now flows within the channel

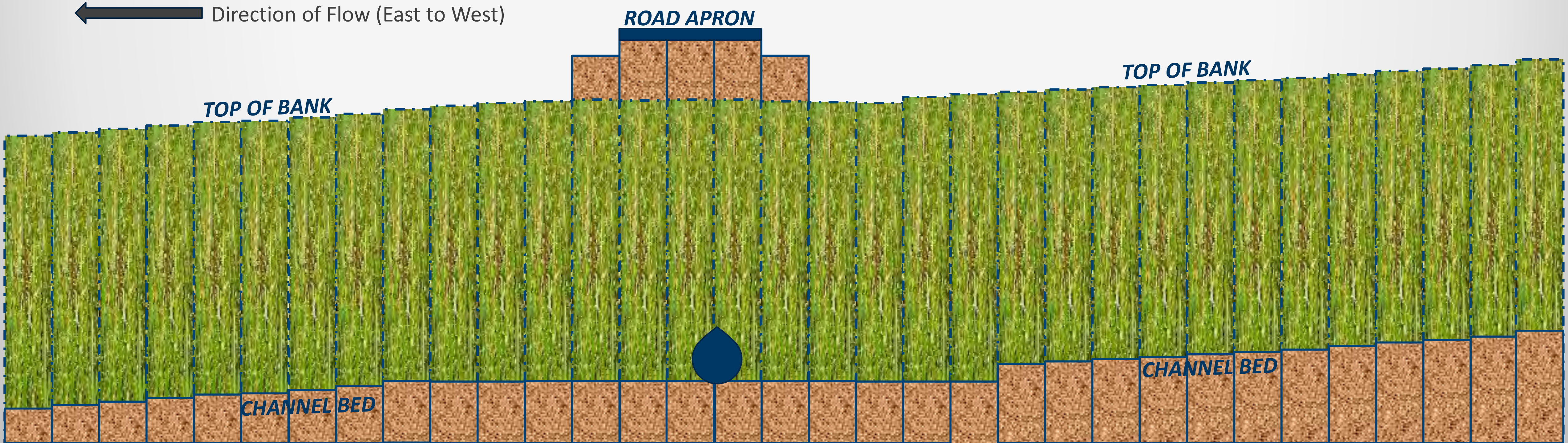


Direction of Flow (East to West)

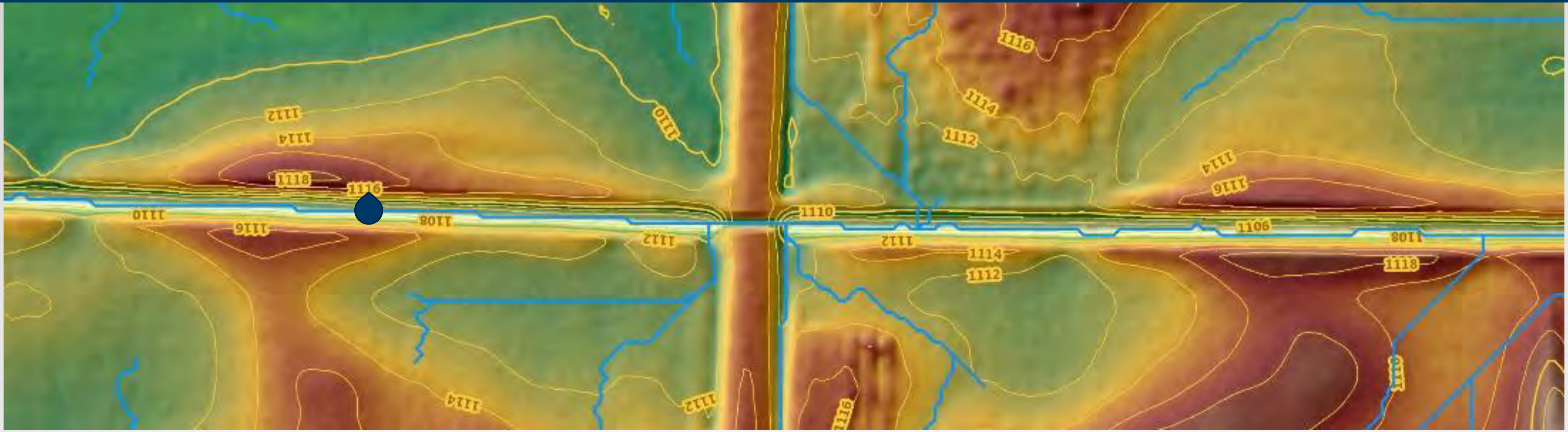


…through the area of the road that was lowered based on the placed breachline

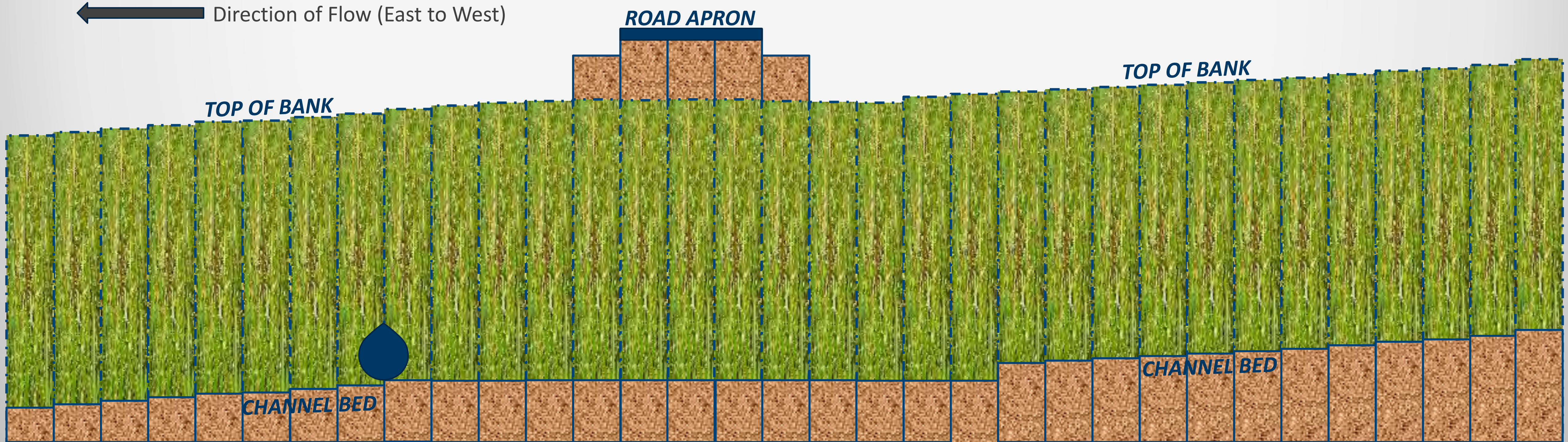




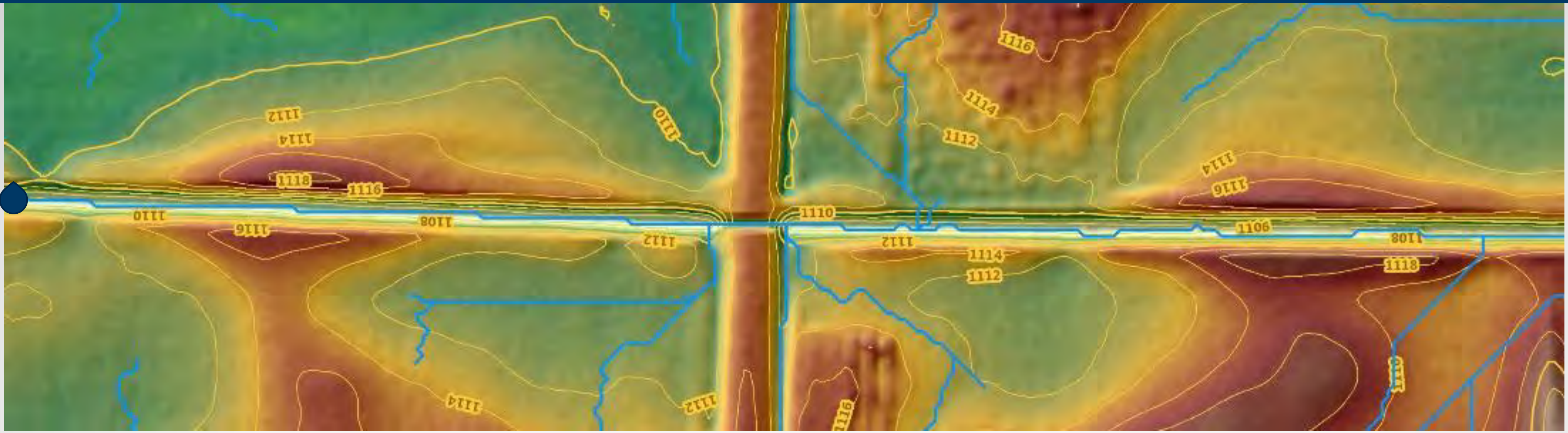
5.) It continues along the flow pathway that is contained within the channel.

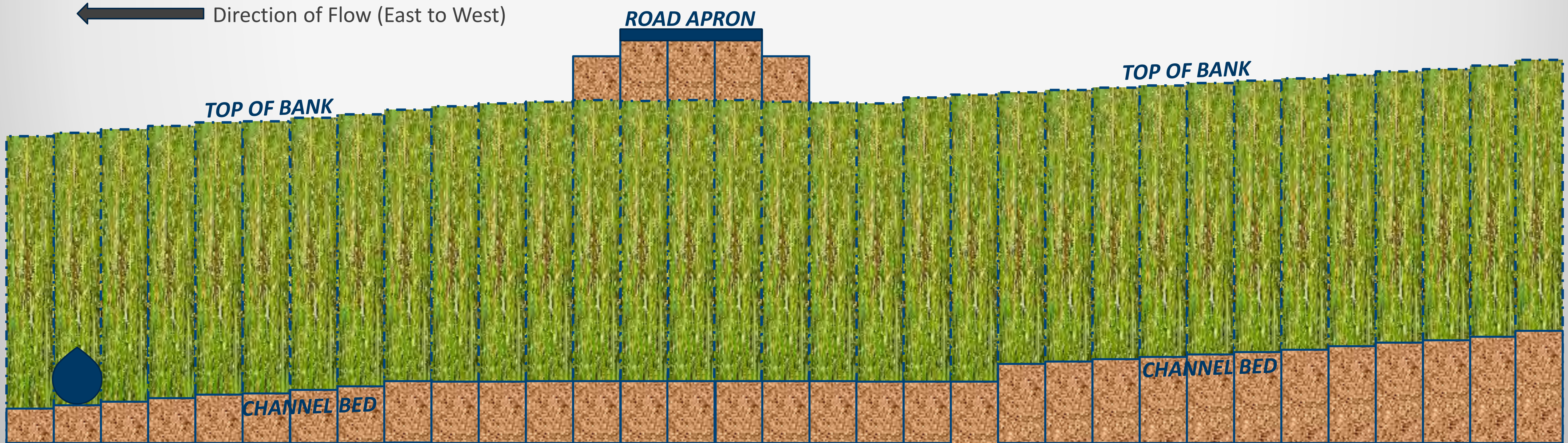


Direction of Flow (East to West)



6.) The process of removing Digital Dams continues as we replicate landscape hydrology. (end)





Methods & Section Wrap-up

2- Methods of DEM Hydro-modification

1. Manual
2. Automated

Cast off to Rick…

Next

3D Geomatics

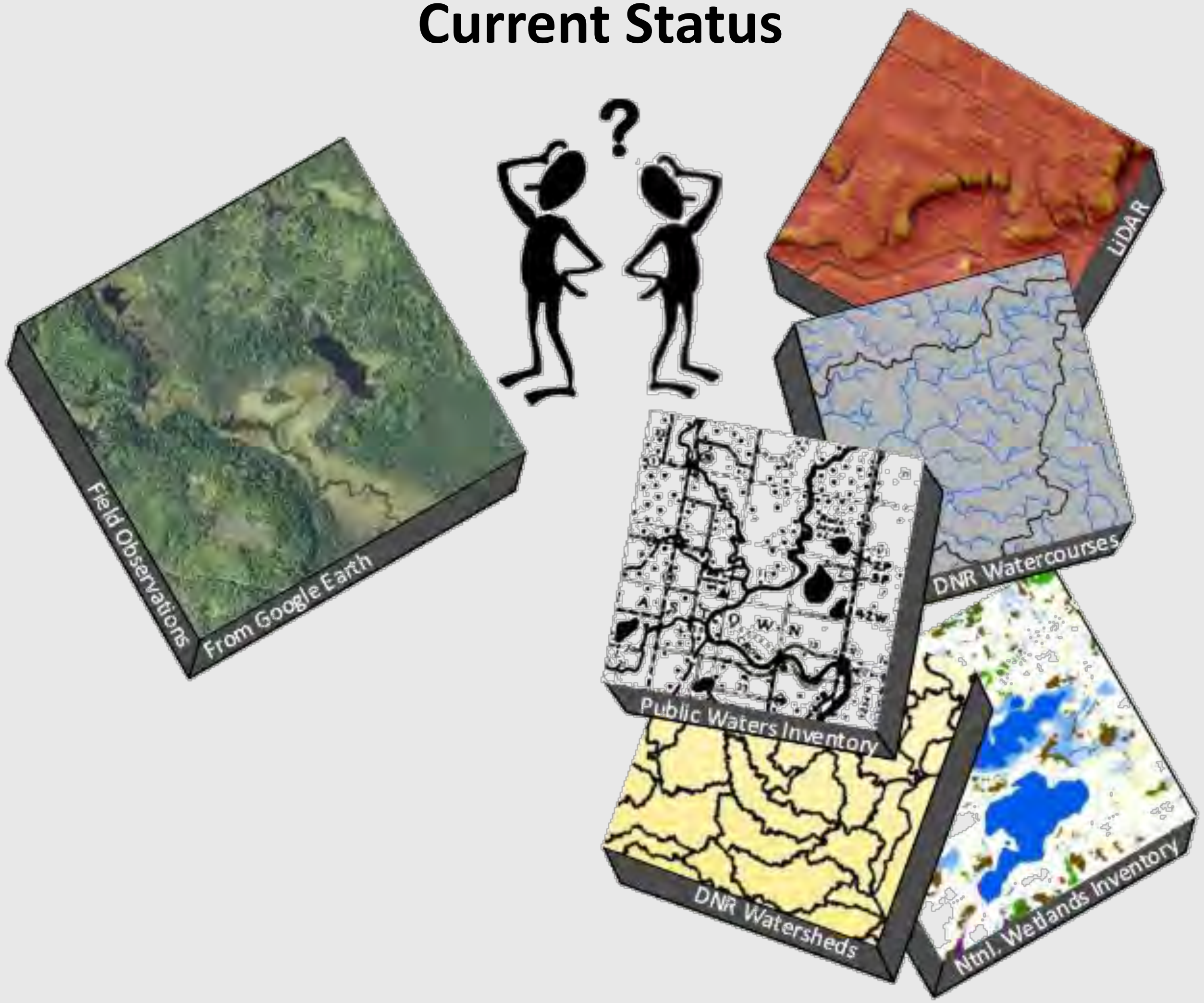
DEM Hydro-modification Subgroup

Where is hydrography and watershed data today?

Today we have:

- Multiple, **out-of-sync** copies of hydrography data
- Locations of stream centerlines based on **historic** maps
- **Inefficient** processes for creating derived data products
- **Costly** field site verifications
- Missing data **lowers public trust**
- **Breachline datasets** from various organizations **created independently**

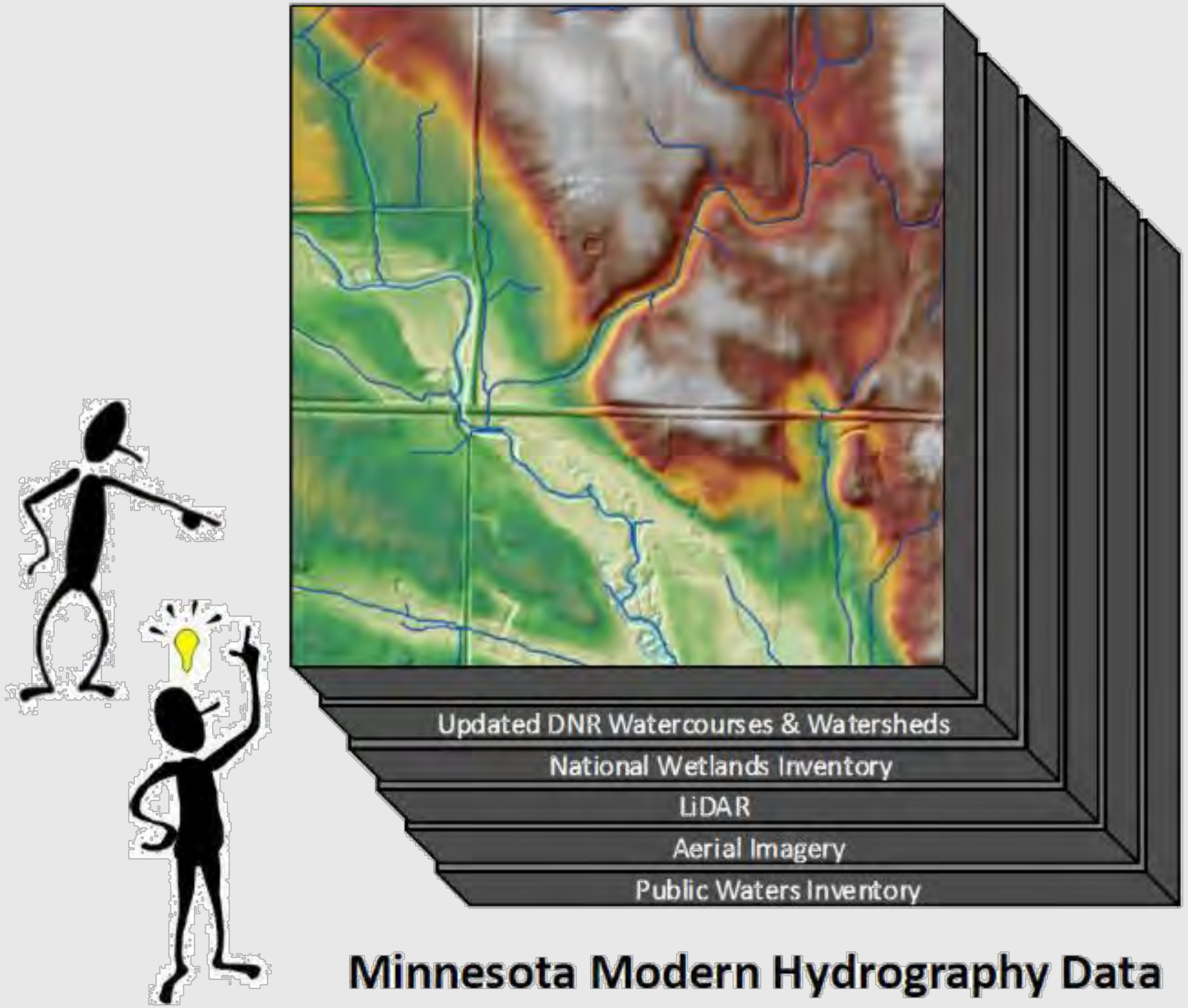
Current Status



The future?

What we could have:

- Single, **authoritative** data source
- **Harmonized data** that leverages recent state investments
- **Automated** processes identify changes on the landscape
- **High-resolution** data that minimizes field site verifications
- Enhanced **public trust** in watershed management decisions

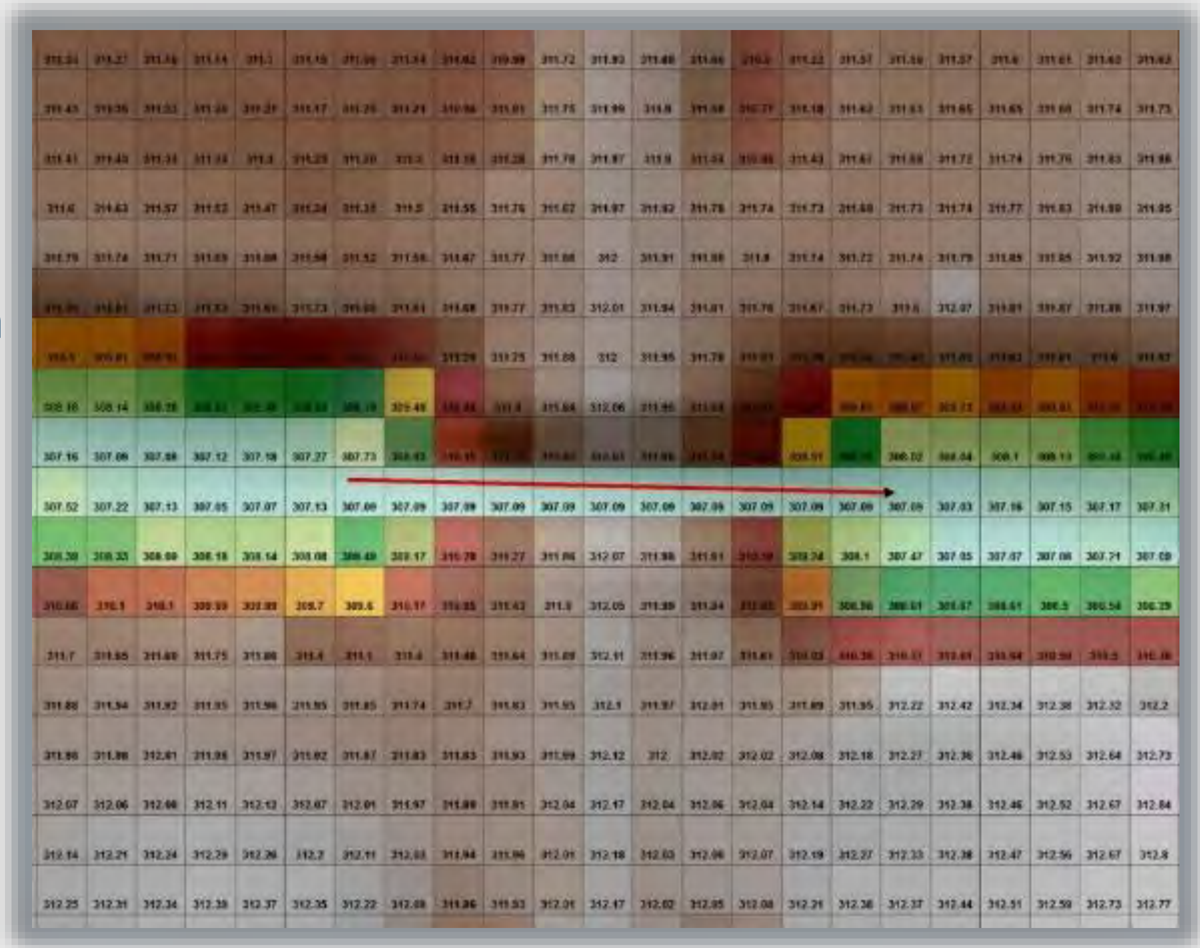


Minnesota Modern Hydrography Data

3D-Geomatics → Hydro Workgroup → DEM Hydro-modification Subgroup

Mission:

Dedicated to developing the foundation for single, **authoritative**, digital dam **breachline** and **hDEM datasets** for Minnesota utilizing standards and methodology developed through collaboration with breachline **subject matter experts**



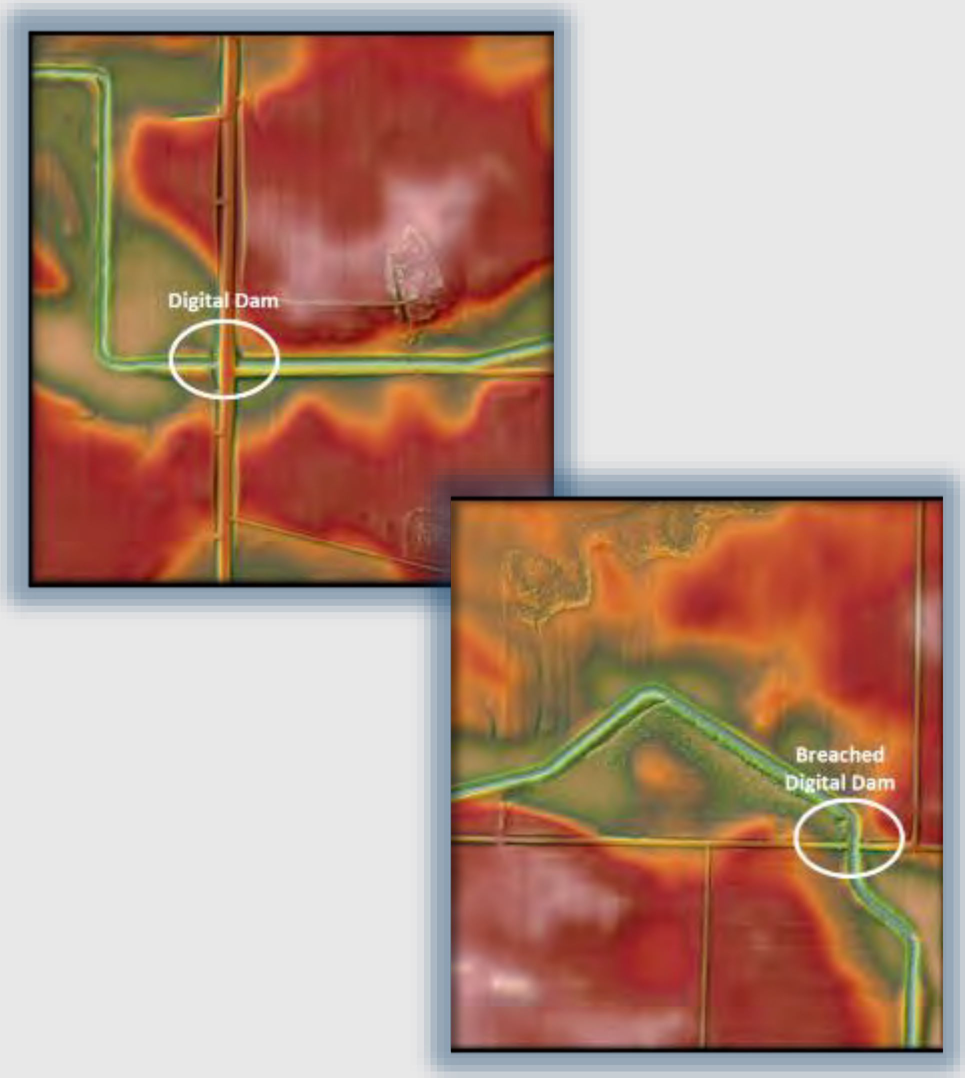
Workgroup

- Co-chairs
  - **Rick Moore**
- Liaison
  - **Sean Vaughn**

3D-Geomatics → Hydro Workgroup → DEM Hydro-modification Subgroup

Purpose of the DEM Hydro-modification Subgroup

- **Capitalize on knowledge of subject matter experts** who have built their own individual digital dam breachline datasets and perform hydro-modification.
- Develop **Standards**, **Methodology**, and QA/QC **Protocol** to support DEM hydro-modification and development of the breachline dataset.
- Publish these features into **one authoritative breachline dataset** for use in developing hydro-modified digital elevation models (hDEMs).
- **Support public and private business needs** associated with hydrologic modeling of the landscape using hydro-terrain analysis tools (e.g., PTMApp and ACPF).



3D-Geomatics → Hydro Workgroup → DEM Hydro-modification Subgroup

Developments of the Breachline Subgroup

- **Standardized Attributes**
- Methodology and Protocol
- Breachline Data and Work Area Identification

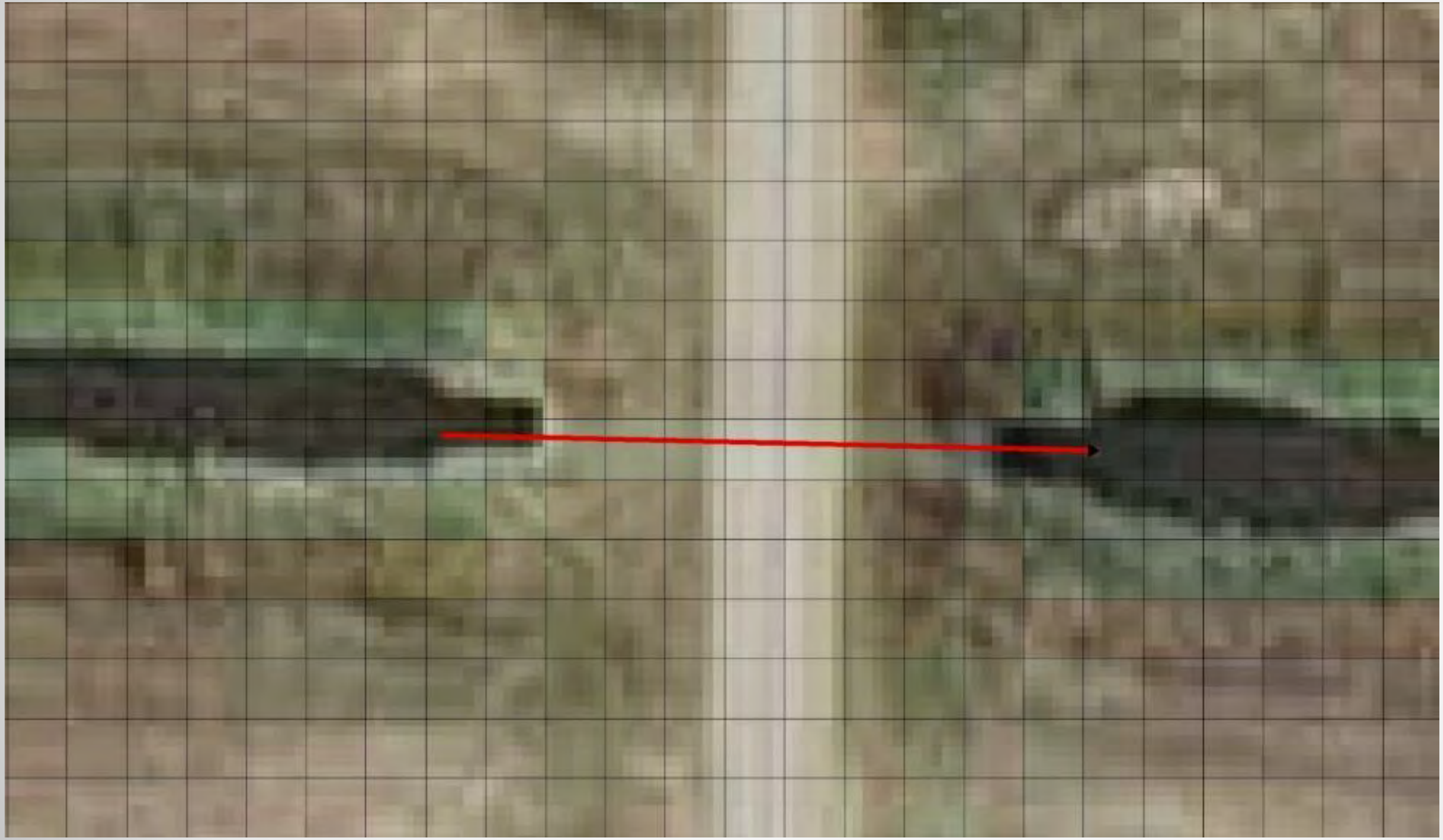
- Data Source - *(future discussion – definition of Data Source)*
  - User Interpretation (Default Value)
  - Culvert Inventory
  - Drainage Lines
  - Storm Sewer
  - Automated Breachlines
  - Other
- Type - (The breachline represents what type of feature on the landscape-
  - Bridge or Culvert (Default Value)
  - Artifact, LiDAR Inconsistency
  - Tile, Ditch, Hydro-Connection
  - Other
- Cell Size of Raw DEM: (Expected Resolution of Use?)
  - Sub-meter
  - 1 meter
  - 3 meter
  - 5 meter
  - 10 meter
- Confidence of Presence
  - High (Surveyed, Field Verified, Aerial Image Verified)
  - Medium (Assumed location based on geospatial evidence) (Default Value)
  - Low (Analyst estimation, but inconclusive evidence)
- What type of project were the Breachlines created for: **(Production Attribute)**
  - hDEM Level 3
  - hDEM Level 2
- Local Review (needs review) **(Production Attribute)**
  - Yes
  - No (Default Value)
- Reviewer **(Production Attribute)**
- Comments – 100 character text field
- Created Analyst – System logged in user name at time of creation
- Created Date – System generated date and time based on time of creation
- Edited Analyst – System logged in user name at time of edit
- Edited Date – System generated date and time based on time of edit

Standardized Attributes

Data Source	Type	Cell Size	Confidence of Presence	Project Type	Local Review	Comments
User Interpretation	Bridge or Culvert	Sub-meter	High (Surveyed, Field Verified, Aerial Image Verified)	hDEM Level 3	Yes	100 Character Text Field
Culvert Inventory	Artifact, LiDAR Inconsistency	1 meter	Medium (Assumed location based on geospatial evidence)	hDEM Level 2	No	
Drainage Lines	Tile, Ditch, Hydro Connection	3 meter	Low (Analyst estimation, but inconclusive evidence)			
Storm Sewer	Other	5 meter				
Automated Breachlines		10 meter				

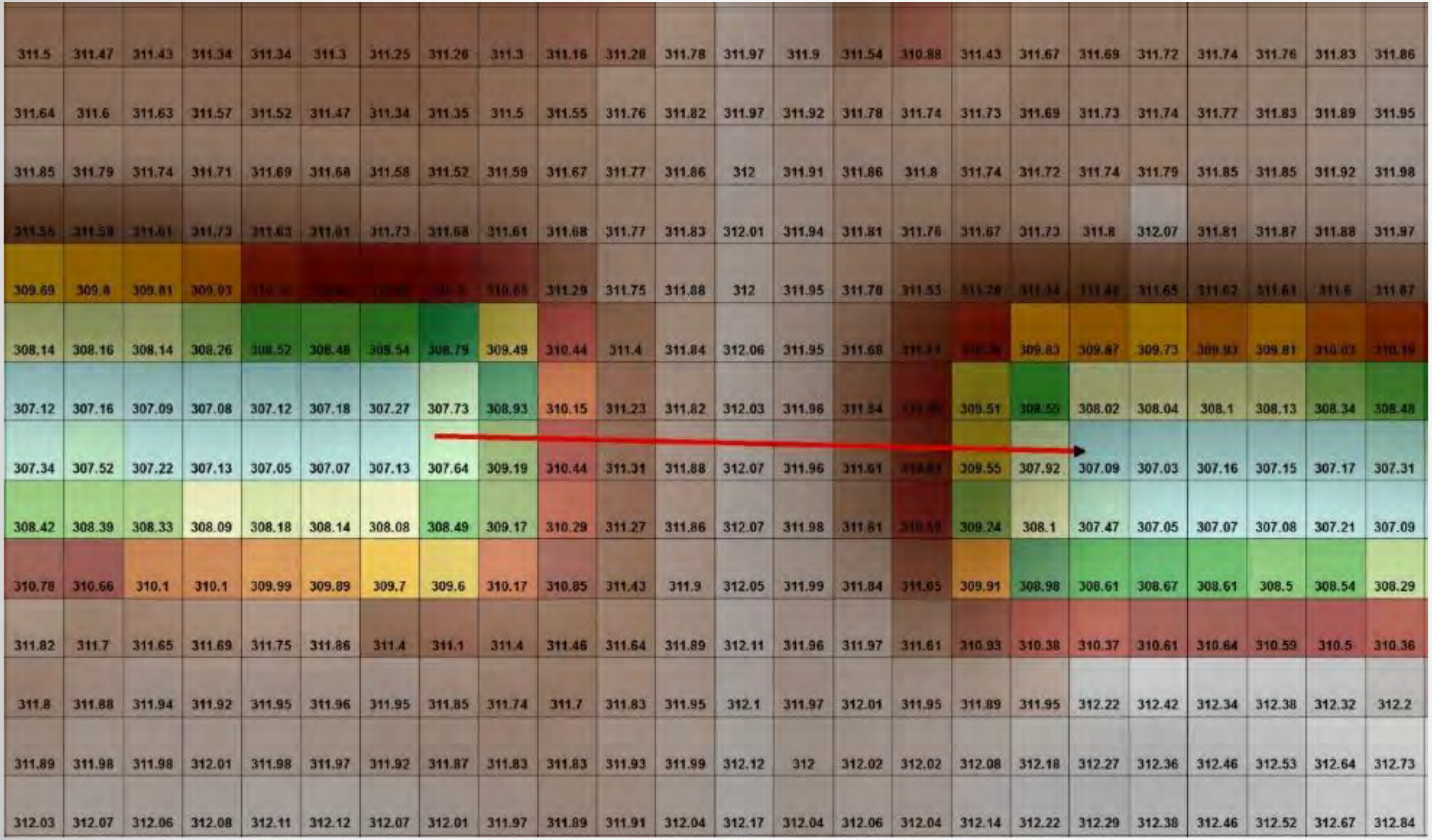
- **Created Analyst**
- **Created Date**
- **Edited Analyst**
- **Edited Date**

DIGITAL DAMS - BREACHLINE PLACEMENT – MINIMUM ELEVATION VALUE METHOD



- In Breachline Placement, locations are identified where **culverts** or bridges have not been breached in the digital elevation model (DEM).
- This image is used to show the location of a culvert

DIGITAL DAMS - BREACHLINE PLACEMENT – MINIMUM ELEVATION VALUE METHOD



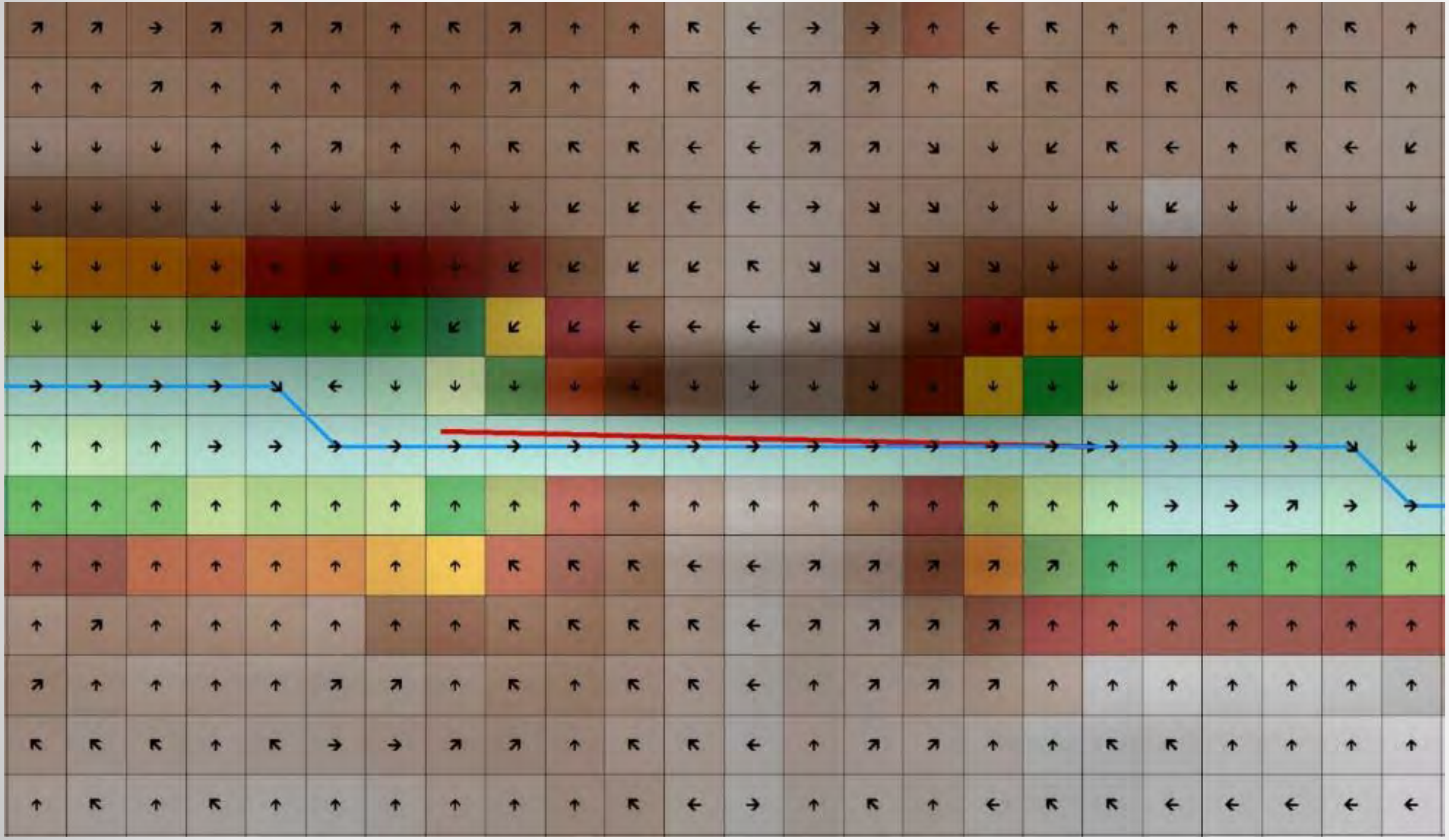
- A breachline is digitized in the direction of flow on the DEM from the upstream low elevation to the downstream **lowest cell** elevation.
- In placement of line, Map Tips can assist with identifying elevation values and placement

DIGITAL DAMS - BREACHLINE PLACEMENT – MINIMUM ELEVATION VALUE METHOD

311.5	311.47	311.43	311.34	311.34	311.3	311.25	311.26	311.3	311.16	311.28	311.78	311.97	311.9	311.54	310.88	311.43	311.67	311.69	311.72	311.74	311.76	311.83	311.86
311.64	311.6	311.63	311.57	311.52	311.47	311.34	311.35	311.5	311.55	311.76	311.82	311.97	311.92	311.78	311.74	311.73	311.69	311.73	311.74	311.77	311.83	311.89	311.95
311.85	311.79	311.74	311.71	311.69	311.68	311.58	311.52	311.59	311.67	311.77	311.86	312	311.91	311.86	311.8	311.74	311.72	311.74	311.79	311.85	311.85	311.92	311.98
311.65	311.59	311.61	311.73	311.63	311.61	311.73	311.68	311.61	311.68	311.77	311.83	312.01	311.94	311.81	311.76	311.67	311.73	311.8	312.07	311.81	311.87	311.88	311.97
309.69	309.8	309.81	309.93	[illegible]	[illegible]	[illegible]	[illegible]	310.65	311.29	311.75	311.88	312	311.95	311.78	311.53	311.28	311.34	311.42	311.65	311.62	311.61	311.6	311.67
308.14	308.16	308.14	308.26	308.52	308.48	308.54	308.79	309.49	310.44	311.4	311.84	312.06	311.95	311.68	[illegible]	[illegible]	309.83	309.87	309.73	309.93	309.81	310.02	[illegible]
307.12	307.16	307.09	307.08	307.12	307.18	307.27	307.73	308.93	310.15	311.23	311.02	312.03	311.96	311.54	[illegible]	309.51	308.55	308.02	308.04	308.1	308.13	308.34	308.48
307.34	307.52	307.22	307.13	307.05	307.07	307.13	307.09	307.09	307.09	307.09	307.09	307.09	307.09	307.09	307.09	307.09	307.09	307.09	307.03	307.16	307.15	307.17	307.31
308.42	308.39	308.33	308.09	308.18	308.14	308.08	308.49	309.17	310.29	311.27	311.86	312.07	311.98	311.61	310.59	309.24	308.1	307.47	307.05	307.07	307.08	307.21	307.09
310.78	310.66	310.1	310.1	309.99	309.89	309.7	309.6	310.17	310.85	311.43	311.9	312.05	311.99	311.84	311.05	309.91	308.98	308.61	308.67	308.61	308.5	308.54	308.29
311.82	311.7	311.65	311.69	311.75	311.86	311.4	311.1	311.4	311.46	311.64	311.89	312.11	311.96	311.97	311.61	310.93	310.38	310.37	310.61	310.64	310.59	310.5	310.36
311.8	311.88	311.94	311.92	311.95	311.96	311.95	311.85	311.74	311.7	311.83	311.95	312.1	311.97	312.01	311.95	311.89	311.95	312.22	312.42	312.34	312.38	312.32	312.2
311.89	311.98	311.98	312.01	311.98	311.97	311.92	311.87	311.83	311.83	311.93	311.99	312.12	312	312.02	312.02	312.08	312.18	312.27	312.36	312.46	312.53	312.64	312.73
312.03	312.07	312.06	312.08	312.11	312.12	312.07	312.01	311.97	311.89	311.91	312.04	312.17	312.04	312.06	312.04	312.14	312.22	312.29	312.38	312.46	312.52	312.67	312.84

- Using the **minimum elevation method**, the cell with the lowest elevation value is identified.
- All cells along the line are assigned that elevation, resulting in each cell elevation value being **lowered** to that value.

DIGITAL DAMS - BREACHLINE PLACEMENT – MINIMUM ELEVATION VALUE METHOD



- **Flow Direction** is then calculated for the Digital Elevation Model (DEM).
- The **arrows** represent the flow direction from each cell to the cell that it would flow into.
- The **blue line** represents the flow network.

Standardized Attributes

Data Source	Type	Cell Size	Confidence of Presence	Project Type	Local Review	Comments
User Interpretation	**Bridge or Culvert**	Sub-meter	**High (Surveyed, Field Verified, Aerial Image Verified)**	**hDEM Level 3**	Yes	100 Character Text Field
Culvert Inventory	Artifact, LiDAR Inconsistency	1 meter	Medium (Assumed location based on geospatial evidence)	hDEM Level 2	**No**	
Drainage Lines	Tile, Ditch, Hydro Connection	**3 meter**	Low (Analyst estimation, but inconclusive evidence)			
Storm Sewer	Other	5 meter				
Automated Breachlines		10 meter				

- **Created Analyst**
- **Created Date**
- **Edited Analyst**
- **Edited Date**

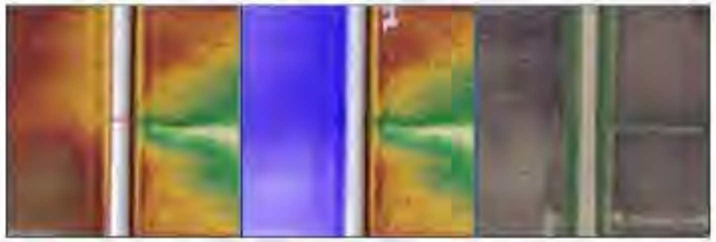
Methodology and Protocol

Developments of the Breachline Subgroup

- Standardized Attributes
- **Methodology and Protocol**
- Breachline Data and Work Area Identification

IV.C. DIGITAL DAM IDENTIFICATION/INVESTIGATION

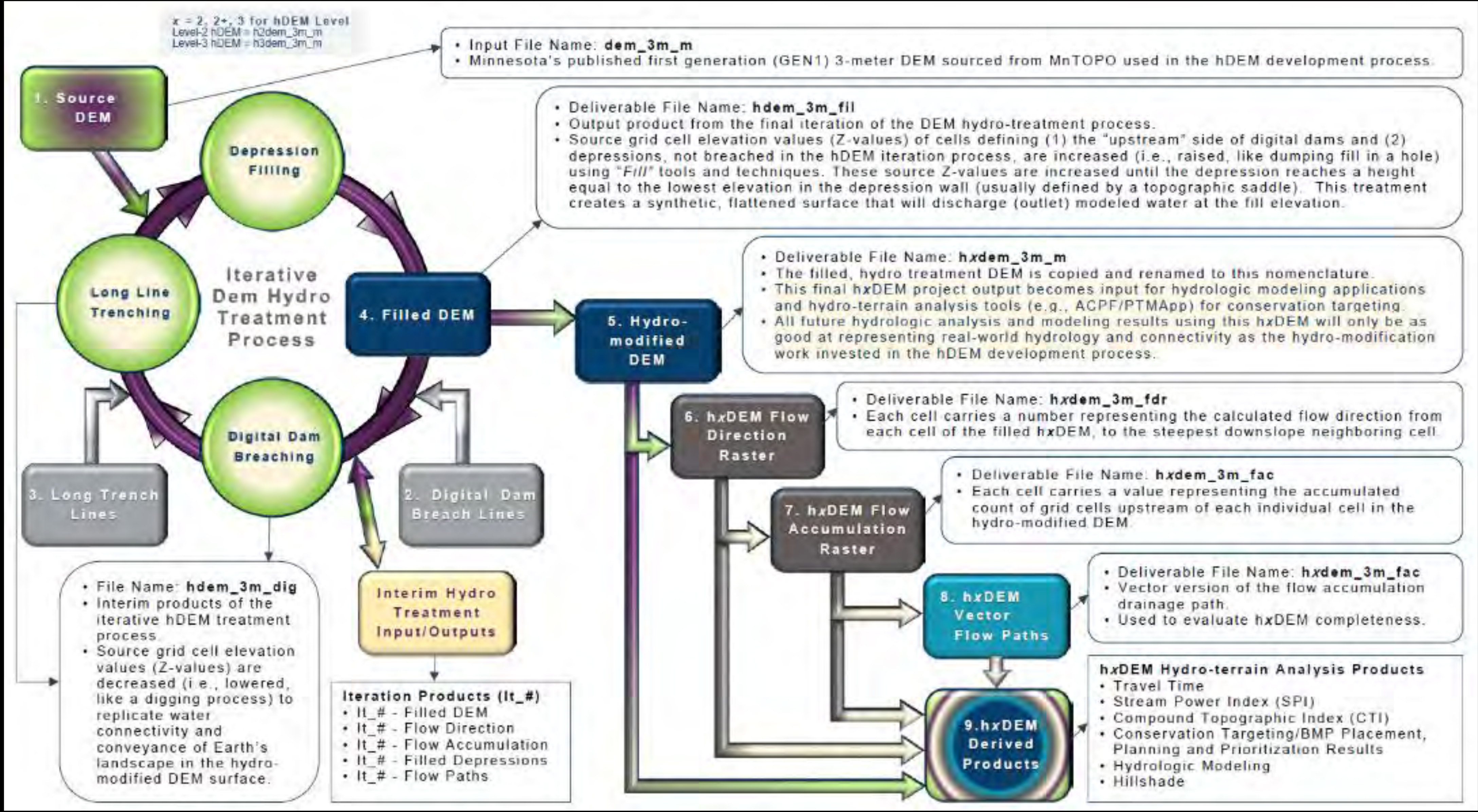
The identification of a digital dam is a multi-step process of looking at many different visual clues from the source data we have compiled. Hydro-modification is essentially depression analysis. Therefore, we start looking at the depth grid and the DEM for areas that show depressions occurring next to roads and other structures. As shown in the top center image, the darker blue colors show the greatest depth and therefore, should yield the lowest elevation value at that location. The process then looks at the aerial image for signs of culvert signatures.



The Flow Network also identifies that the flow pathways converge in this area from higher up in the watershed and overtop the road. This is a good indicator of the location of a culvert. Dark black circles within the green vegetation of a roadway is a good indicator of a culvert. This can be seen on the FSA image in the upper right. The image in the center right, an oblique image from Pictometry shows a culvert signature as well as the bottom center left image from the same Pictometry dataset.

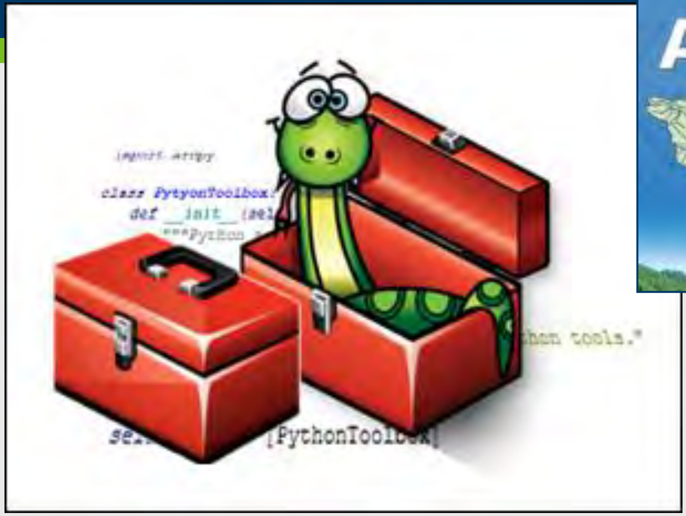
Another tool we use in this process is street view images from Google and Bing, which can be accessed through the Google Bing toolbar referenced earlier in this document. We can see metal poles in the road ditch area which is a good indicator of a culvert. They are placed there to identify culvert openings for ditch mowers as well as any person that is proceeding through a road ditch, be it vehicle, tractor, ATV, or snowmobile. Using all these clues, we can proceed with a high confidence that there is a culvert at this location. Using the DEM as the placement reference, we would draw the

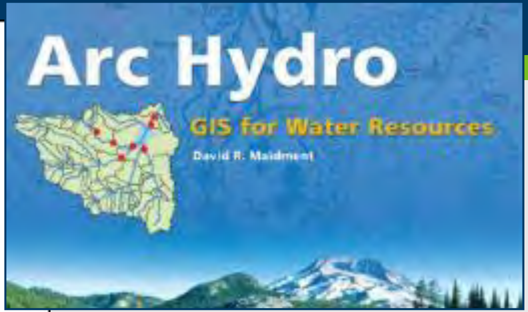
Methodology and Protocol

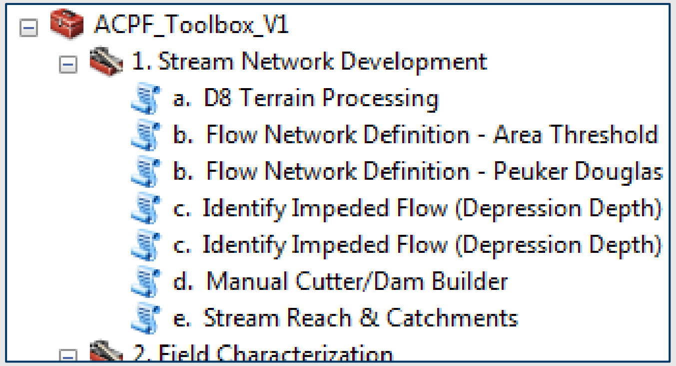


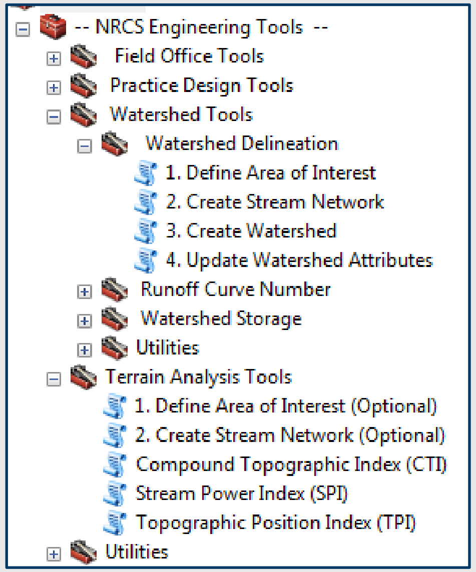
Methodology and Protocol

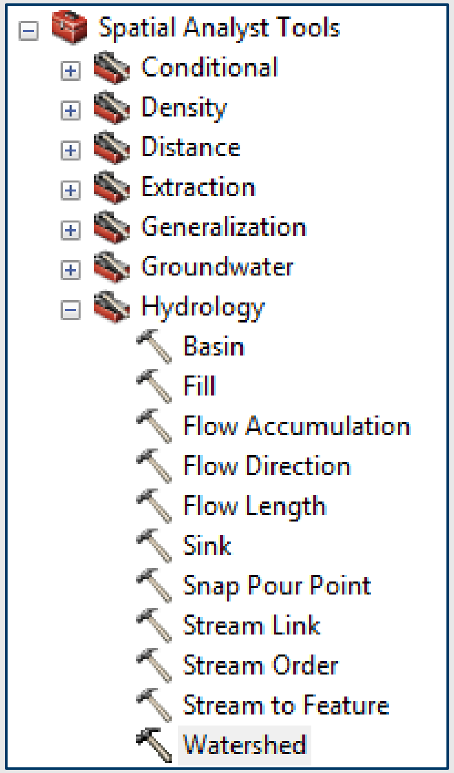
- **Tools/Methods within ArcGIS:**
- **DEM Hydro-Modification**
  - Breachline identification accounts for ~70% time
  - Performance Based
  - Most tools built on ArcGIS Platform
  - Most tools are calling the same code
  - Results tend to be the same
  - All strive to represent landscape hydrology
  - **Utilize tools that <u>improve the process</u> of terrain analysis and hydro-modification. <u>Utilize your time to identify the digital dams</u>, <u>not in running</u> the tools**







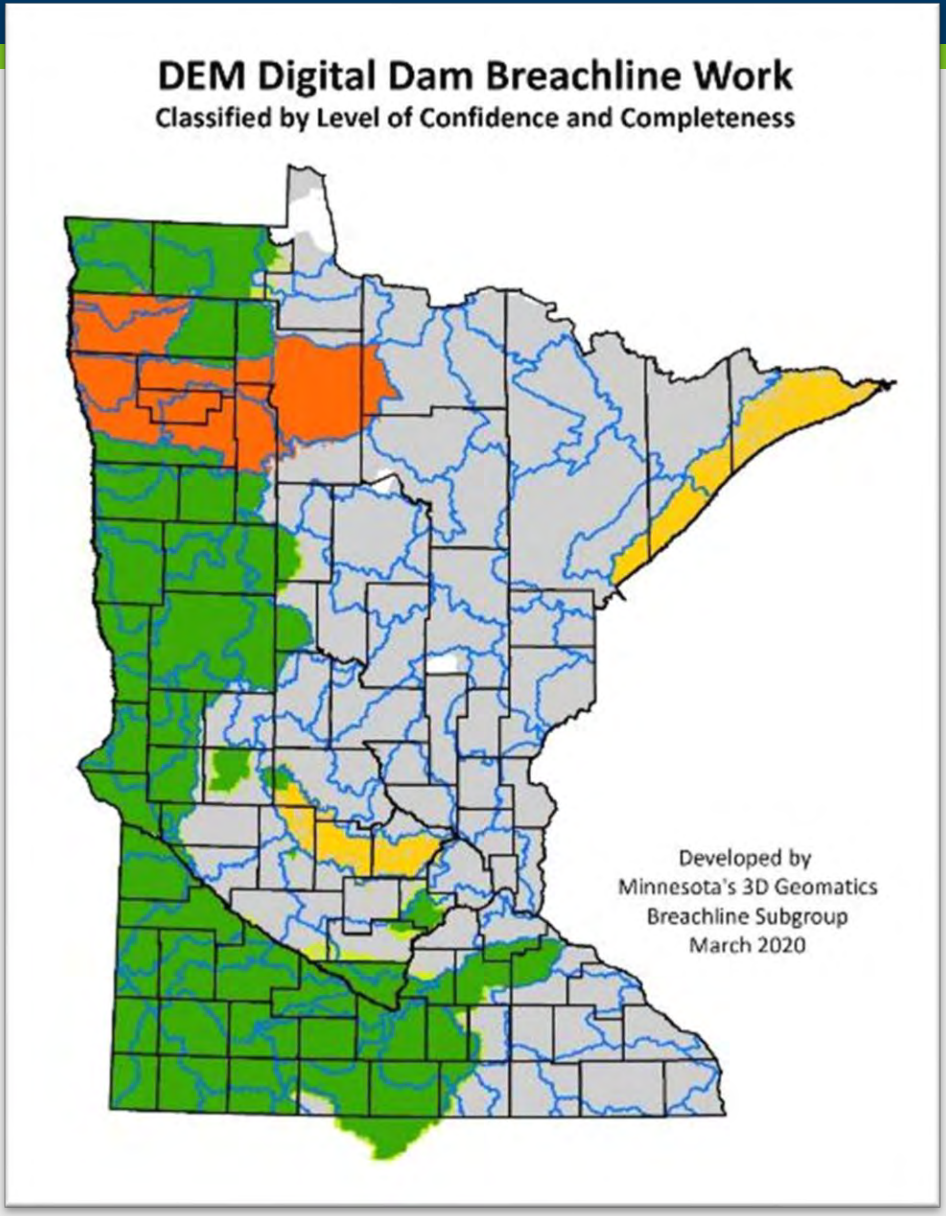




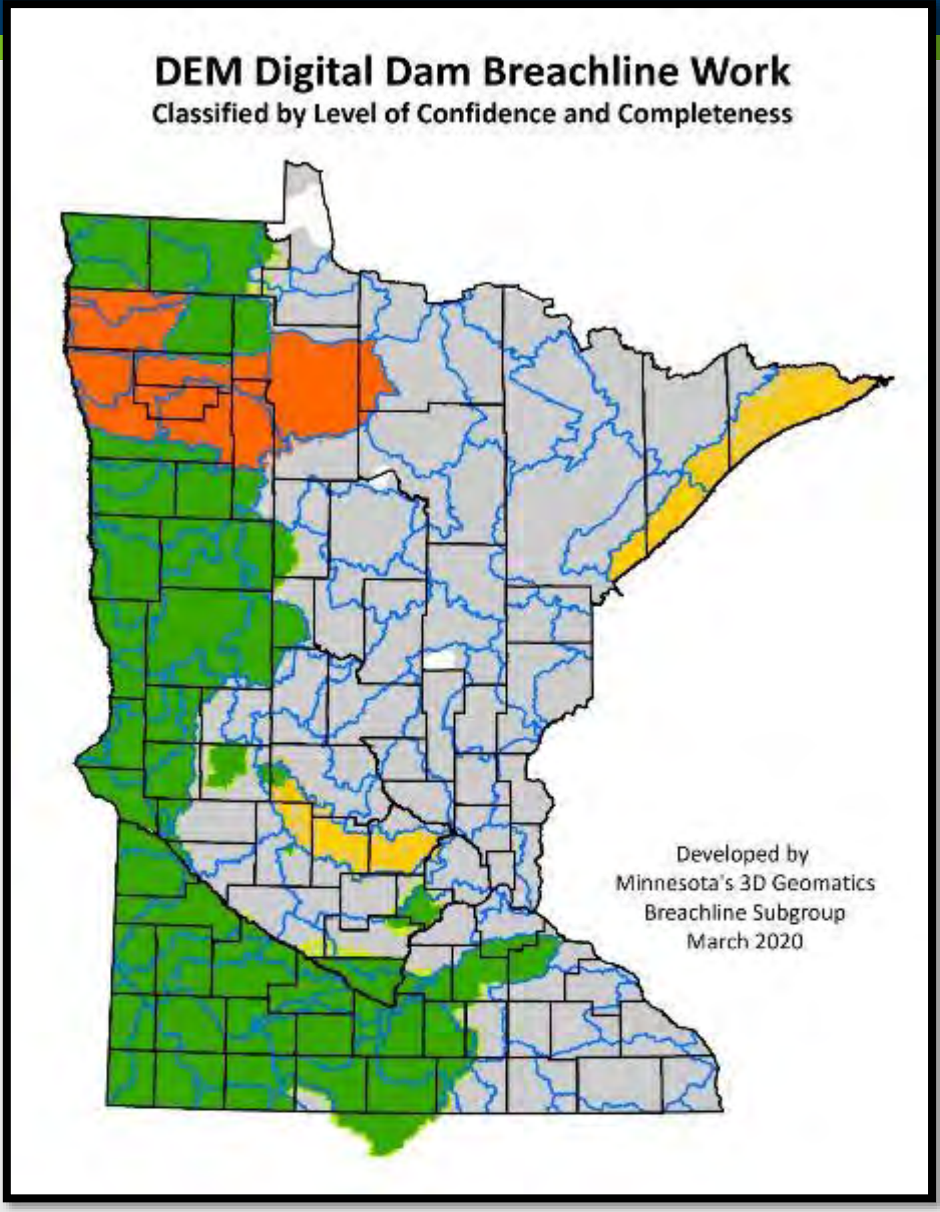
Breachline Data and Work Area Identification

Developments of the Breachline Subgroup

- Standardized Attributes
- Methodology and Protocol
- **Breachline Data and Work Area Identification**

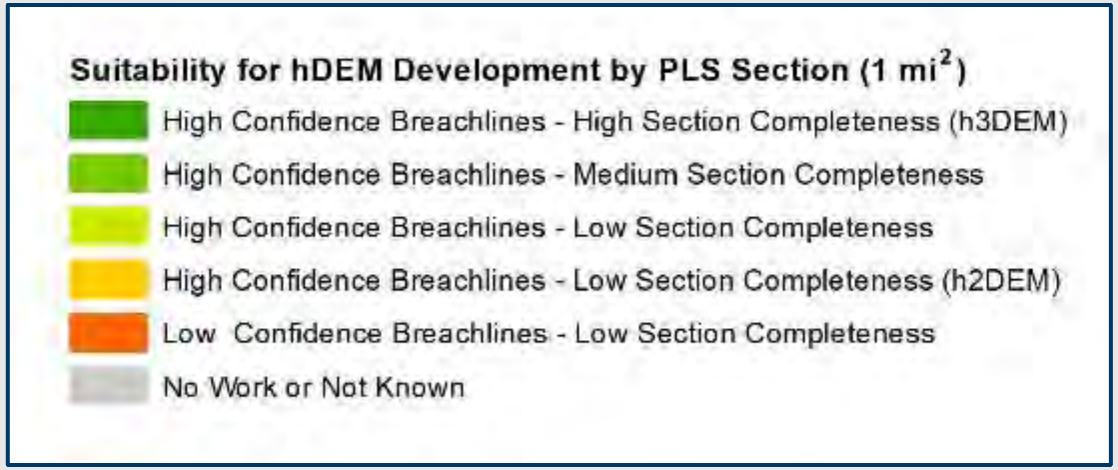


Breachline Data and Work Area Identification



DEM Digital Dam Breachline Work

- Breachline datasets developed within Minnesota by subject matter experts.
- Tracks the development of breachline datasets utilizing the tiling scheme of PLS sections
- Identifies the confidence of breachline placement (accuracy) as well as the completeness of the PLS Section (1 mi^2)



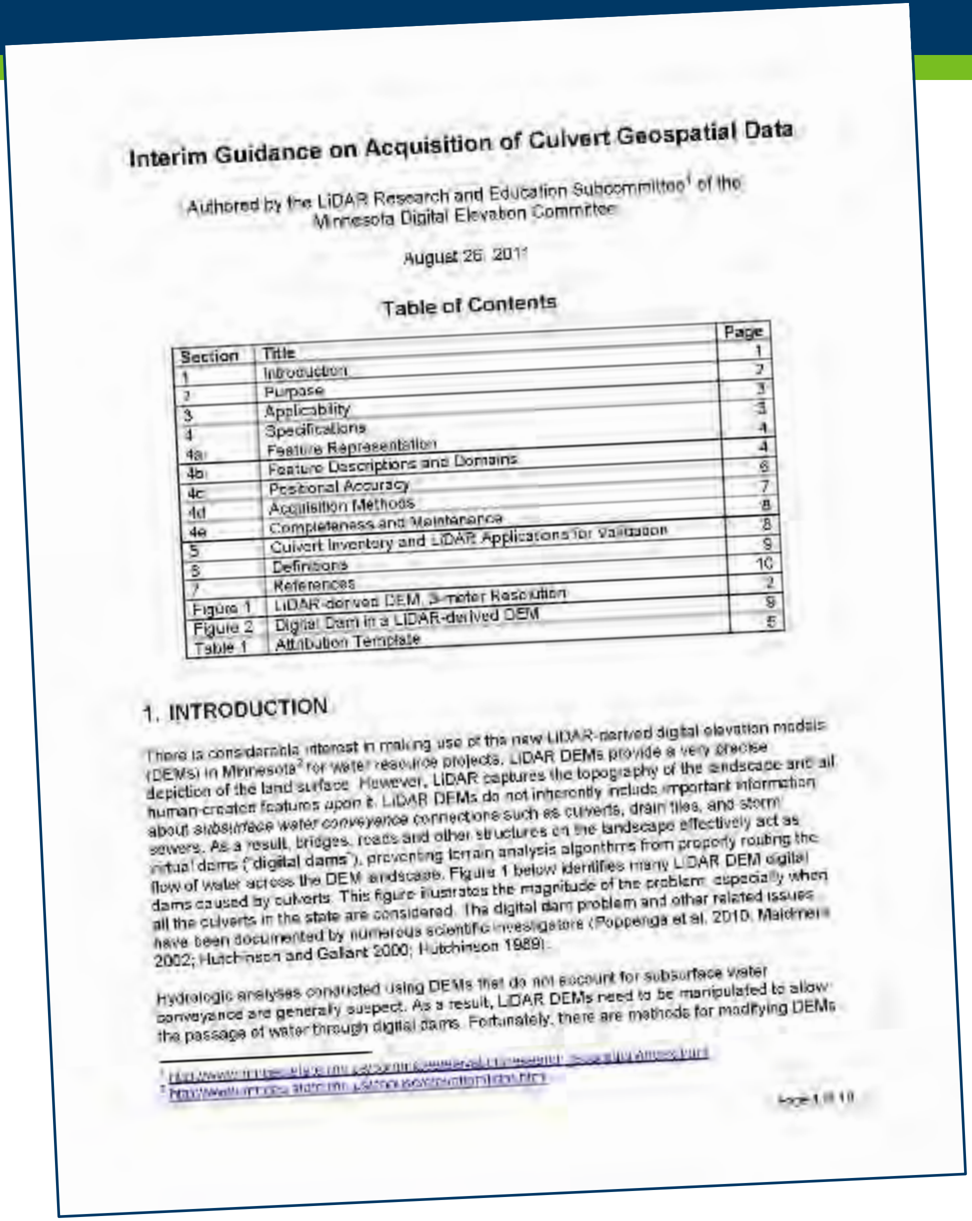
Culvert Inventory:

The Key to Building Confidence from Accuracy and Completeness

Culvert Data Standard

- Culvert Inventory brings confidence to the placement of breachlines based on the accuracy of the inventoried culvert feature.
- Culvert Data Standard can bring efficiencies into outdated processes by reducing data entry time, minimizing human error, and making data available in real-time.

Interim Guidance – LiDAR R & E (2011)



Interim Guidance on Acquisition of Culvert Geospatial Data

Authored by the LiDAR Research and Education Subcommittee[1] of the Minnesota Digital Elevation Committee

August 26, 2011

Table of Contents

1. INTRODUCTION

There is considerable interest in making use of the new LiDAR-derived digital elevation models (DEMs) in Minnesota[2] for water resource projects. LiDAR DEMs provide a very precise depiction of the land surface. However, LiDAR captures the topography of the landscape and all human-created features upon it. LiDAR DEMs do not inherently include important information about subsurface water conveyance connections such as culverts, drain tiles, and storm sewers. As a result, bridges, roads and other structures on the landscape effectively act as virtual dams ("digital dams"), preventing terrain analysis algorithms from properly routing the flow of water across the DEM landscape. Figure 1 below identifies many LiDAR DEM digital dams caused by culverts. This figure illustrates the magnitude of the problem, especially when all the culverts in the state are considered. The digital dam problem and other related issues have been documented by numerous scientific investigators (Poppenga et al. 2010; Maidment 2002; Hutchinson and Gallant 2000; Hutchinson 1989).

Hydrologic analyses conducted using DEMs that do not account for subsurface water conveyance are generally suspect. As a result, LiDAR DEMs need to be manipulated to allow the passage of water through digital dams. Fortunately, there are methods for modifying DEMs

[1] [illegible]
[2] [illegible]

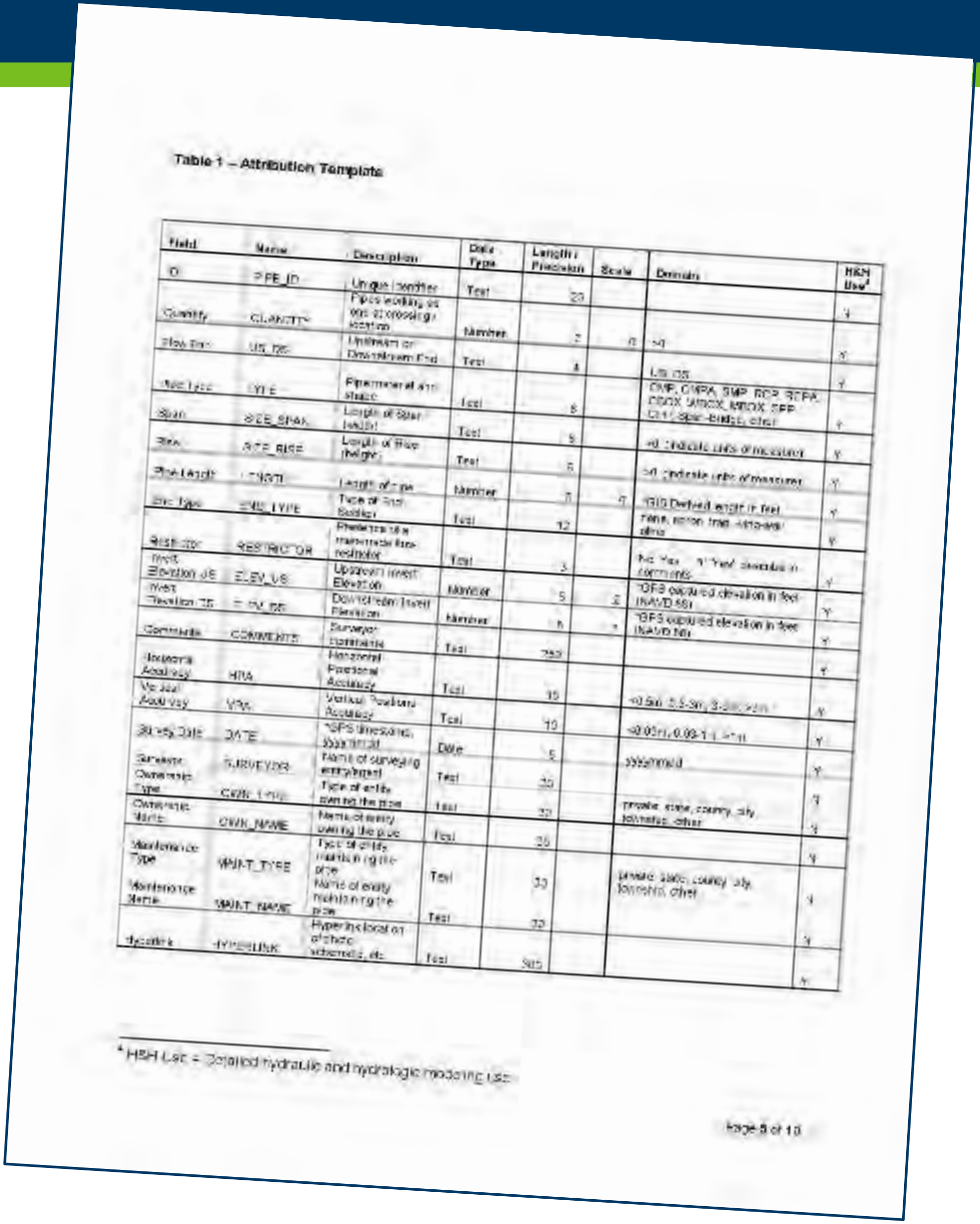
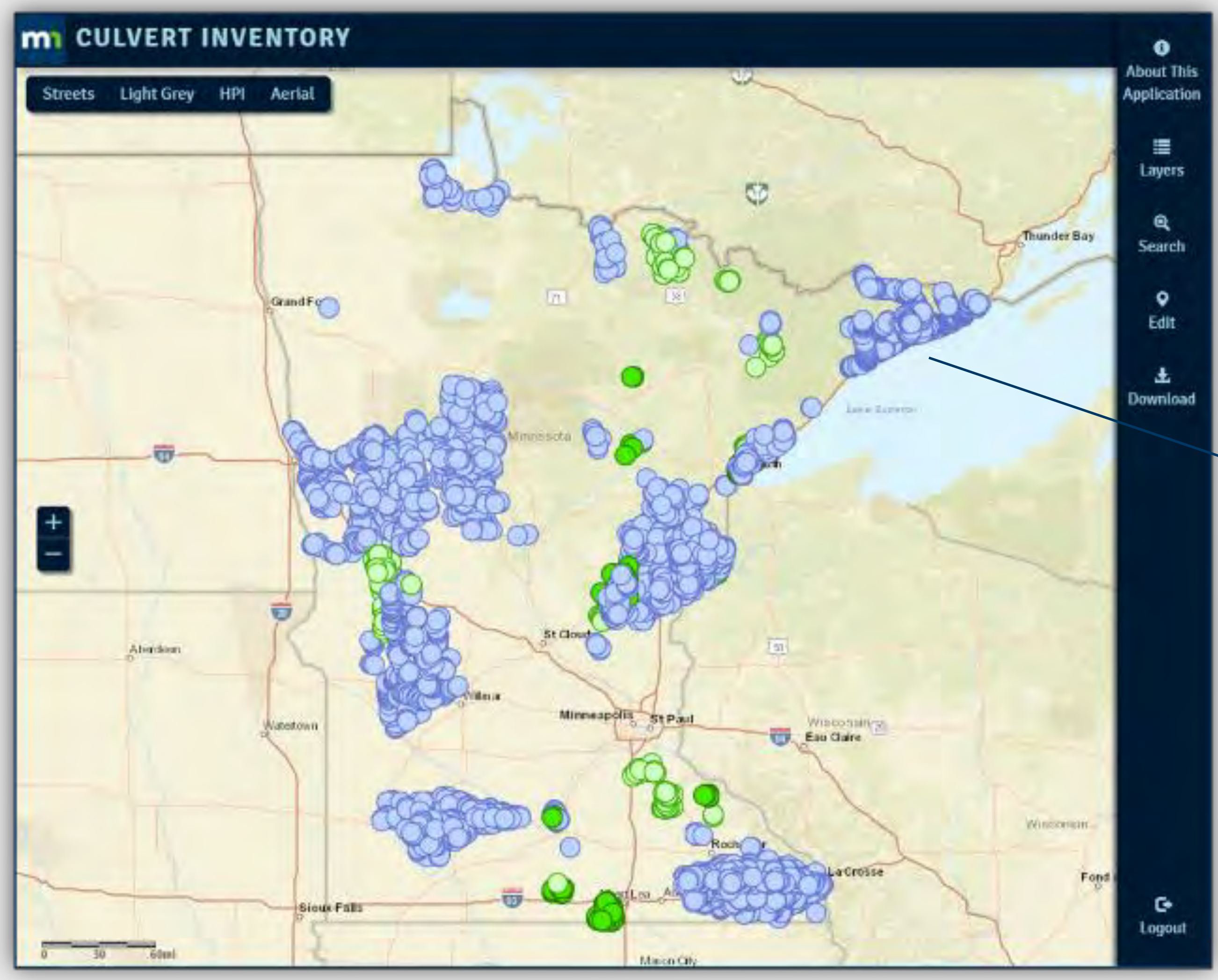


Table 1 – Attribution Template

Field	Name	Description	Data Type	Length / Precision	Scale	Domain	H&H Use[4]
ID	PIPE_ID	Unique Identifier	Text	20			
Quantity	QUANTITY	Pipes existing at one crossing location	Number	2	0	>0	Y
Flow End	US_DS	Upstream or Downstream End	Text	4		US, DS	Y
Pipe Type	TYPE	Pipe material and shape	Text	8		CMP, CMPA, SMP, RCP, RCPA, CBOX, WBOX, MBOX, SPP, CIP, span-bridge, other	Y
Span	SIZE_SPAN	Length of Span (width)	Text	5		>0; indicate units of measure	Y
Rise	SIZE_RISE	Length of Rise (height)	Text	5		>0; indicate units of measure	Y
Pipe Length	LENGTH	Length of pipe	Number	7	1	*GIS Derived length in feet	Y
End Type	END_TYPE	Type of End Section	Text	12		flare, apron, trash, wing-wall, other	Y
Restrictor	RESTRICTOR	Presence of a man-made flow restrictor	Text	3		No, Yes – if "Yes" describe in comments	Y
Invert Elevation US	ELEV_US	Upstream Invert Elevation	Number	5	2	*GPS captured elevation in feet (NAVD 88)	Y
Invert Elevation DS	ELEV_DS	Downstream Invert Elevation	Number	5	2	*GPS captured elevation in feet (NAVD 88)	Y
Comments	COMMENTS	Surveyor Comments	Text	252			Y
Horizontal Accuracy	HPA	Horizontal Positional Accuracy	Text	15		<0.5m, 0.5-3m, 3-5m, >5m	Y
Vertical Accuracy	VPA	Vertical Positional Accuracy	Text	10		<0.05m, 0.05-1.1m, >1m	Y
Survey Date	DATE	*GPS timestamp, yyyymmdd	Date	5		yyyymmdd	Y
Surveyor	SURVEYOR	Name of surveying entity/agent	Text	20			Y
Ownership Type	OWN_TYPE	Type of entity owning the pipe	Text	20		private, state, county, city, township, other	N
Ownership Name	OWN_NAME	Name of entity owning the pipe	Text	25			N
Maintenance Type	MAINT_TYPE	Type of entity maintaining the pipe	Text	20		private, state, county, city, township, other	N
Maintenance Name	MAINT_NAME	Name of entity maintaining the pipe	Text	20			N
Hyperlink	HYPERLINK	Hyperlink location of photo, schematic, etc.	Text	505			N

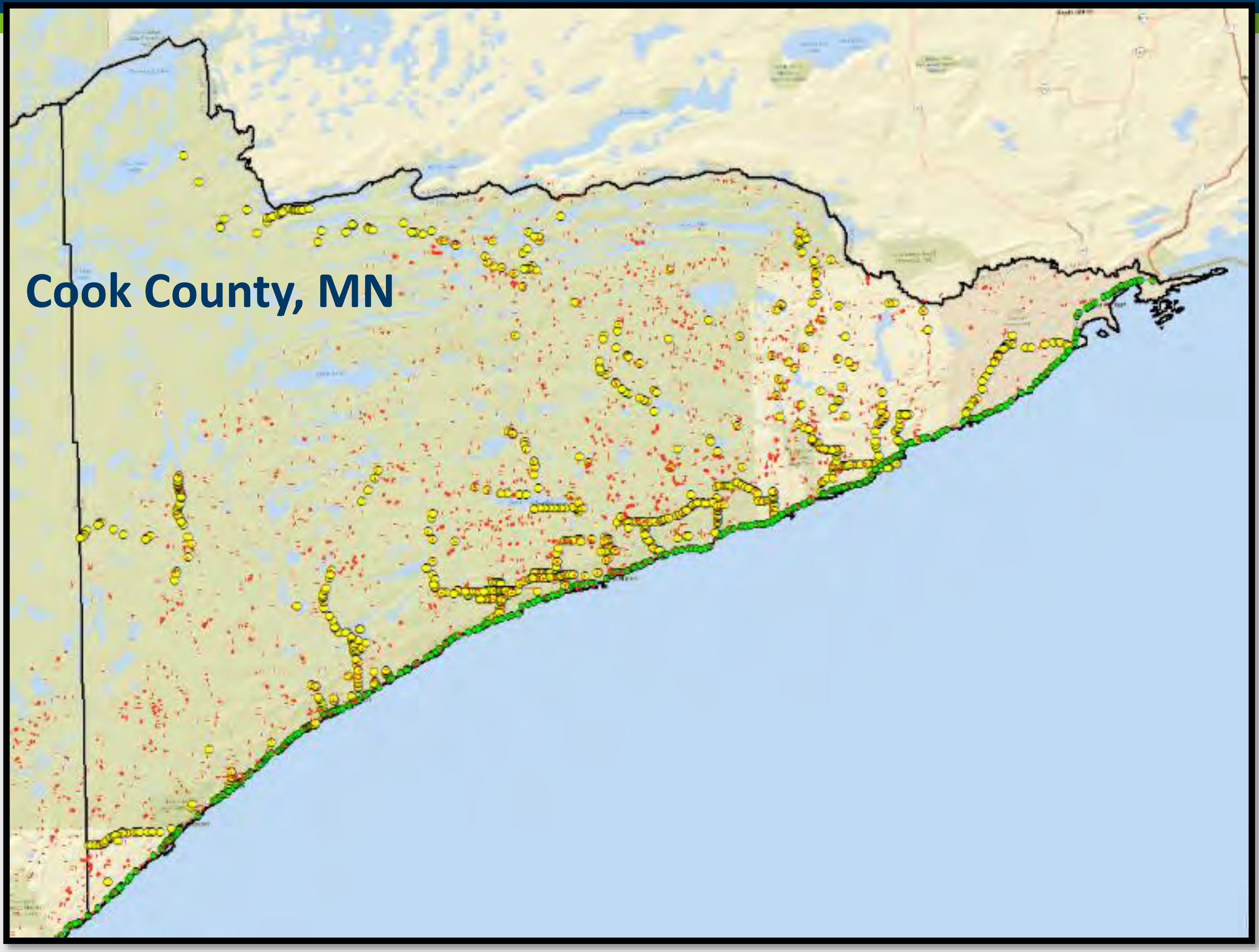
[4] H&H Use = Detailed hydraulic and hydrologic modeling use

MN DNR Culvert Inventory Application



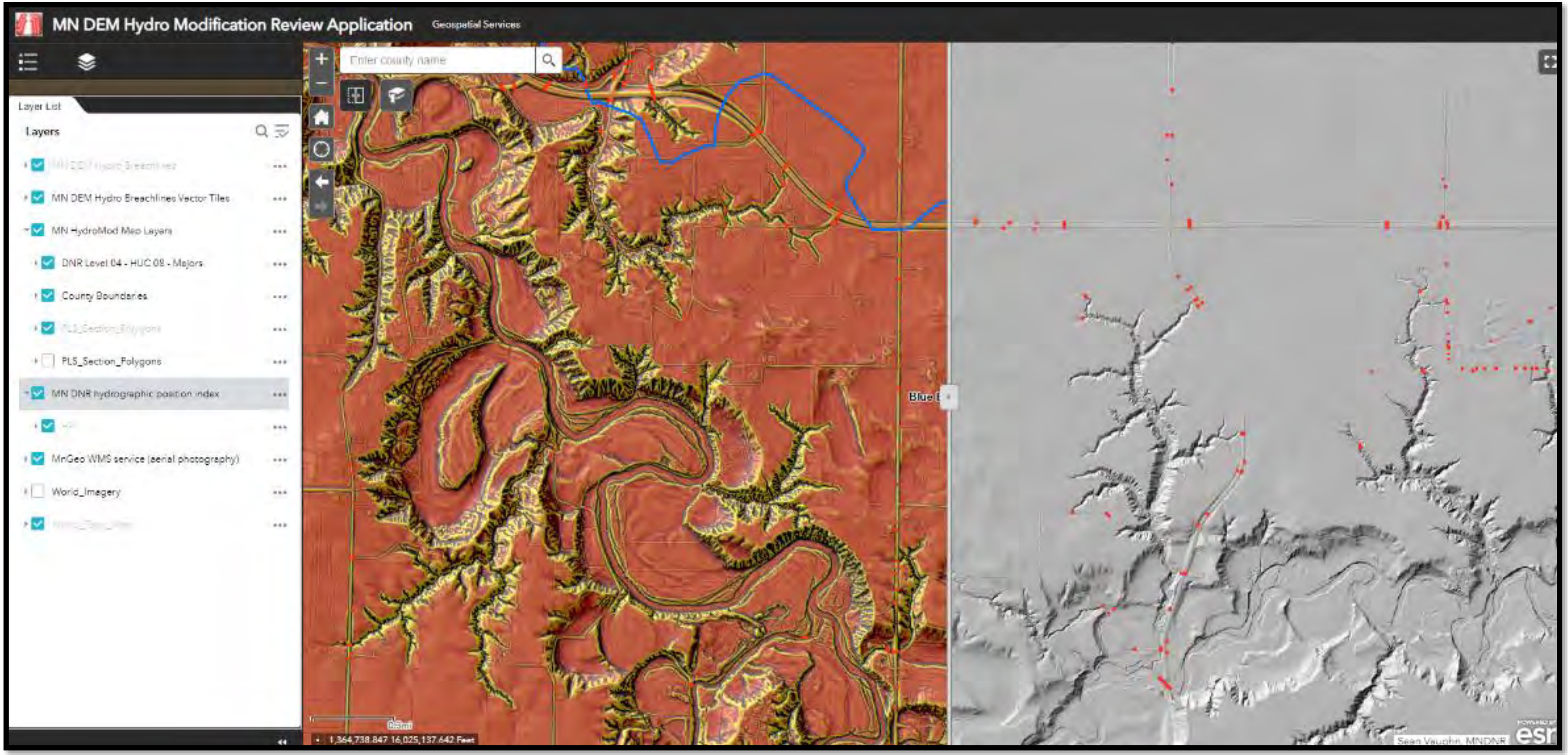
- Developed by DNR, the DNR Culvert Inventory Web Application allows data collected in the field to be reviewed in office in real time.

LiDAR → Point Cloud → DEM → Digital Dams → Culvert Data



- Hydro-modified DEM's use breachlines/culverts to breach digital dams and replicate landscape hydrology.
- Culvert inventories inform technicians of locations of digital dams/breachline placement during the hydro-modification process.
- Most of the time and effort in performing hydro-modification is reviewing various datasets and layers in a GIS to determine if there is a digital dam at a certain location

MN DEM Hydro Modification Review Application



DEM

Takeaway Messages

- LiDAR **does its job,** lack of flow in DEMs is not a flaw of lidar
- Proper **replication of landscape hydrology** in DEMs is required
- hDEMs are **foundational data** (Point Cloud, DEMs)
- Establish **Coordination** via a committee to formulate a *Community of Practice* to ensure hDEM development is conducted to a level of completeness and accuracy that serves all hydraulic and hydrologic business.
- **Culvert Database** supports culvert data sharing for DEM hydro-modification

Thank You!

Sean Vaughn | Rick Moore

sean.vaughn@state.mn.us

rick.moore@state.mn.us

3D Geomatics Committee
www.mngeo.state.mn.us/committee/3dgeo

3D Geomatics Hydrogeomorphology Workgroup – DEM Hydro-modification Subgroup
www.mngeo.state.mn.us/committee/3dgeo/hydro