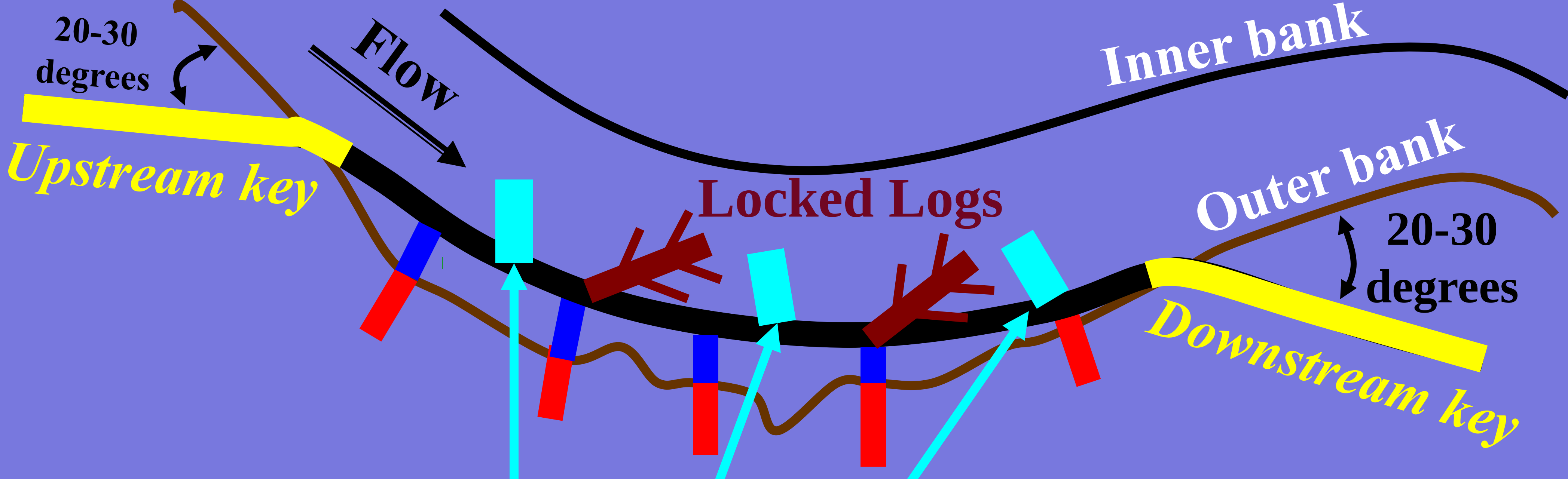
SHOW THE DUCK CREEK STABILIZATION VIDEO

COMBINATIONS OF RESISTIVE & REDIRECTIVE METHODS: CASE STUDY- Duck Creek East of Eastern Avenue, Davenport, Iowa

Constructed June-July. 2008

Longitudinal Peaked Stone Toe Protection {LFSTP} with interspaced Short Bendway Weirs & Locked Logs



Bendway Weirs at intervals, keyed into the LPSTP. BW designed to act as a system to realign the thalweg & reduce velocities near the LPSTP

LPSTP with Bendway Weirs & Locked Logs modified from: www.E-SenSS.com

FROM DOWNSTREAM LOOKING UPSTREAM AT THE THALWEG ALIGNMENT

From DS looking US @ thalweg trace.

CONSTRUCTION-DUCK CR. E. OF EASTERN AVE. PIX BY DERRICK 7-1-2008

3 YEARS AFTER PROJECT COMPLETION

Looking US to DS

Photos: Brian Stineman

SEPTEMBER 2011

3 YEARS LATER-From DS bend looking US. All stable & fully functional. Great diversity & complexity of vegetation.

3 YEARS LATER-DUCK CR-BRIAN STINEMAN 9-2011

3 YEARS LATER-Looking US in the bite of the bend @ Bendway Weirs & Locked Logs providing hyd. roughness & habitat

3 YEARS LATER-DUCK CR-BRIAN STINEMAN 9-2011

3 YEARS LATER-Looking US @ no-mow riparian corridor that connects two forested areas. Fully functional!!

3 YEARS LATER-DUCK CR-BRIAN STINEMAN 9-2011

THE SECRET TO BANK STABILIZATION:

MAKE THE BANK THAT IS PROTECTING SOMETHING TOUGHER & HYDRAULICALLY ROUGHER THAN THE OPPOSITE BANK

(OPPOSITE BANK SHOULD BE SMOOTHER & WEAKER)


THE GOOD OLE DAYS !!
“Carhenge”
War Eagle
Creek, AR

BEWARE OF FOUNDATION DEPENDANT BANK STABILIZATION METHODS !!!

If the foundation is erodeable, the bank protection method might have to be toed down (excavated) to the level of maximum anticipated scour (at least below the thalweg elevation), then add a factor of safety.

Looking DS @ failed gabion baskets. A good meander on those baskets!! Foundation is important with this method!!!

CATTAURAGUS CR @ HAUK ROAD DERRICK 12-8-2011

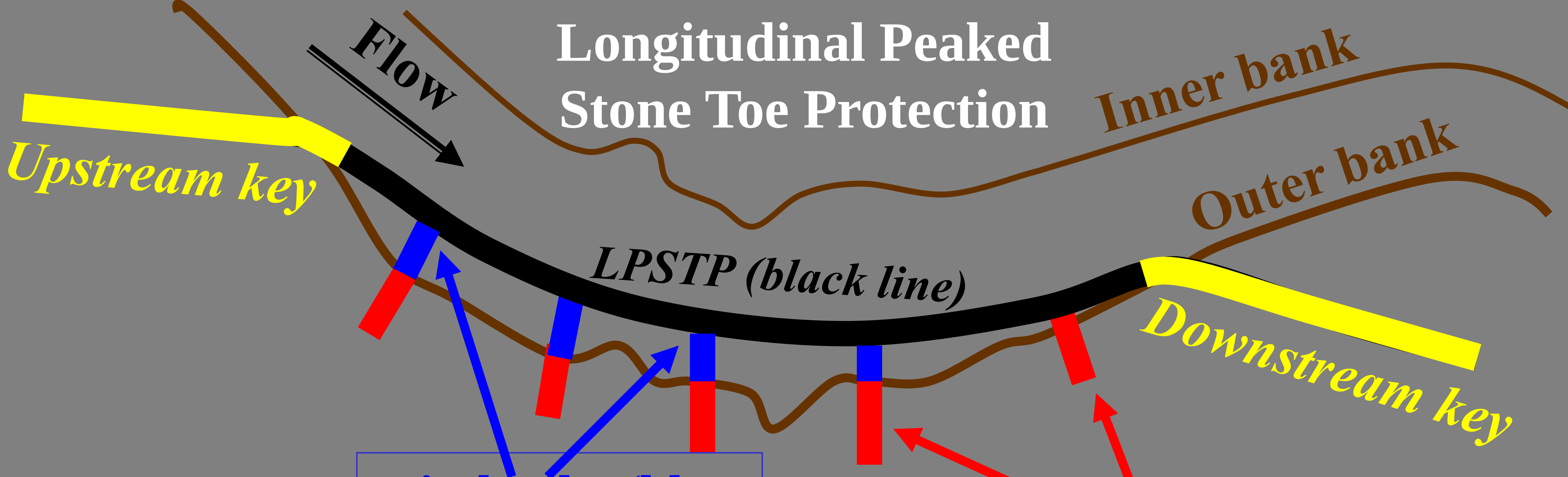
Introduction to Longitudinal Peaked Stone Toe Protection (LPSTP)

LONGITUDINAL PEAKED STONE TOE PROTECTION {LPSTP}

- **Description:** A continuous stone dike placed longitudinally at, or slightly streamward of, the toe of the eroding bank. Cross-section is triangular. The LPSTP does not necessarily follow the toe exactly, but can be placed to form a "smoothed" alignment through the bend. Smoothed alignment might not be desirable from the environmental or energy dissipation points of view . Amount of stone used (1 ton/ lineal ft, 2 tons/ft, etc.) depends on depth of scour at the toe, estimated stream forces (impinging flow) on the bank, and flood durations and stages.

- **Tie-backs** are short dikes connecting the LPSTP to the bank at regular intervals. Tie-backs are usually the same height as the LPSTP or elevated slightly toward the bank end, and are keyed into the bank. If tie-backs are long they should be angled upstream to act as bendway weirs.

Longitudinal Peaked Stone Toe Protection

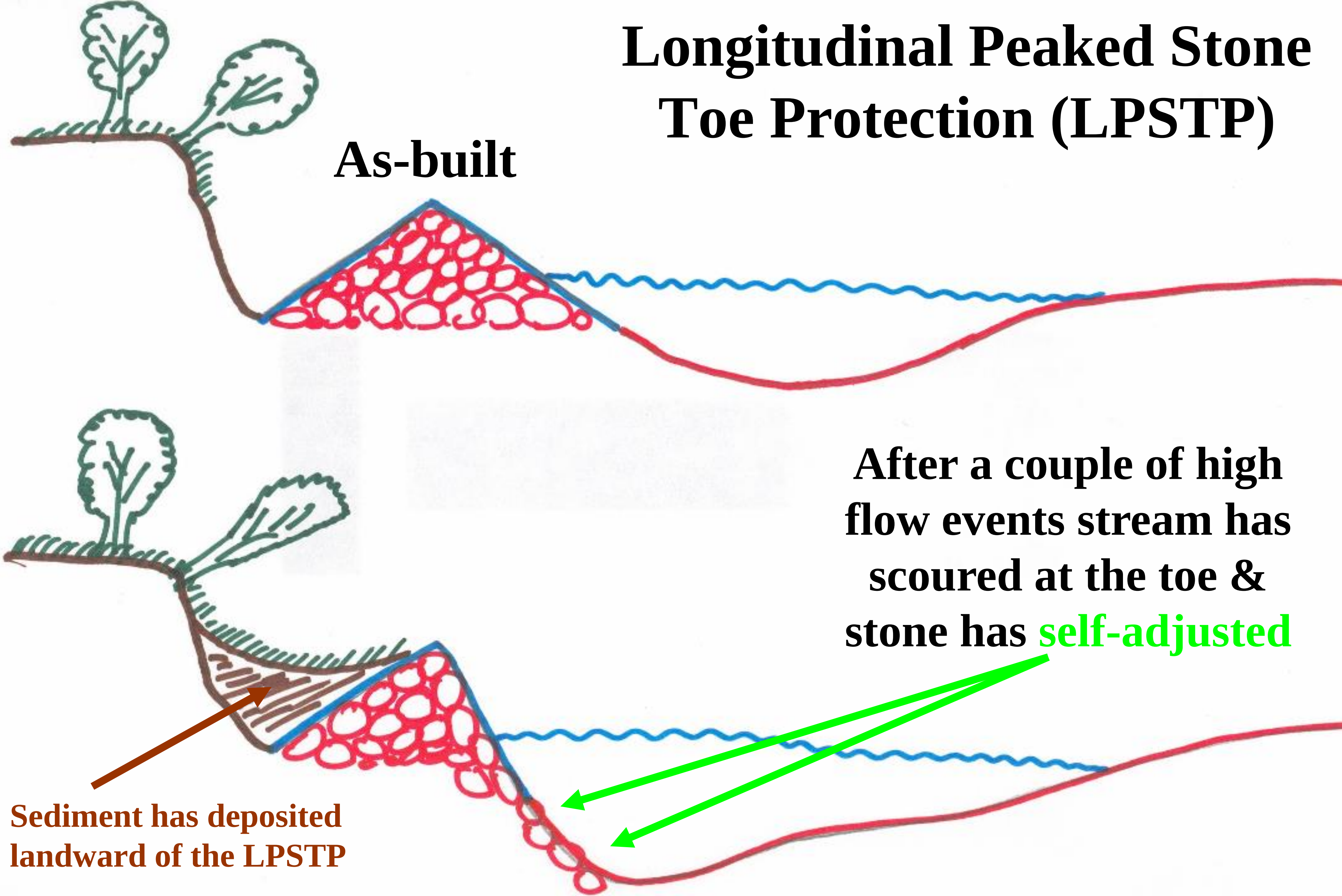


Tie-backs (blue lines) will connect the LPSTP to the key. The key, sometimes called the key root, is dug into the bank.

Mid-project keys (red lines) are perpendicular to high flow & connect the tie-back to the bank

Modified from:
www.E-SenSS.com

Longitudinal Peaked Stone Toe Protection (LPSTP)



Johnson Creek, MS. Pre-project rapidly eroding near-vertical bank {rural, sand bed, slope < 1%, pool-riffle-pool, meandering, incised}

Johnson Creek, MS. As-built protection consists of Longitudinal Peaked Stone Toe protection (LPSTP) applied at 1 ton/ lineal foot

Mini case study: 2 of 3

Johnson Creek-LPSTP one year later (note volunteer willow growth)

Mini case study: 3 of 3

Functions and Attributes of Longitudinal Peaked Stone Toe Protection

- **Resists** the erosive flow of the stream, only stabilizes the toe, does not protect mid and upper bank areas.
- "Smoothed" longitudinal alignment results in improved flow near toe.
- Success depends on ability of stone to launch into scour hole.
- Bank grading is not needed (existing vegetation is not disturbed).
- Weight of stone (loading of toe) might resist some shallow-fault geotechnical bank failures.
- Captures alluvium & upslope failed material on bank side of structure.
- Good where outer bank alignment makes abrupt changes, where the bank must be built back out into the stream (realignment of channel, or construction of a backfilled vegetative bench or terrace for habitat improvement and/or velocity attenuation), where a minimal continuous bank protection is needed, or where a “false bankline” is needed.
- Works well in combination with other methods (Bendway Weirs, or bioengineering within the stone {joint planting, Bent willow poles} or immediately behind stone {Live Siltation, Living Dikes}, & in mid to upper bank areas {brush layering, Slit Brush Layering, Live Staking, rooted stock or container plants}).

Longitudinal Peaked Stone Toe Protection {installed 1977, picture taken Sept 2003} at Batapan Bogue, Grenada, MS.

LPSTP has launched as intended (note steep angle of repose), armored the scour hole as expected, & mature vegetation is assisting with overall bank stability

A bank protection project should start & end in stable (usually depositional) areas.


FEMME CREEK, ST. LOUIS AREA, MO.
Protection starts late & ends early, resulting in erosion at both ends of project

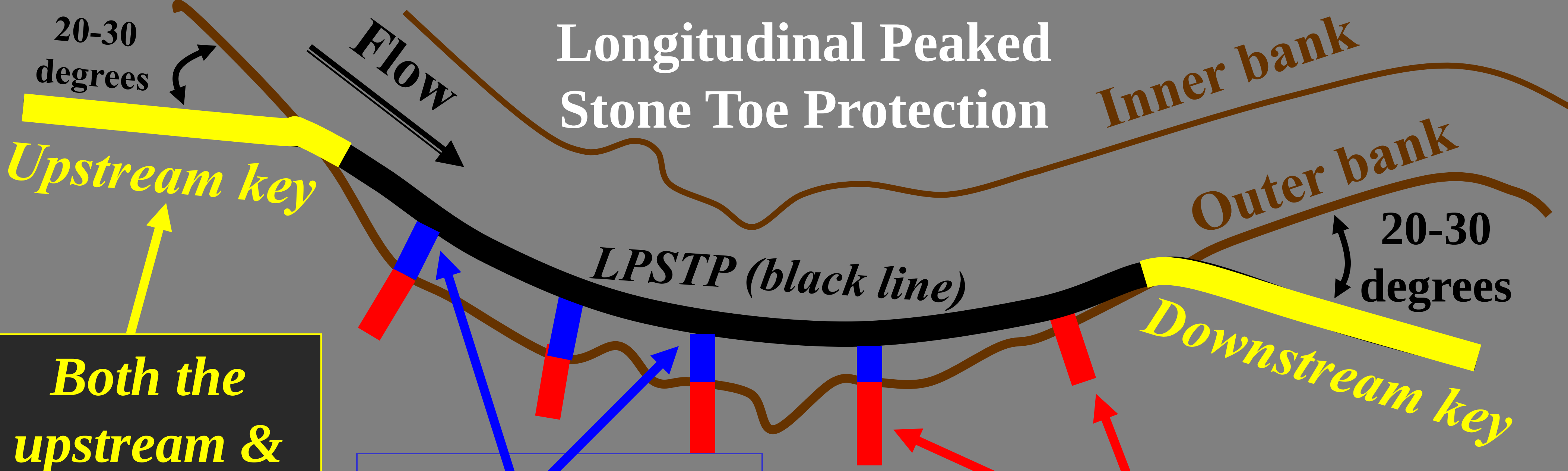
KEY ALL STRUCTURES INTO THE BANK

Flanked perpendicular grade control structure. Water should be flowing over this structure.

9 Mile Run - April 2007

A key has one main function: to connect bank protection (or a river training structure) to the rest of the world, & not let the river "flank" (get behind) the improvement or protection works.

Longitudinal Peaked Stone Toe Protection



Both the upstream & downstream keys should be angled 20 to 30 degrees to high flow. All keys are vegetated and soil choked

Tie-backs (blue lines) will connect the LPSTP to the key. The key, sometimes called the key root, is dug into the bank.

Mid-project keys (red lines) are perpendicular to high flow & connect the tie-back to the bank

Key design for continuous bank protection, modified from: www.E-SenSS.com

On the landward end (away from the stream), all keys need to tie into roughness, or a higher elevation, or hopefully both!! Elevation can be determined by flow (Q-10, Q-100, etc.)

Looking US on Harland Creek, Tchula, MS at smooth LPSTP (1.5 tons/ft) with correctly angled downstream key with deposition (free bank protection) right where the photographer is standing. Installed Aug 1993.

The key itself should be heavily vegetated with adventitious rooting poles or rooted stock plants so as to slow velocities over the key. Slow water on the overbank means less chance of flanking. Vegetation is designed to act like a Living Dike & can be closely spaced adventitious rooting poles, or rooted stock plants, or both. In some cases the length of the key can be extended with vegetation alone.

The upstream key on Chenunda Creek, Wellsville NY. The key is angled 30 degrees to dominant (high) flow. This same angle should be used for the downstream key.

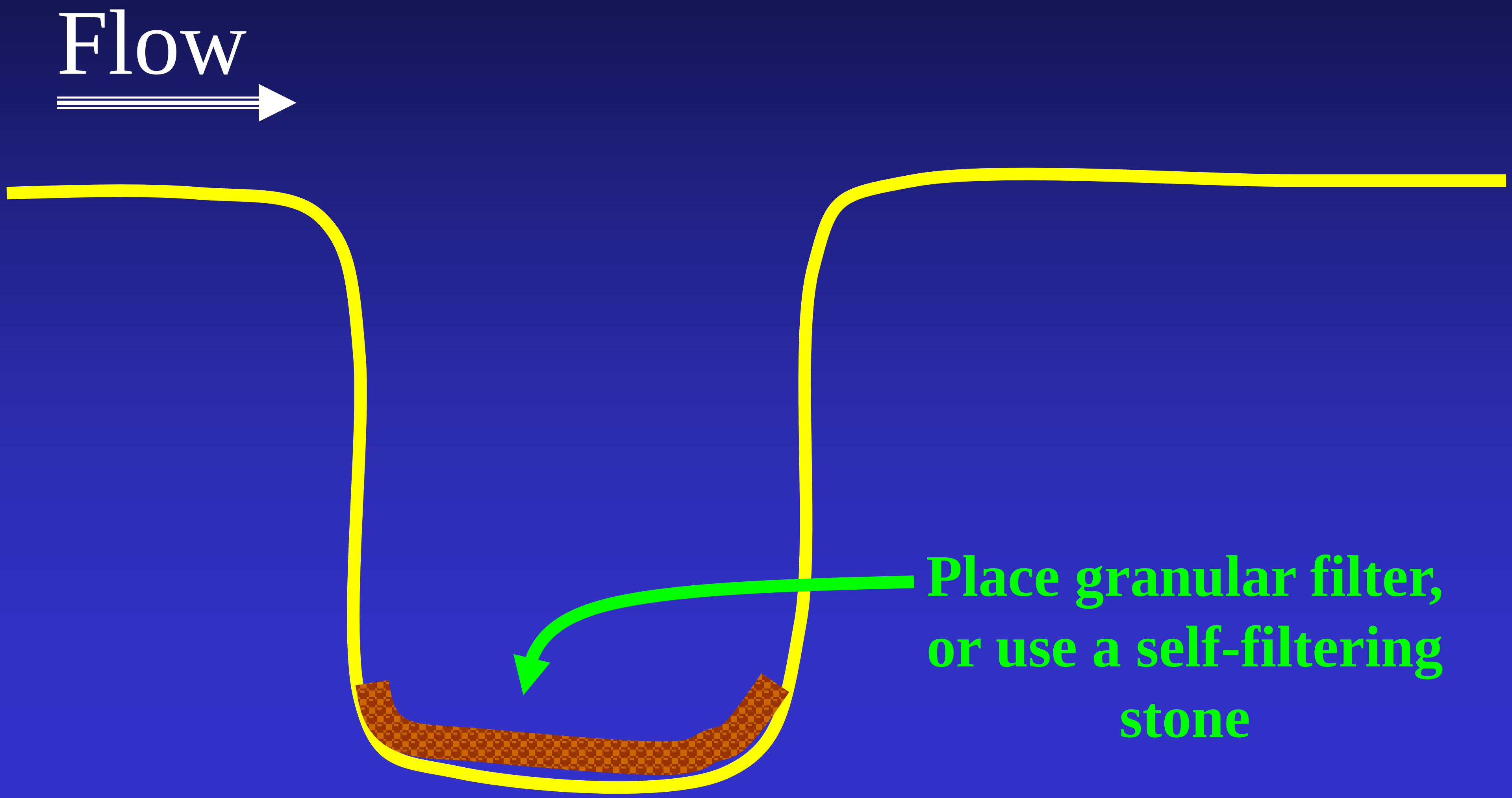
Construction 9/20/2006. Looking at angle of key to stream flow. More stone will be added & then soil choked so the landowner can grow a lawn.

Dump truck load level full of Sandbar & Streamco Willow, & Ruby Red osier dogwood, (1,500 poles total).

A MID-PROJECT KEY ON CHENUNDA CREEK

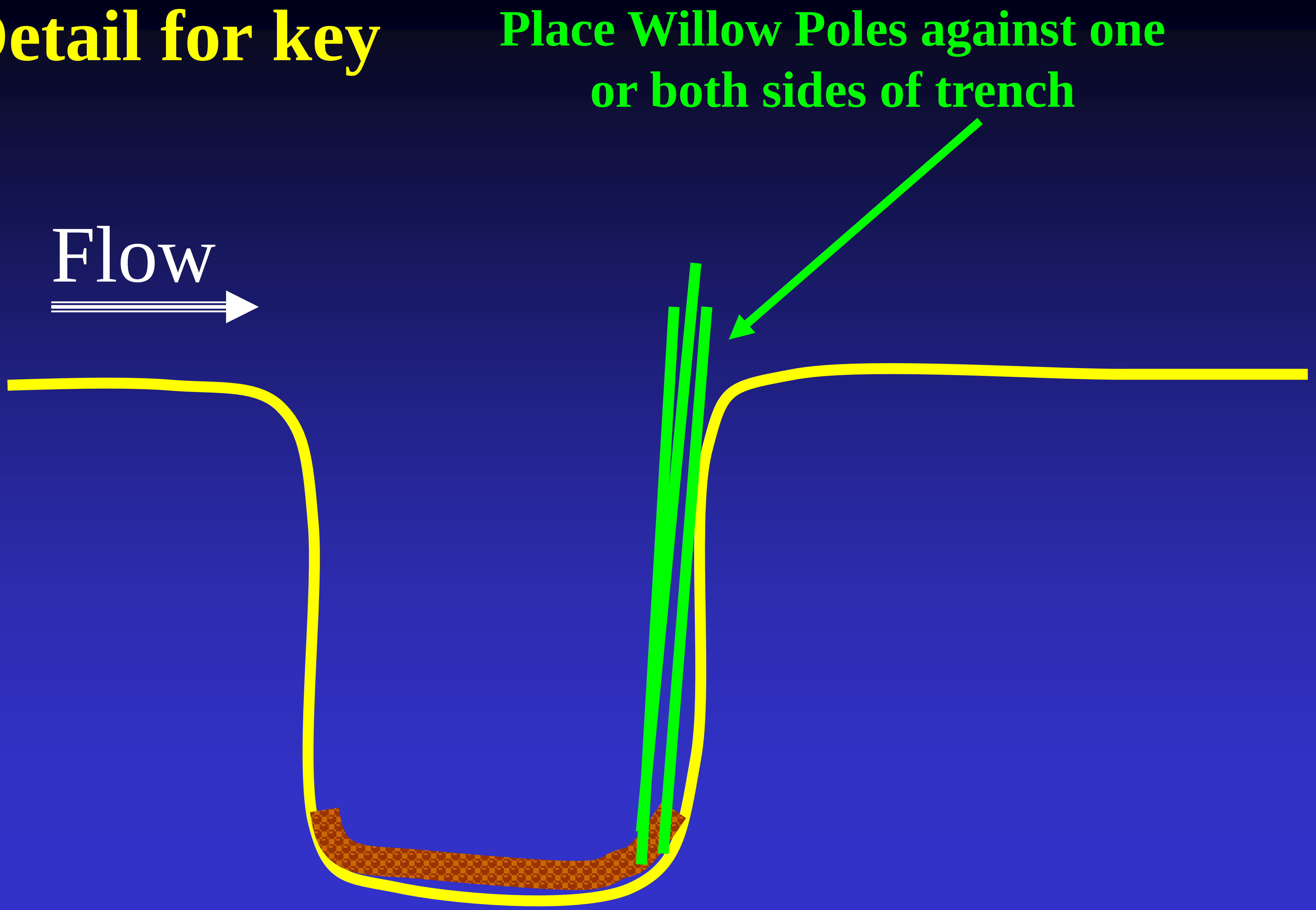
Vegetated & soil-choked stone key is perpendicular to high flow (& the bank)

Detail for key



VEGETATE THE KEYS TO MAKE THEM HYDRAULICALLY ROUGHER

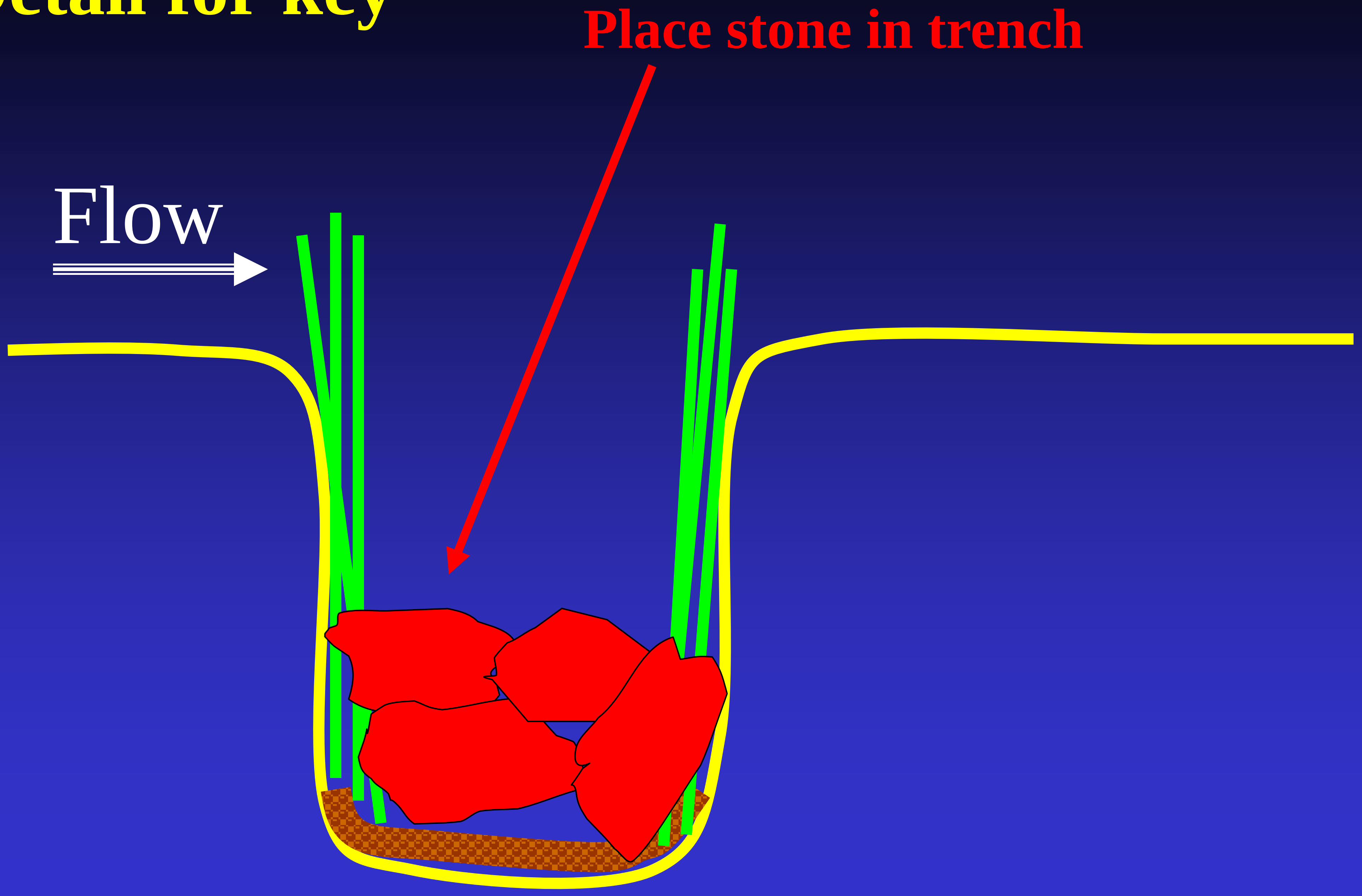
Detail for key



Construction 9/19/2006. Digging a mid-project key perpendicular to the bank. Some veg (willow poles) in place

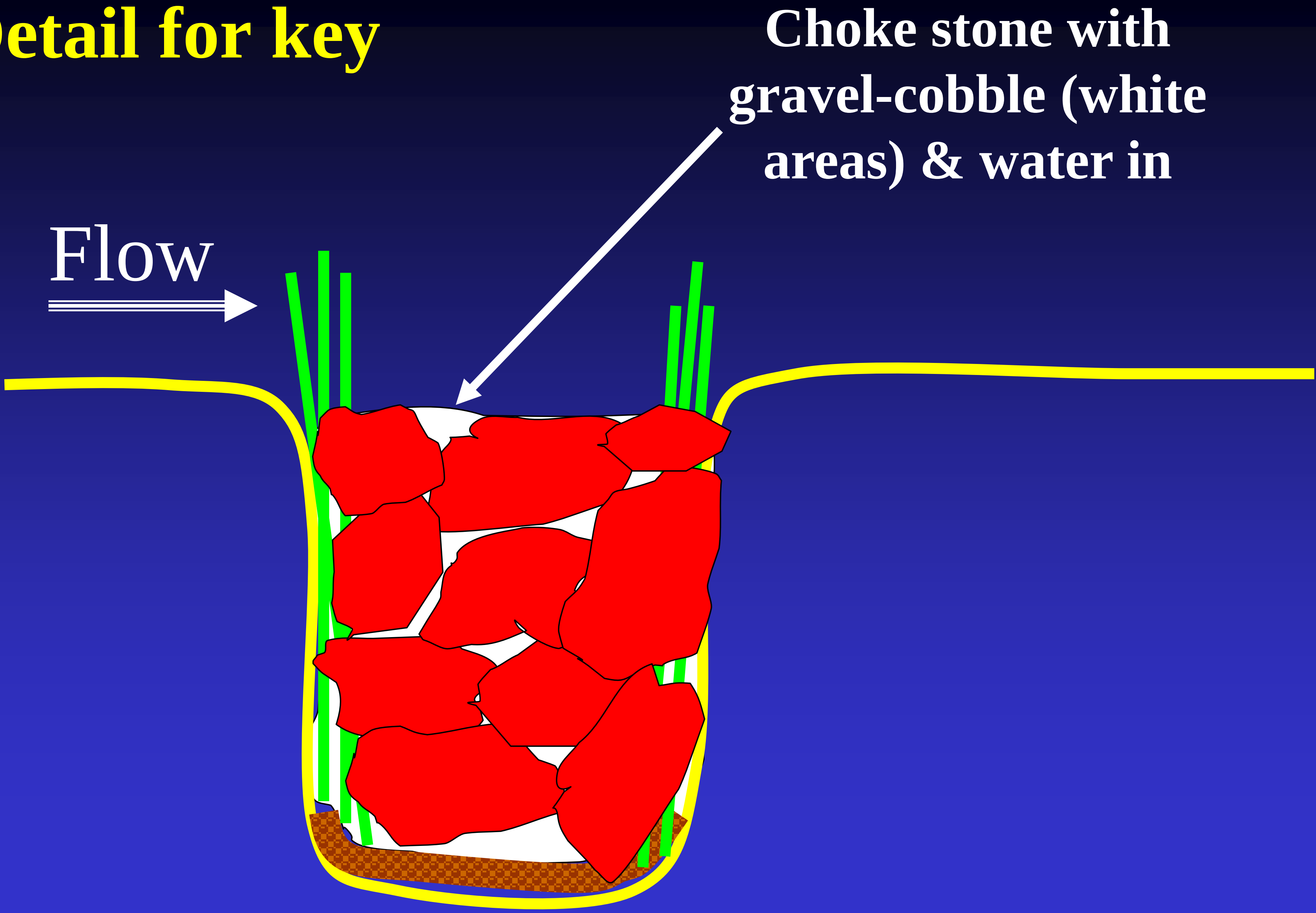
Pix by Derrick

Detail for key



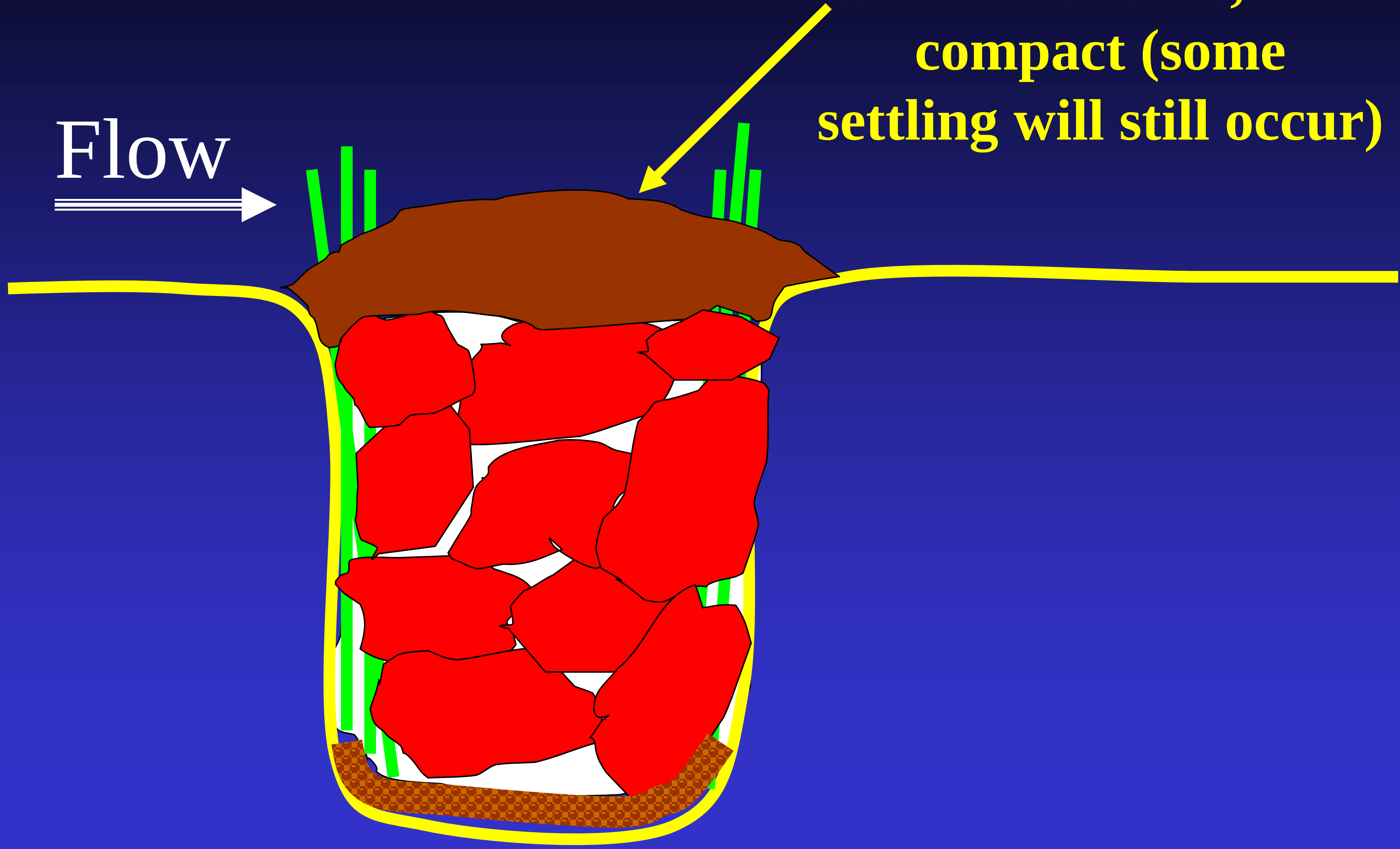
Construction 9/19/2006. Looking at key. Butt ends of willow & dogwood poles down deep.

Detail for key



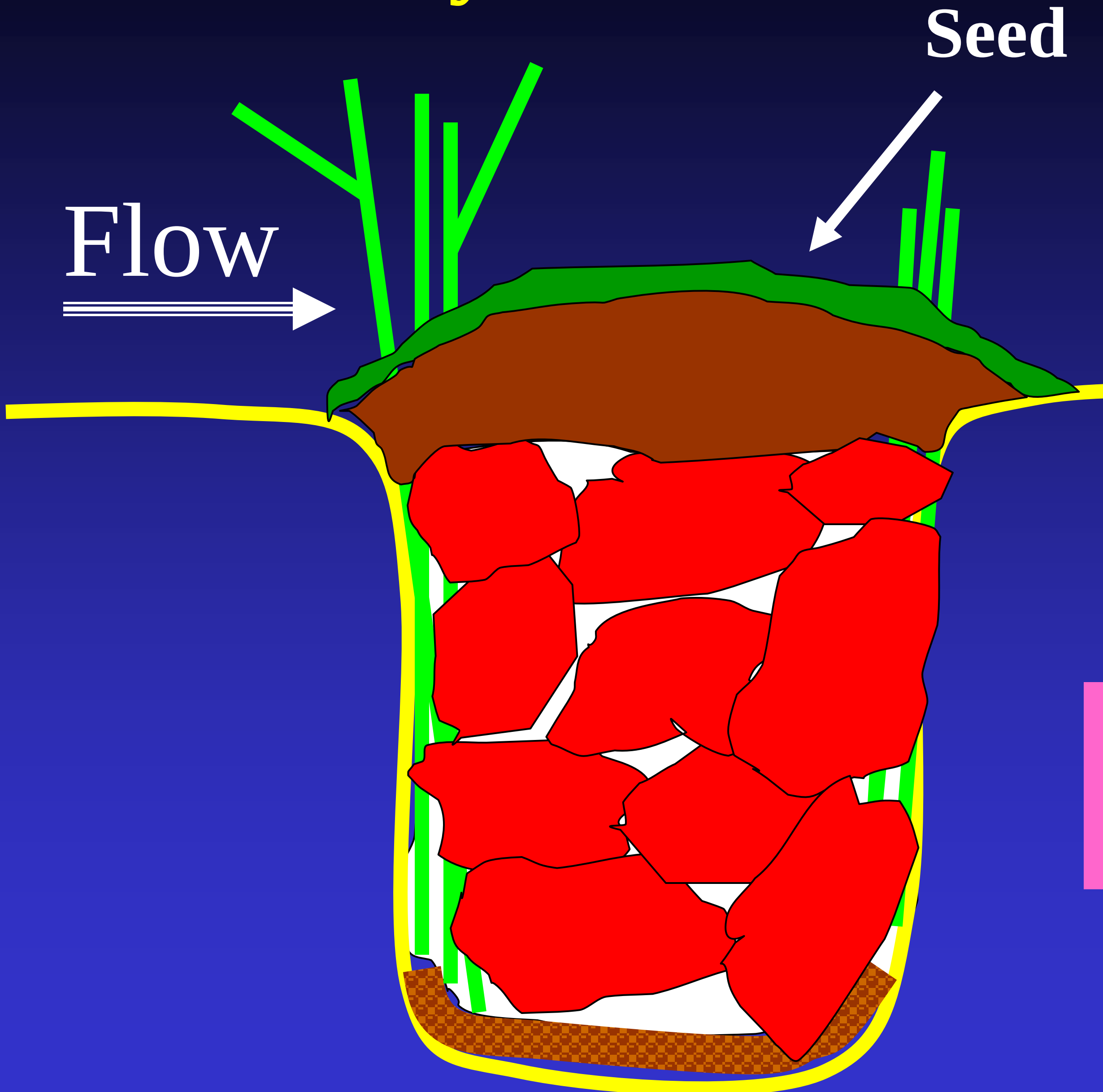
Detail for key

Backfill and overfill with native soils, then compact (some settling will still occur)



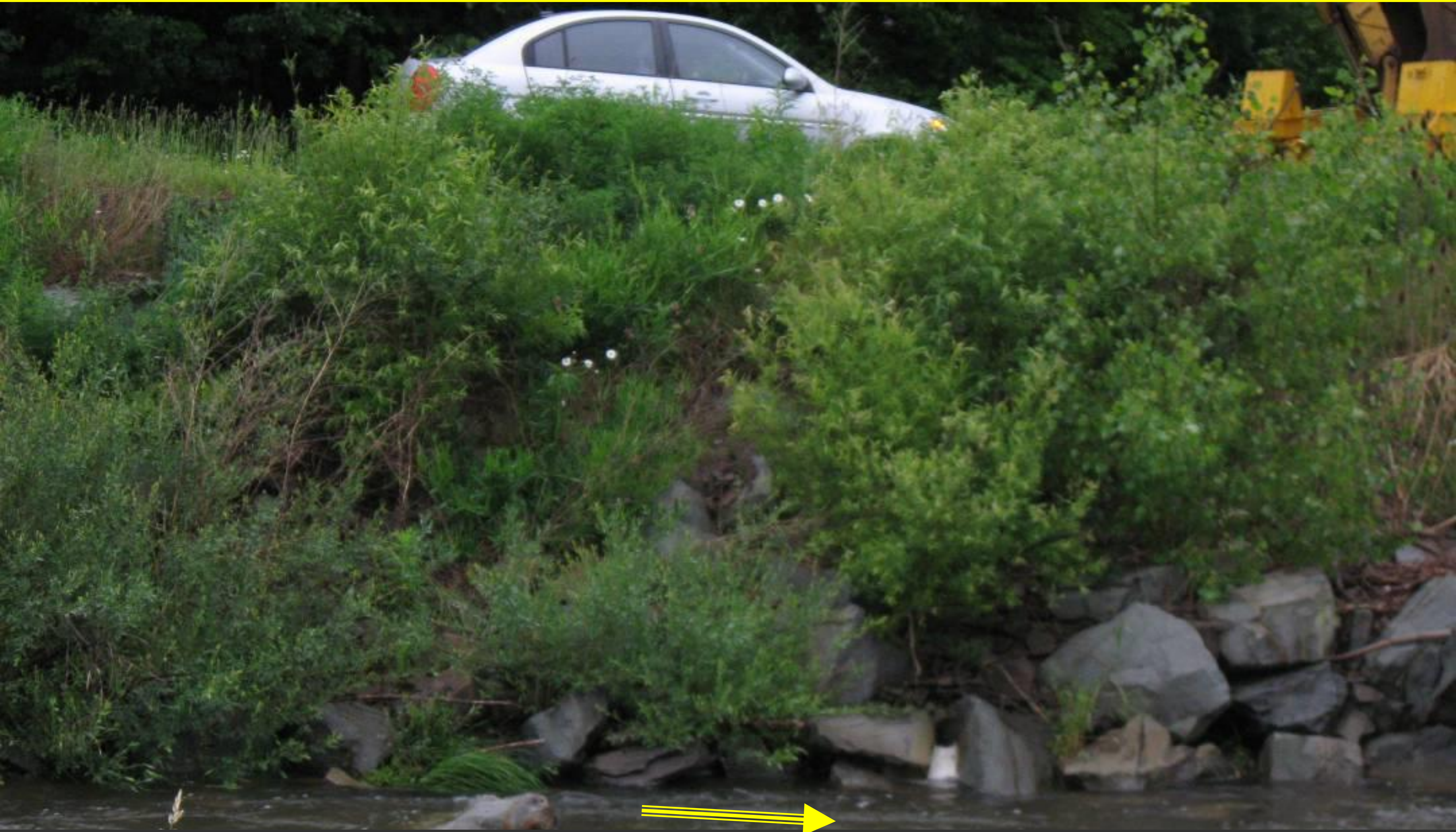
Construction 9/21/2006. Key stone is now soil-choked.

Detail for key



DONE

2.75 YEARS LATER-Lush growth from unrooted poles on mid-project key.



2 YEARS 9 MONTHS AFTER CONSTRUCTION-CHENUNDA CR.-DERRICK 6-18-09

DESIGN CONSIDERATIONS FOR LPSTP KEYS

- LPSTP must be deeply keyed into the bank at both the upstream and downstream ends and at regular intervals along its entire length. Charlie Elliott's spacing rules-of-thumb for keys in flat-sloped sand bed water bodies: 50 to 100 ft intervals on smaller streams, 1 to 2 bankfull widths on larger waterways.
- Keys at the upstream and downstream ends of LPSTP should not be at a 90 degree angle to the LPSTP structure, but at 20 to 30 degrees to HIGH FLOW.
- Keys should go far enough back into the river bank so river migration will not flank the key and the LPSTP.
- Keys should be vegetated if possible. Key length can be extended with vegetation in some cases.
- Volume of material per ft of key should equal or exceed the volume of material per ft in the LPSTP
- Minimum key width should be two times the D-100 of the stone used

LSTP - CHAPTER 4:

Filters

7 year old riprap without filter fabric allows for natural plant colonization. Spring River, AR

Arkansas

Filter fabric could prove problematic with over-launching of stone (shown), interferes with root architecture, plus roots can “run” on filter & open up overlaps

Thoughts on Filters

A filter has at least three tasks: prevent loss of underlying fine bank materials due to piping, extrusion, or erosion; allow water to drain from the bank thus preventing the buildup of excessive hydrostatic pressure; and to prevent bank stabilization materials from sinking into the underlying substrate. A trained soil scientist, geologist, and/or geotechnical engineer is needed to perform an analysis of the stability and erodability of bank materials and determine what, or if any filter is required.

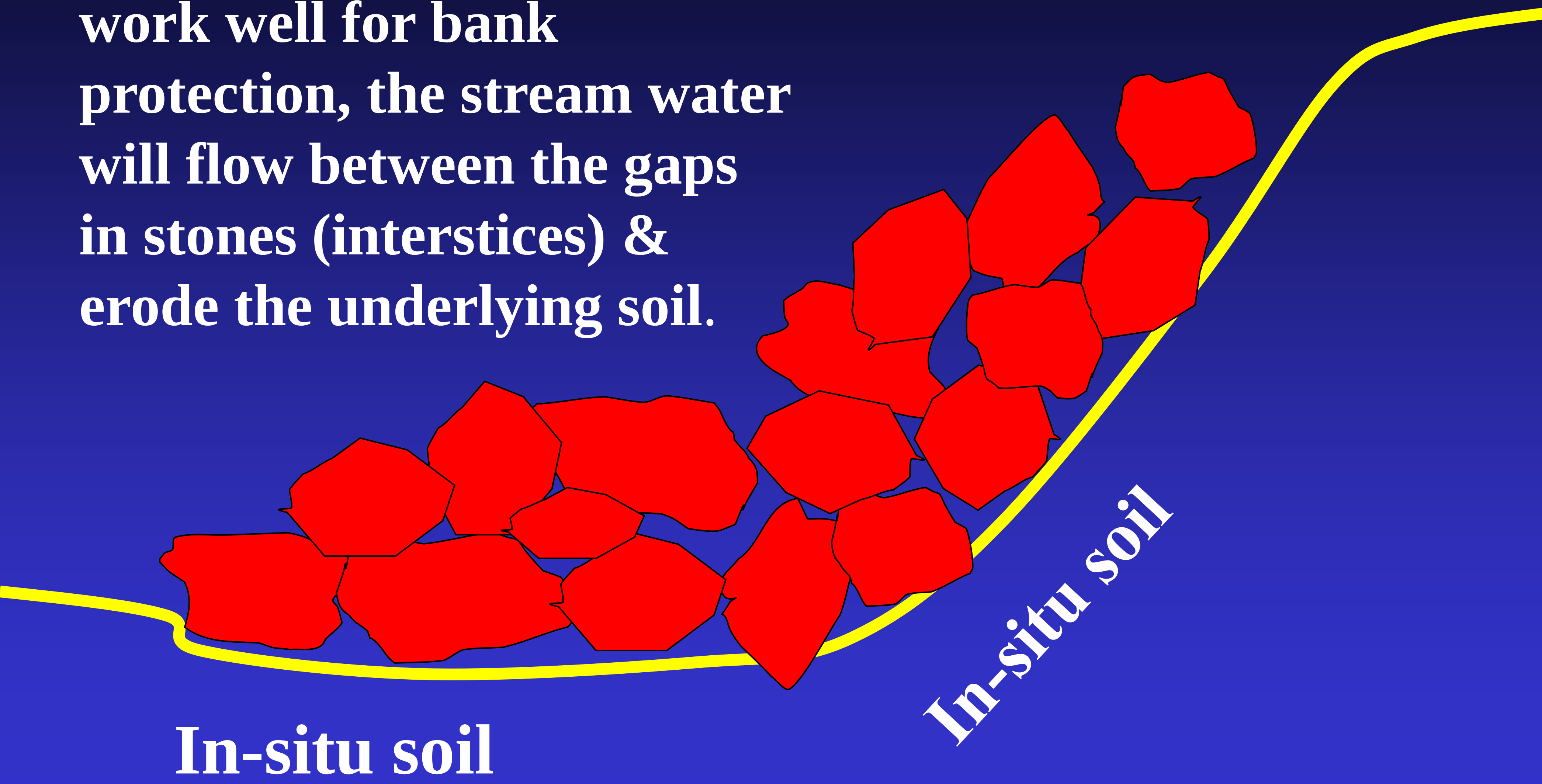
Different Types of Filters

- Self-filtering stone - Designed with a specific gradation that has a component that acts as a granular filter. Typically 10% to 15% of the gradation is either less than 4 inches in diameter, or less than one pound in weight, depending on how the stone is specified. When placed on-site the smaller stones fall through the interstices and cover the substrate, essentially acting as a granular filter.
- Granular filters - Progressively larger diameter layers of (possibly) sands, gravels, and/or rock.
- Geotextile filters: **Non-Woven -** has a thickness, similar in appearance to felt, dull finish, fibers can be seen but don't form a pattern.
- Geotextile filters: **Woven -** slick and shiny, has a discernable weave (a pattern similar to a cotton shirt), designed with a specific size of opening to allow the passage of water, but not the underlying bank material. When looking through a section of used filter light should be visible. If no light can be seen the filter has been "blinded", in other words the filter has been clogged by the bank material. It can also be blinded by deposition from the stream side.
- Is a filter needed?? - gravels, cobbles, bedrock and some clays usually do not require a filter. Always always consult with a learned geotechnical expert!!!

FILTER TYPES, & THE FOLLY OF BIG STONE BY ITSELF

No filter with large stone

Big stones alone will not work well for bank protection, the stream water will flow between the gaps in stones (interstices) & erode the underlying soil.



Large stone as bridge protection. Voids will allow water to flow through & under stone protection. No filter size stone

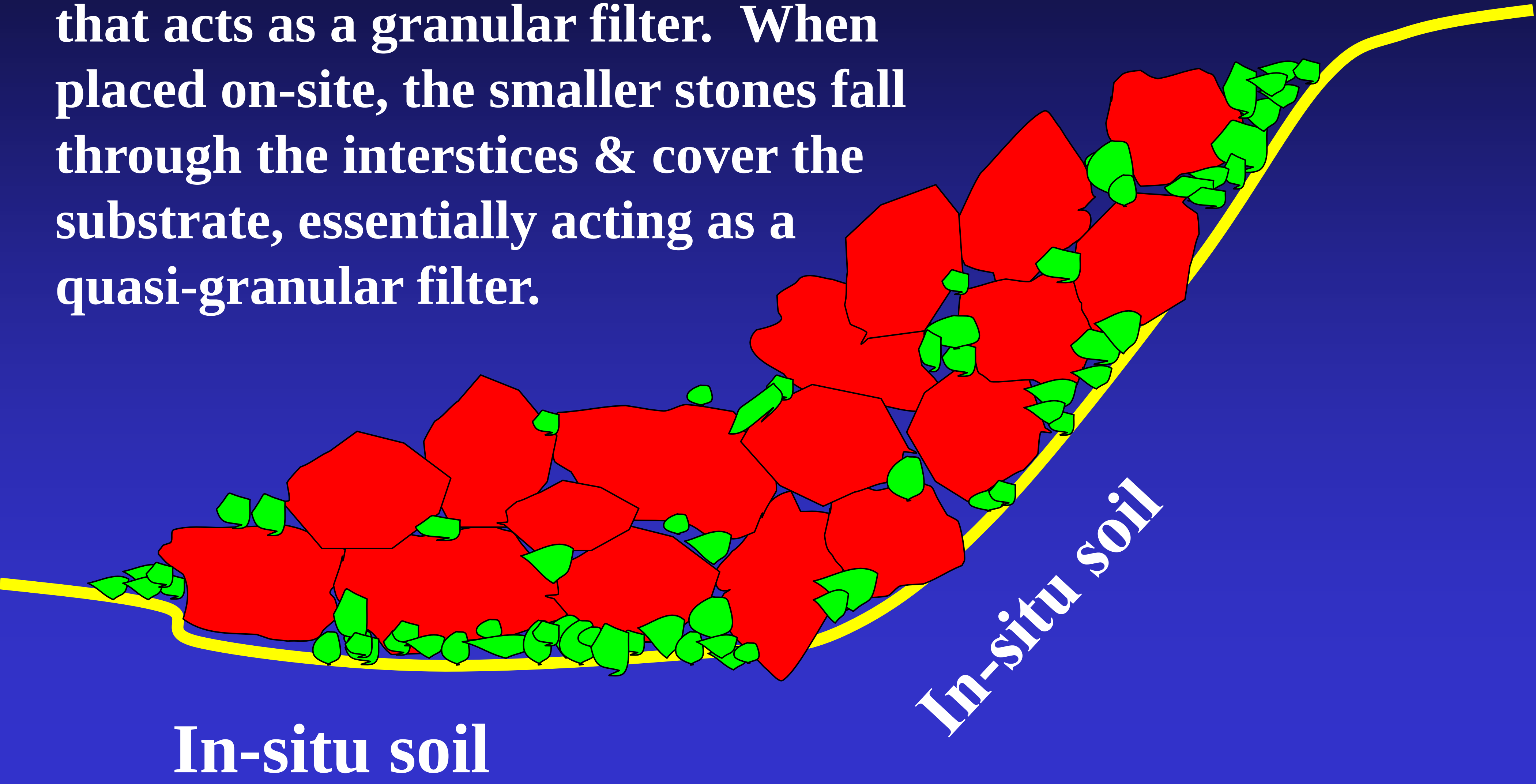
BIG DITCH – OREGON, OHIO - DERRICK 11-30-2011

Geotextile filter – can be woven or non-woven

Geotextile filter provides a barrier between stream forces & in-situ bed & bank materials, it should allow groundwater passage, & provide a foundation for protection materials.

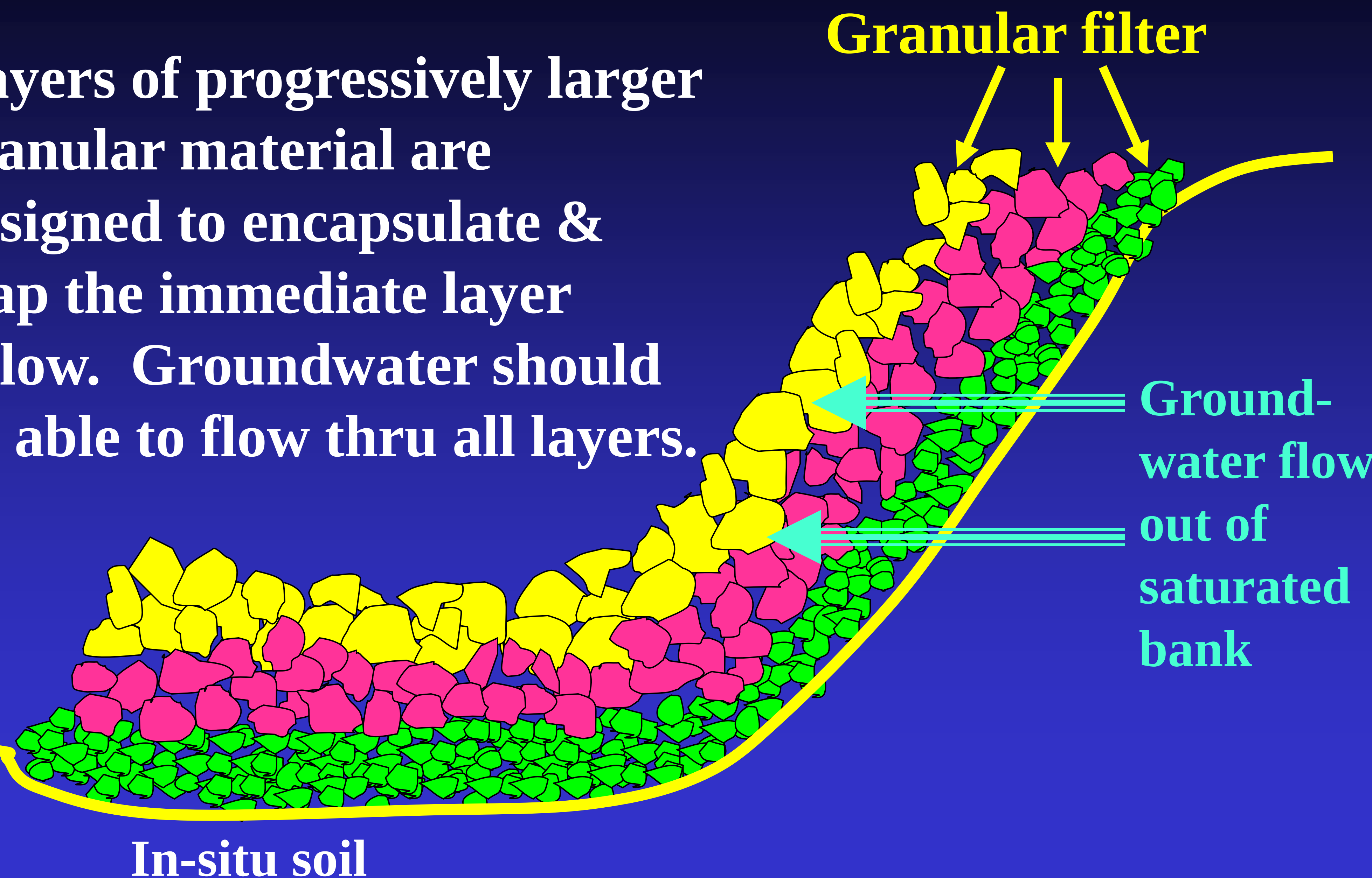
Concept behind Self-Filtering Stone

Stone gradation has a component that acts as a granular filter. When placed on-site, the smaller stones fall through the interstices & cover the substrate, essentially acting as a quasi-granular filter.



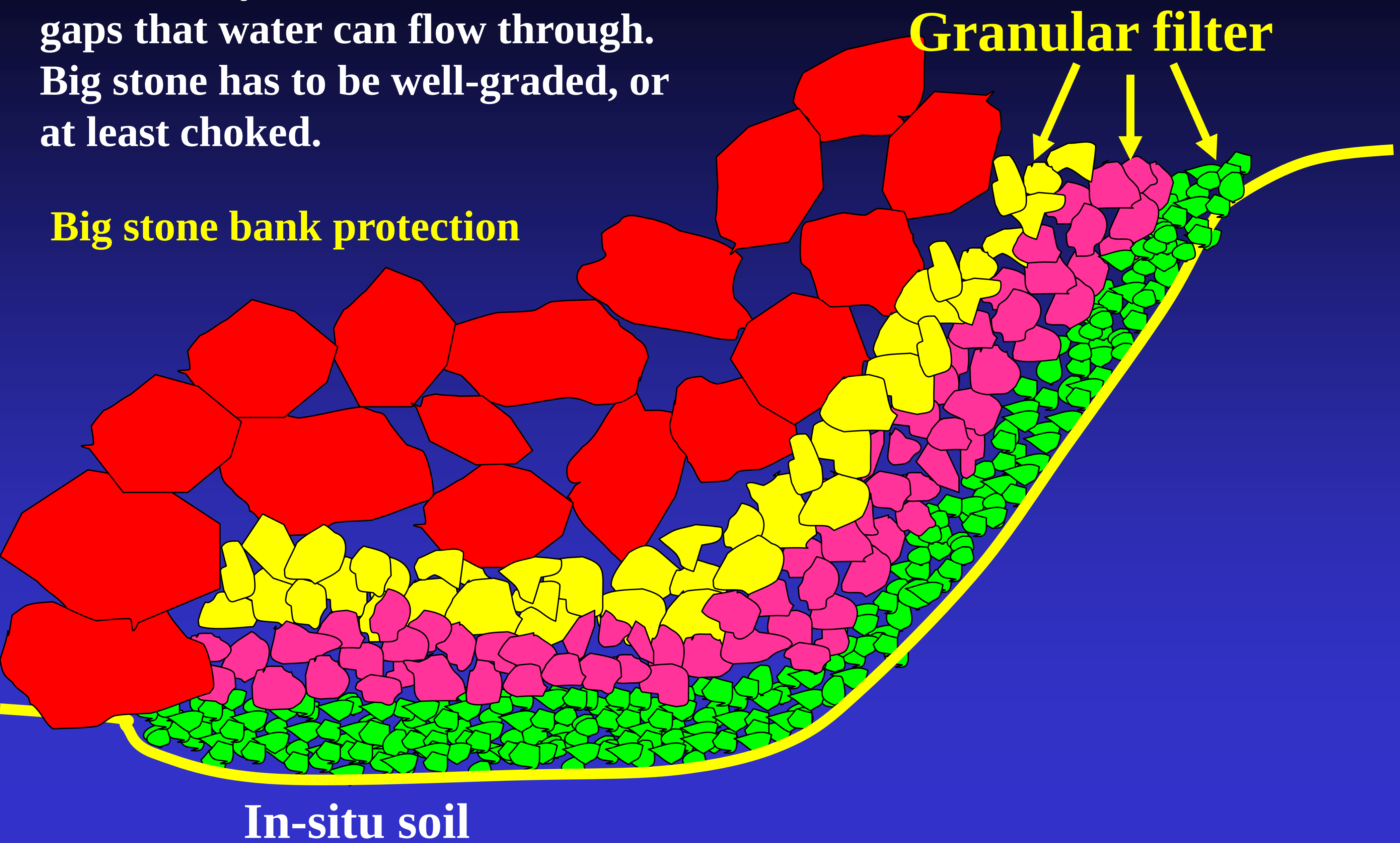
Concept behind a granular filter

Layers of progressively larger granular material are designed to encapsulate & trap the immediate layer below. Groundwater should be able to flow thru all layers.



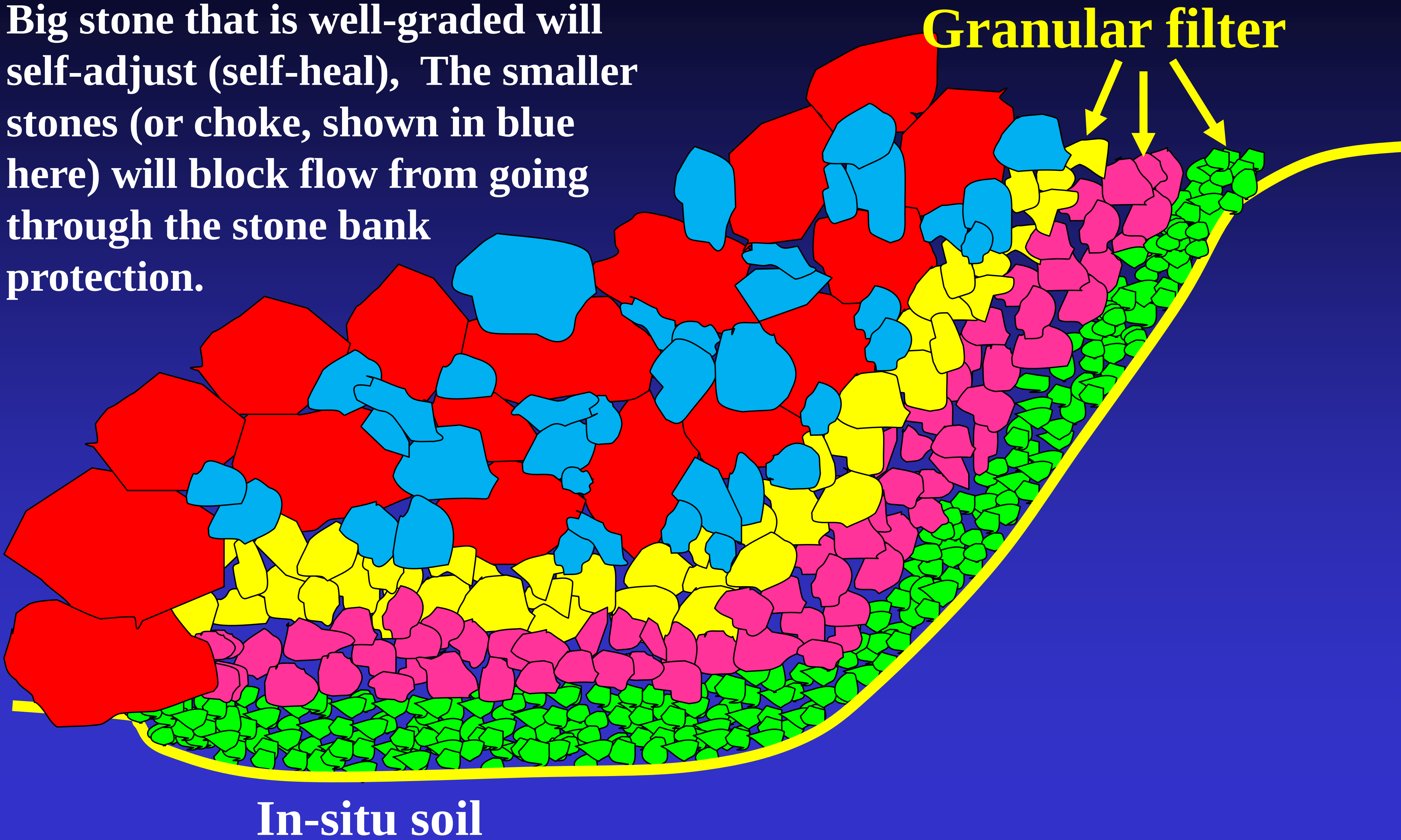
Big stone protection

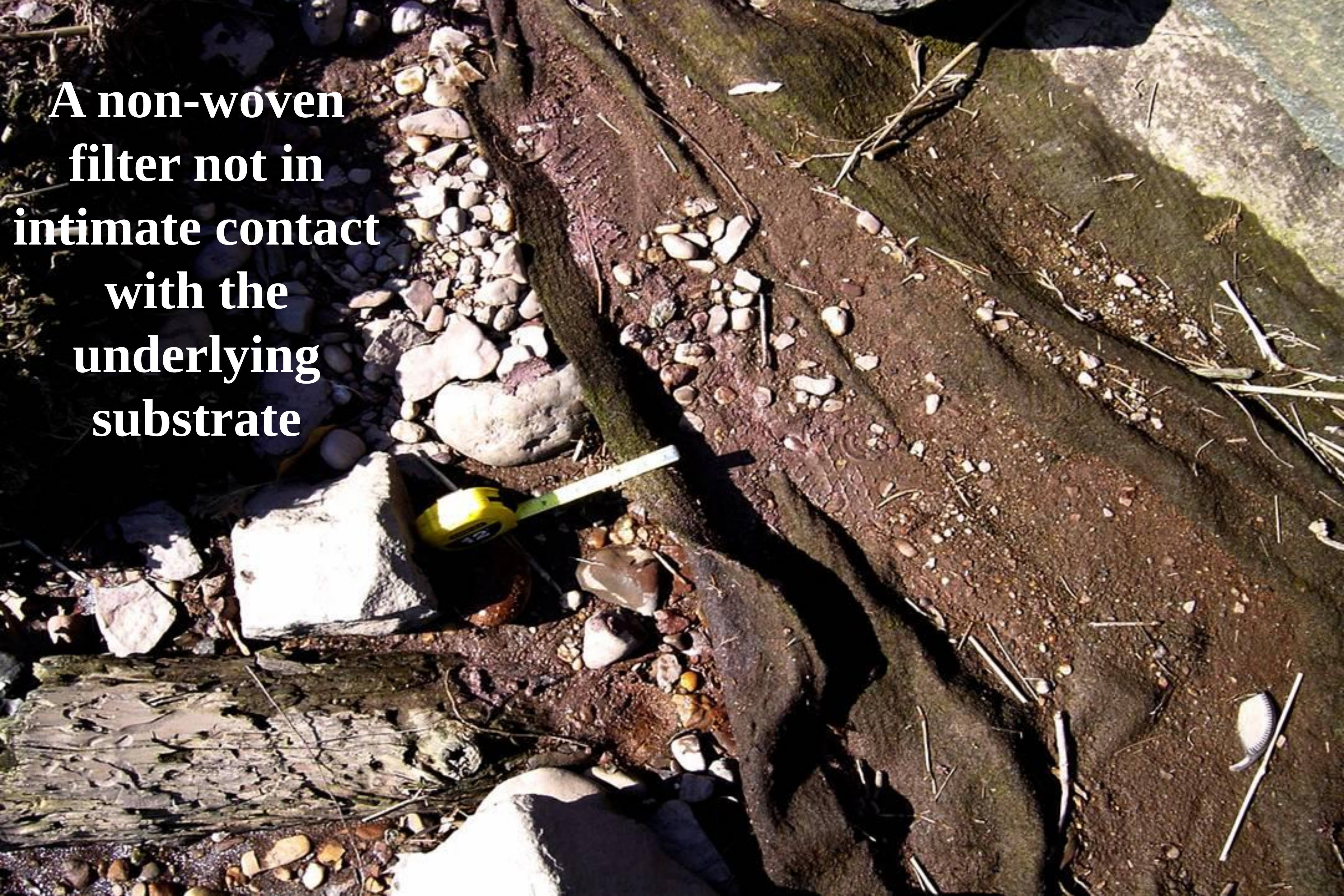
Big stone is not the answer & does not work by itself. Look at all the gaps that water can flow through. Big stone has to be well-graded, or at least choked.



Big stone protection with choke stone

Big stone that is well-graded will self-adjust (self-heal), The smaller stones (or choke, shown in blue here) will block flow from going through the stone bank protection.




A non-woven filter not in intimate contact with the underlying substrate

Woven filter, not blinded, sunshine visible through weave. Woven filters can sometimes be blinded from either the river or bank side

LSTP - CHAPTER 5:

Stone

Self-Adjusting, Self-Filtering Stone

Depending on size, angularity, and gradation, stone can be neither, either, or both!!

- **Self-Adjusting Stone:**

  Stone must be well-graded (from coarse to fine) so that it has the ability to "launch", or self-adjust into, and armor, scour holes formed on the streamward side, and/or stream end, of a river training structure.

  Charlie Elliott says a good rule of thumb in Mississippi sand-bed streams {CAUTION: this might not apply equally well to every stream in the world} is that one ton of rock per linear ft will armor approximately three ft of scour

- **Self-Filtering Stone**

  A soil analysis should always be performed to determine stability and erodability of bank materials and whether a filter material, (either granular or synthetic) is required.

  A self-filtering stone that has worked well on the Mississippi River, and numerous other rivers and smaller streams (acting as a granular filter to prevent loss of underlying bank material) has 10% to 15% of the gradation either less that 4 inches in diameter, or less than one pound in weight, depending on how the stone is specified.

An ugly pile of rock!! Median of I-220, Jackson MS. Self filtering, in fact too many fines, but steep angle of repose shows that stone will not self-adjust. This is due to the lack of medium-sized stone (stone is not well graded).

Analyze gradation, amount of “fines”, look at pile side slopes (flatter is better). Climb the pile, if it moves that is the stone you need. This is well graded stone, note flat angle of pile

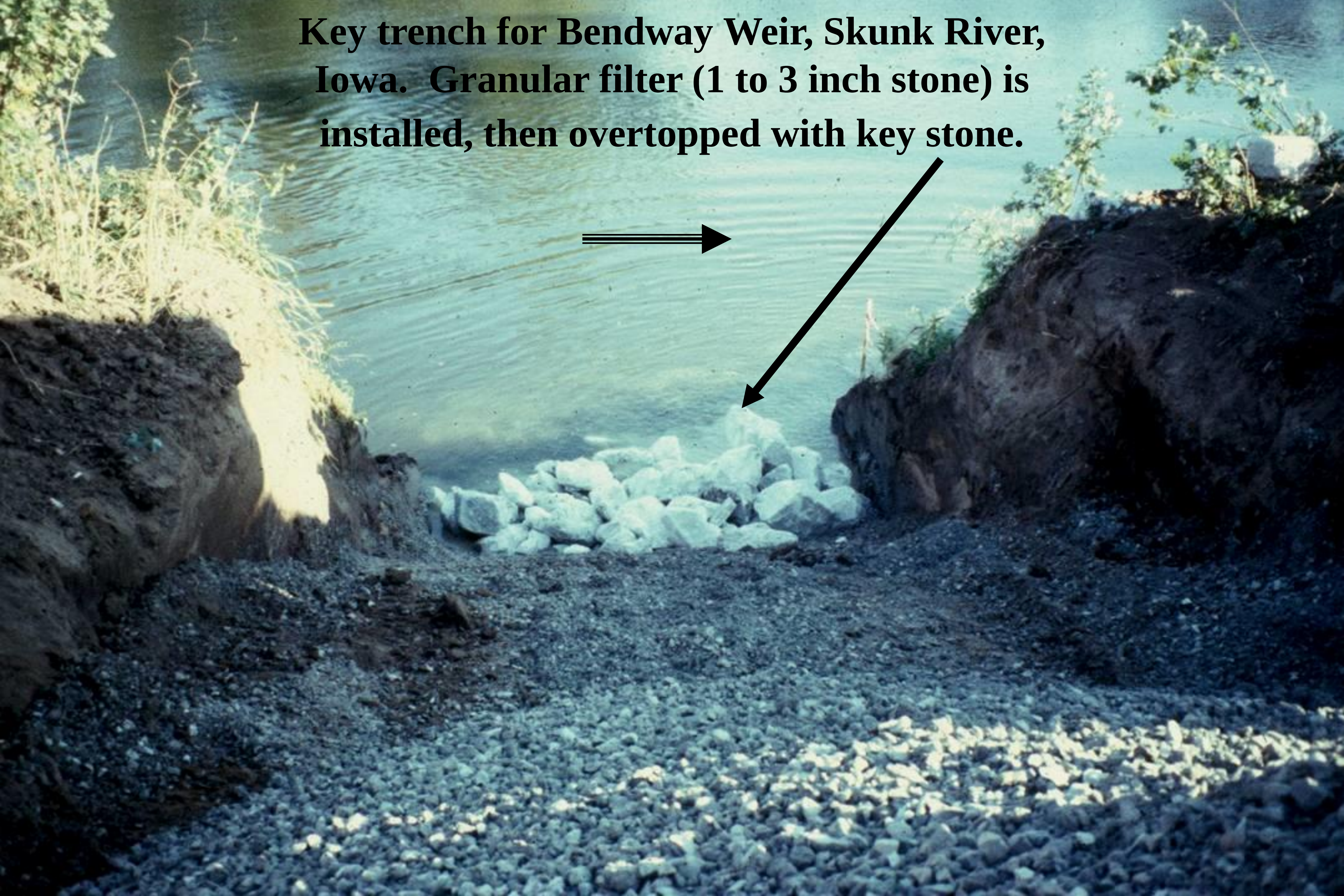
Medina Quarry, TX.

Blocky rock will not adjust, but can be used in interesting ways, including end-to end compression, or in a stacked configuration.

Better looking stone, note flat pile, Medina Quarry, TX. We mixed the two piles of stone from the previous picture to come up with a well-graded stone that will self-adjust.


Eudora bend, Kansas River, KS. End dumping like this will sort out even a well-graded stone!! Don’t do this!!

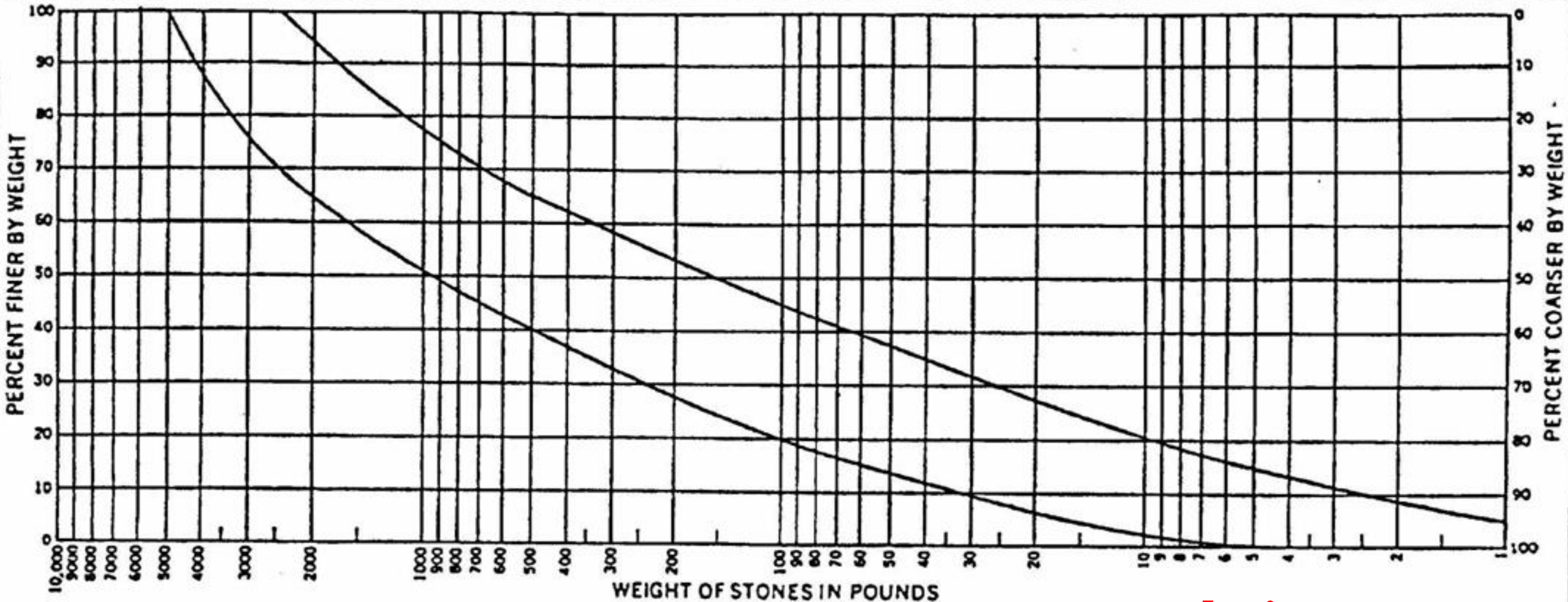
Well-graded stone, but few fines, for Skunk River project, Denmark, IA. To effectively use this stone we installed a granular filter of 1 to 3 inch stone, then installed this stone.


Key trench for Bendway Weir, Skunk River, Iowa. Granular filter (1 to 3 inch stone) is installed, then overtopped with key stone.

A SHORT TALK ABOUT ROCK

- QUARRIES - distance from project, quality of rock, price, ability to deliver amount of rock needed (14 to 16 tons per truckload for tandem axle trucks is typical)
- COMPOSITION - granite, limestone, basalt, dolomite, sandstone, etc.
- HARDNESS - varies from quarry to quarry and sometimes within the quarry
- SHAPE & SIZE - block shaped rocks will lock together, look at the shape of the pile of rock at the quarry, climb the pile to see how well rocks will roll downhill, measure for size (B-axis) and visually access gradation, compare quarry's gradation curves to standard gradation curves.
- GRADATION - well graded (poorly sorted) is best (largest, then smaller, smaller, smallest with the fine component that will work as a granular filter)
- WEIGHT - varies, for limestone 1.5 tons per cubic yard is good for estimation purposes (115 lbs/cu. ft.)
- VOLUME ESTIMATES - estimate amount needed, then add 10 to 15 percent
- SPECIFICATIONS - Can be "made" to custom specifications or to common specs
  HAUL RATES - Stone weighing over 400 pounds must be transported in steel bodied trucks, or a "bedding layer" of gravel is placed in aluminum bodied trucks. Haul rates are usually multiplied 1.5 or 1.75 times the base haul rate.
- WEATHERING - look for examples in the quarry &/or local stream or highway projects, check rocks lining the entrance to the quarry

Differential weathering turning big stone to gravel, Dome Pipeline Crossing, Minnesota River, Mankato, MN



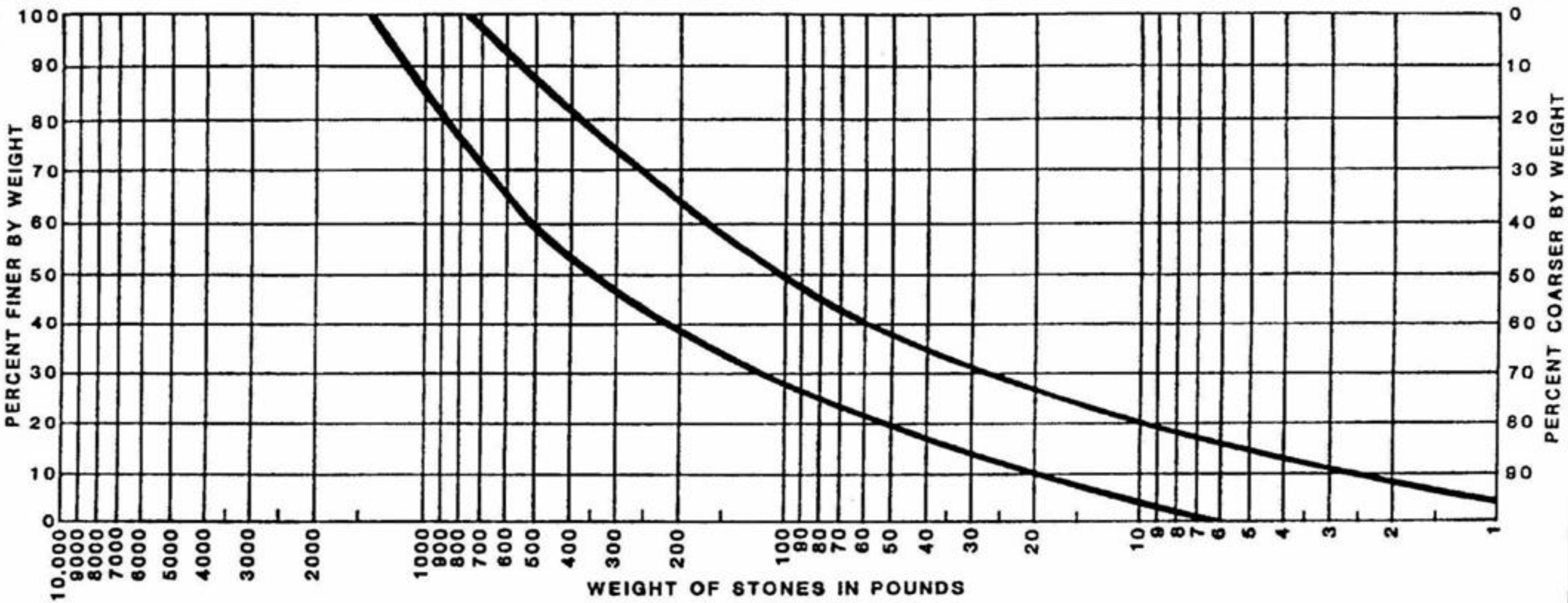
Gradation curves courtesy of Vicksburg District, COE

STONE WEIGHT (LBS)	CUMULATIVE % FINER BY WEIGHT
5000	100
2500	70-100
500	40-65
100	20-45
5	0-15
1	0-5

* ASSUMING STONE SHAPE MIDWAY BETWEEN A SPHERE AND CUBE

U.S ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS
VICKSBURG MISSISSIPPI

GRADATION
GRADED STONE A



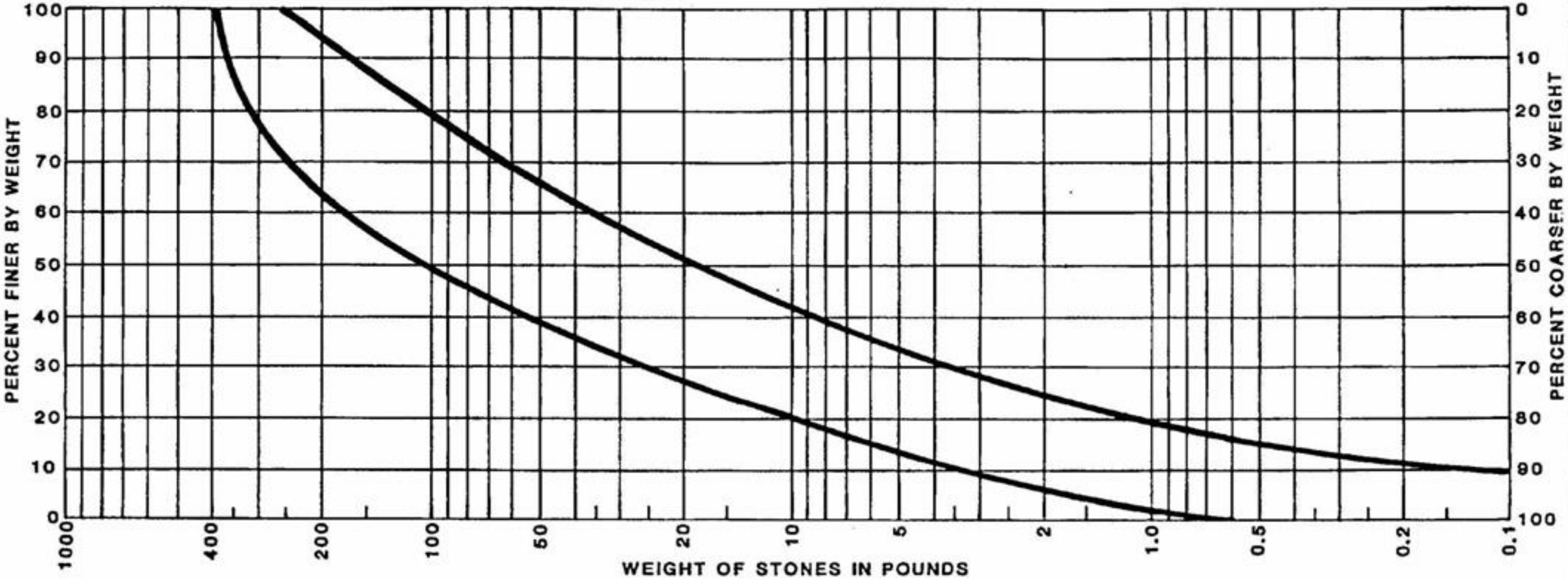
STONE WEIGHT POUNDS	CUMULATIVE % FINER BY WEIGHT
1200	100
750	72–100
200	40–65
50	20–38
10	5–22
5	0–15
1	0–5

GRADATION

GRADED STONE B

MAY 1975

Gradation curves courtesy of Vicksburg District, COE



STONE WEIGHT POUNDS	CUMULATIVE % FINER BY WEIGHT
400	100
250	70-100
100	50-80
30	32-58
5	15-34
1	2-20
less than 1/2" max. dimension	0-10

NOTE: 5% of the material can weigh more than 400 pounds. However no piece shall weigh more than 500 pounds.

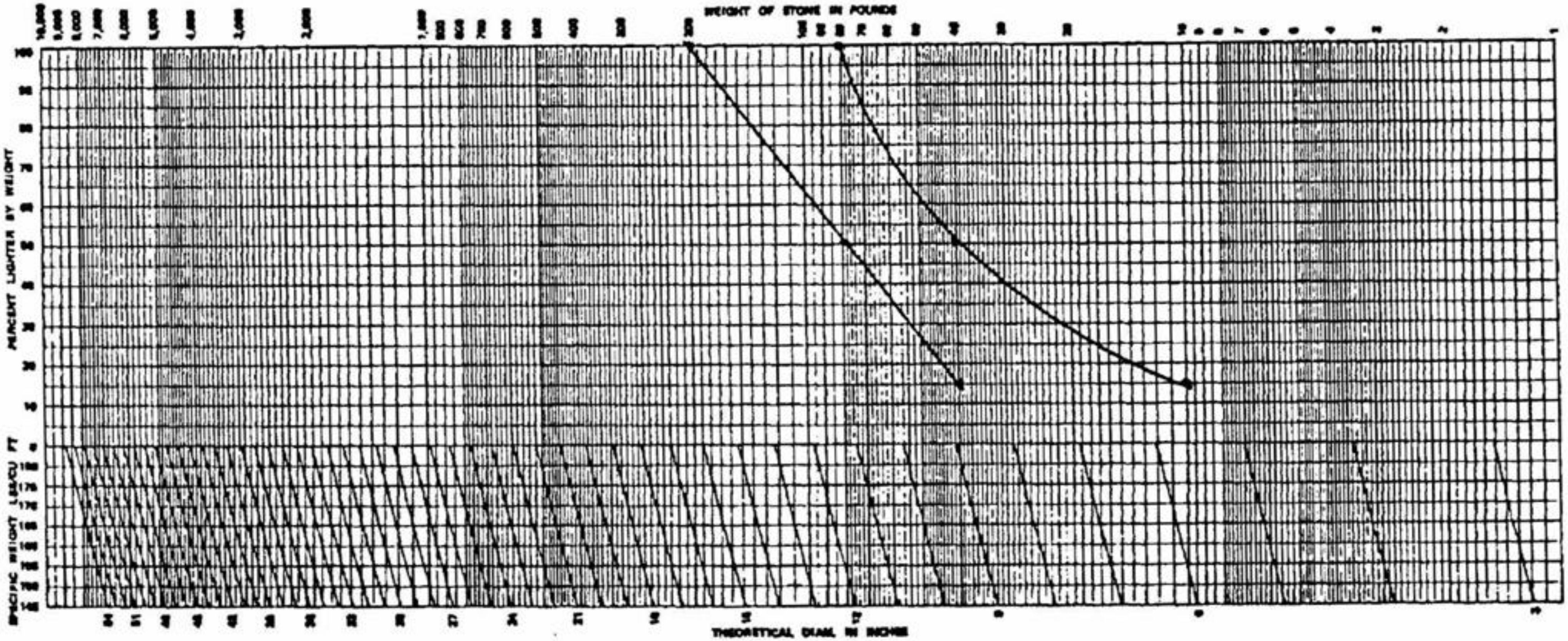
Gradation curves courtesy of Vicksburg District, COE

GRADATION

GRADED STONE C

SEPTEMBER 1976

Gradation curves courtesy of Vicksburg District, COE



"R 200"

SPECIFIC WEIGHT OF STONE ________ LBS/CU FT

PROJECT ______________________

AREA ______________________

DATE ________ BY ______________

RIPRAP GRADATION CURVES

BEDLOAD=CONSTRUCTION STONE=TROUBLE, ARKANSAS

"SHOT ROCK"

(Also called “quarry run”, or ungraded stone)

- "Shot" rock, also called "quarry run" stone, is an ungraded stone blasted at the quarry with the only specification being a maximum (top) size or weight. No specific gradation, or amount of "fines" is specified.
- The amount of usable stone depends on the skill and knowledge of the blasting technician.

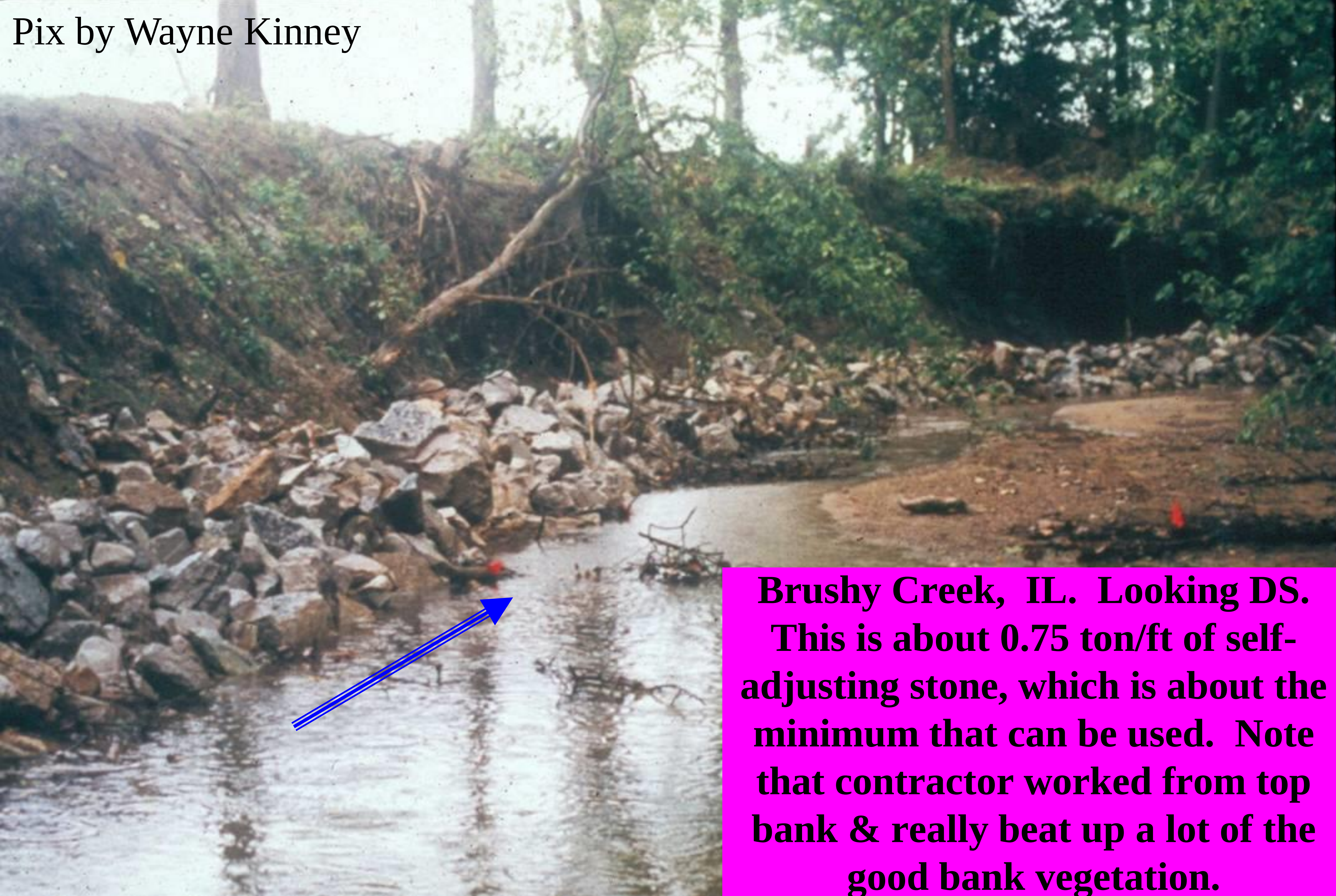
Advantages: Cheaper, usually close to 1/2 the cost of graded stone. The ungraded characteristics of the stone can result in increased void spaces (interstices), possibly providing within-channel refugia for aquatic species (especially juveniles).

Disadvantages: A truckload of rock might be all top size or dust. Inspector's knowledge/experience critical when deciding where, or if, a load of stone should be placed/used. Some material might be wasted. This stone is typically **NOT** self-adjusting. It might or might not be self-filtering and could vary by the truckload.


Gradation can be varied for environmental purposes
Hat for scale

LSTP - CHAPTER 6:

Minimal LPSTP



Pix by Wayne Kinney

Brushy Creek, IL. Looking DS. This is about 0.75 ton/ft of self-adjusting stone, which is about the minimum that can be used. Note that contractor worked from top bank & really beat up a lot of the good bank vegetation.

LSTP - CHAPTER 7:

Transitioning from LPSTP to full bank paving

Looking DS on Harland Cr. Tchula, MS, very smooth transition in the downstream direction from one ton/ft LPSTP to full bank paving

Design Rules-of-Thumb for LPSTP

(developed from experience in Mississippi on incised, relatively flat-sloped, sand bed streams)

- Dr. Dave Biedenharn recommends that if you have never used LPSTP in your area, get a designer with LPSTP experience to design your first project!
- If there is the opportunity to build a demonstration project do so. Either test different heights of LPSTP in a number of similar bends, or for testing in a single bend start at the upstream end with a reasonably tall 50 ft long section of LPSTP (take the amount of stone calculated from consideration #2 and add 4 ft to the height). Continue in the downstream direction reducing height in 1 ft increments until an unusually small amount of stone is used (3 ft below low-flow water surface elevation for example, or below the vegetation line if one exists). After a reasonable time and at least two flood or long-duration high-flow events the sections that failed will provide some guidance for the minimum effective crest height
- At this time, no specific design criteria exists that relates the crest elevation of LPSTP to the channel forming discharge, effective discharge, or dominant discharge.
- One ton of LPSTP/per lineal ft is approx. 3 ft tall (using limestone@110lbs/cu ft)
- Two tons/per lineal ft is approx. 5 ft tall (height calculations from Vicksburg Dist.)
- Three tons of LPSTP/per lineal ft is approx. 6 ft tall 7.5 tons is 9.5 ft tall
- Four tons of LPSTP/per lineal ft is approx. 7 ft tall 10 tons is 11 ft tall
- Six tons of LPSTP/per lineal ft is approx. 8.5 ft tall 14 tons is 13 ft tall

Design Rules-of-Thumb for LPSTP

(continued)

Maximum stone size and correct gradation can be generated using any of many available riprap sizing design programs (“ChanlPro”, WEST Consultants “RIPRAP”, etc.)

* Consideration #1: The minimum amount of stone that would have a launchable component to any degree, would be ½ to ¾ of a ton of stone per ft. The ½ ton/ft amount would provide a triangular section of stone approximately 2 ft tall.
* Consideration #2: Maximum scour depth in the bend should be numerically calculated, or estimated from field investigations (depths might be underestimated due to in-filling of scour holes during the falling side of the high-water hydrograph). Typically 1 ton of stone will protect against every 3 ft of scour. Amount of stone required to amour the estimated maximum scour depth should be calculated, and a factor of safety added. ** If scour is greater than 3 ft (as calculated in Consideration #2) then a Longitudinal Fill Stone Toe Protection (LFSTP) should be considered.

Design Rules-of-Thumb for LPSTP (continued)

* Consideration #3: If there is a vegetation line, the mature well-established section of the veg line should be analyzed, and if Considerations #1 and 2 are met, then the veg. line elevation would be the absolute minimum crest elevation. But, since plants immediately above the vegetation line are typically not very robust, and there is no factor of safety included, this minimum crest height should be increased at least 2 to 4 ft or more, dependant on situation.
- Consideration #4: The height of the bend's opposite bank pointbar bench should be analyzed. If the point bar bench height is taller than the crest of the designed LPSTP, then consideration should be addressed as to whether the LPSTP height should be raised to a height equal to, or taller than, the pointbar bench elevation.
- Scour estimation and various methods of positioning launchable stone are discussed in CORPS Engineering Manual "EM-1601, Chapter 3"

LSTP - CHAPTER 8:

False Banklines using LPSTP (small stream)

FALSE BANKLINES USING LPSTP

- Useful when thalweg requires realignment
- Good in areas where more space is required between the river and the objects to be protected
- Excellent method where areas claimed by lateral stream migration must be reclaimed

Red Banks, MS. 3-92 LPSTP with tiebacks, some flow since construction

Red Banks, MS. 6-93One year later, unrooted willow stakes plus natural revegetation equals stability.

LSTP - CHAPTER 9:

CASE STUDY: Grand River at Route "A"

100 miles north of Kansas City, MO.

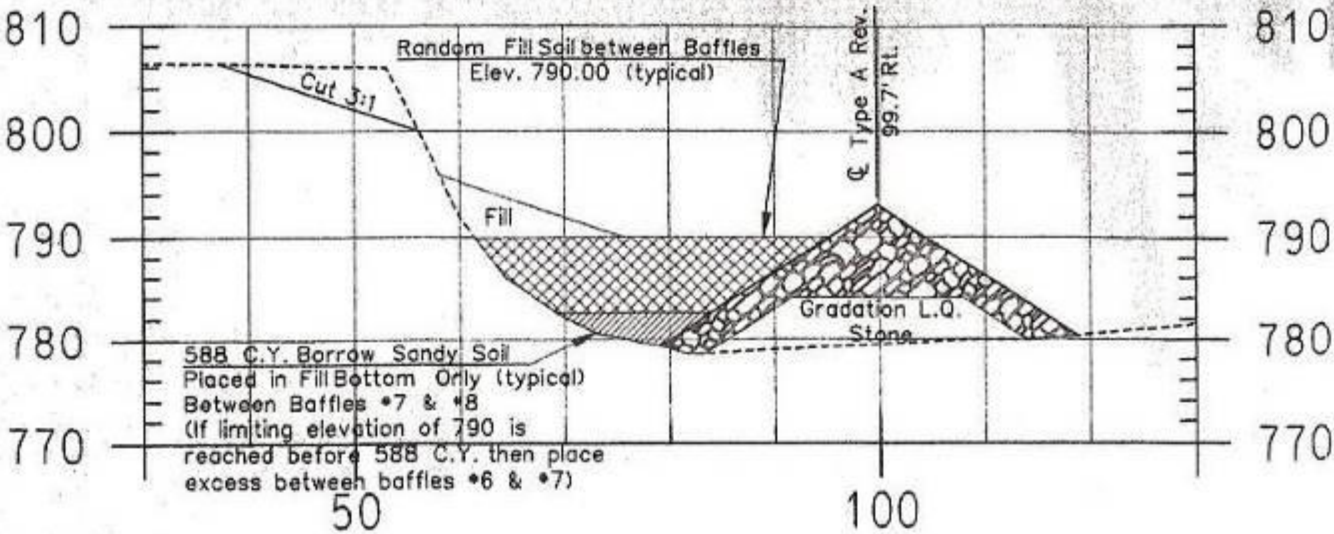
Constructed June 2001

False Banklines using LPSTP

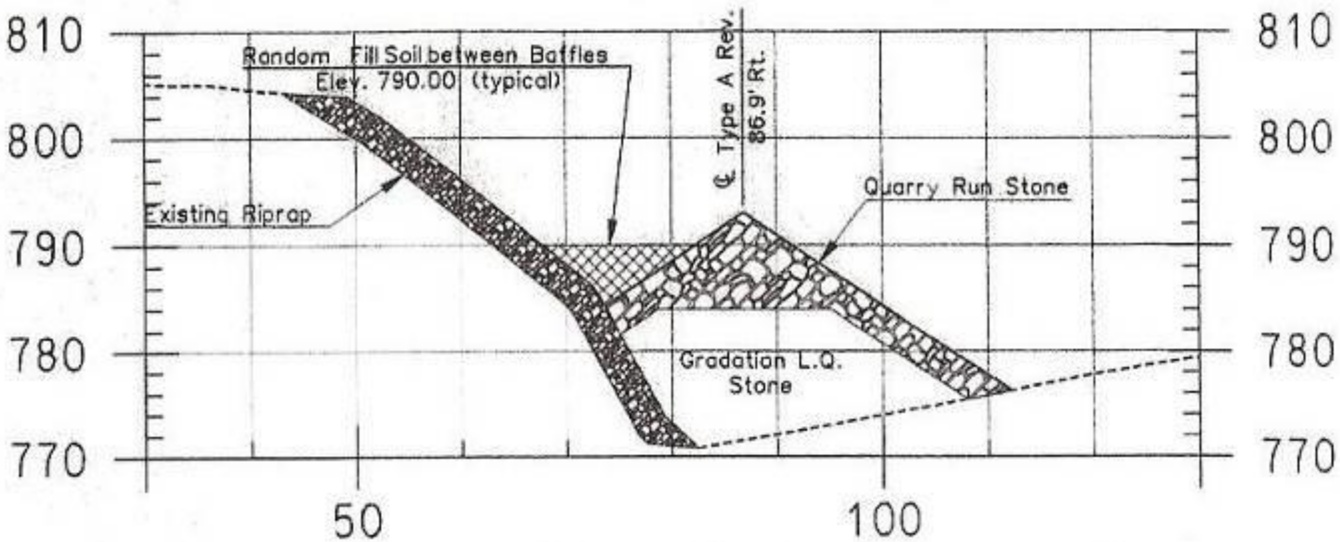
(medium-sized river)

LPSTP CONFIGURED AS A FALSE BANKLINE ON A LARGE RIVER, MINIMAL BACKFILLING BEHIND LPSTP

Grand River at Route "A" 100 miles north of Kansas City, MO. {rural, sand-gravel, slope <1%, pool-riffle-pool, meandering}. This is a Kansas City District Corps of Engineers Section 14 project, emergency bank stabilization to protect existing public works (highway and bridge). I was involved in the conceptual design, & HNTB, Inc. developed Plans and Specs. Much thanks to John Blancett, engineer with HNTB for project monitoring, great pix, & Plans and Specs.



12+00



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LPSTP Cross-sections.

Top bank = el. 806

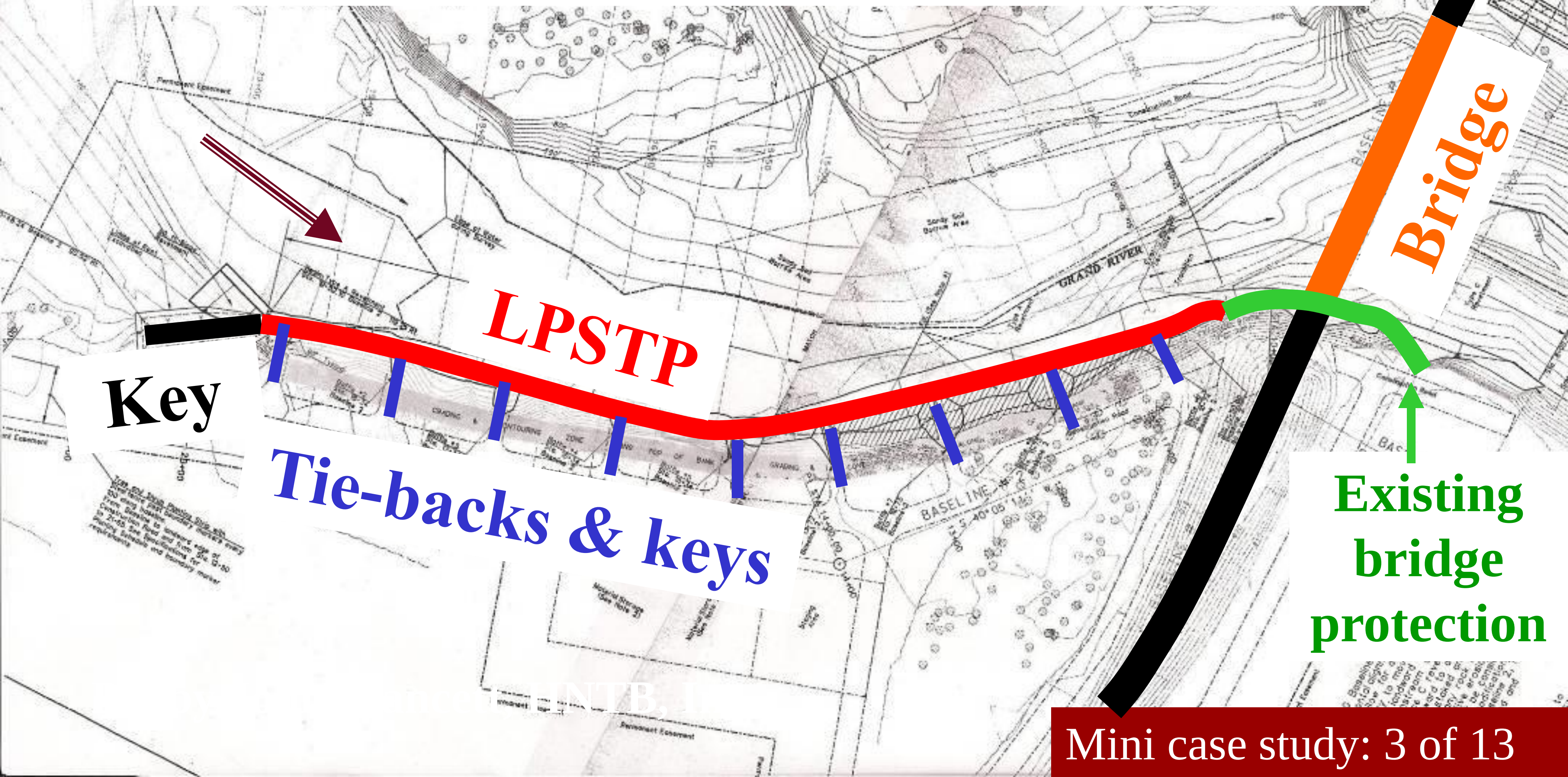
Q-2 flow = el. 803

LPSTP crest = 793

Designed to be overtopped 13 days/yr.

Core section of LPSTP was built of a less expensive stone, while quarry run stone was used for all exposed surfaces

Planform design drawing from HNTB. **The bend US of the project bend** **had migrated 1,100 ft in 59 years, but was averaging 50 ft per year from 1993-1999 (after disturbance from 1993 flood).**




LPSTP on a large river, looking US. The bend US of this bend had migrated 1,100 ft in 59 years.
Pix by John Blancett, HNTB, Inc.
Mini case study: 4 of 13

MAIN PROJECT GOALS

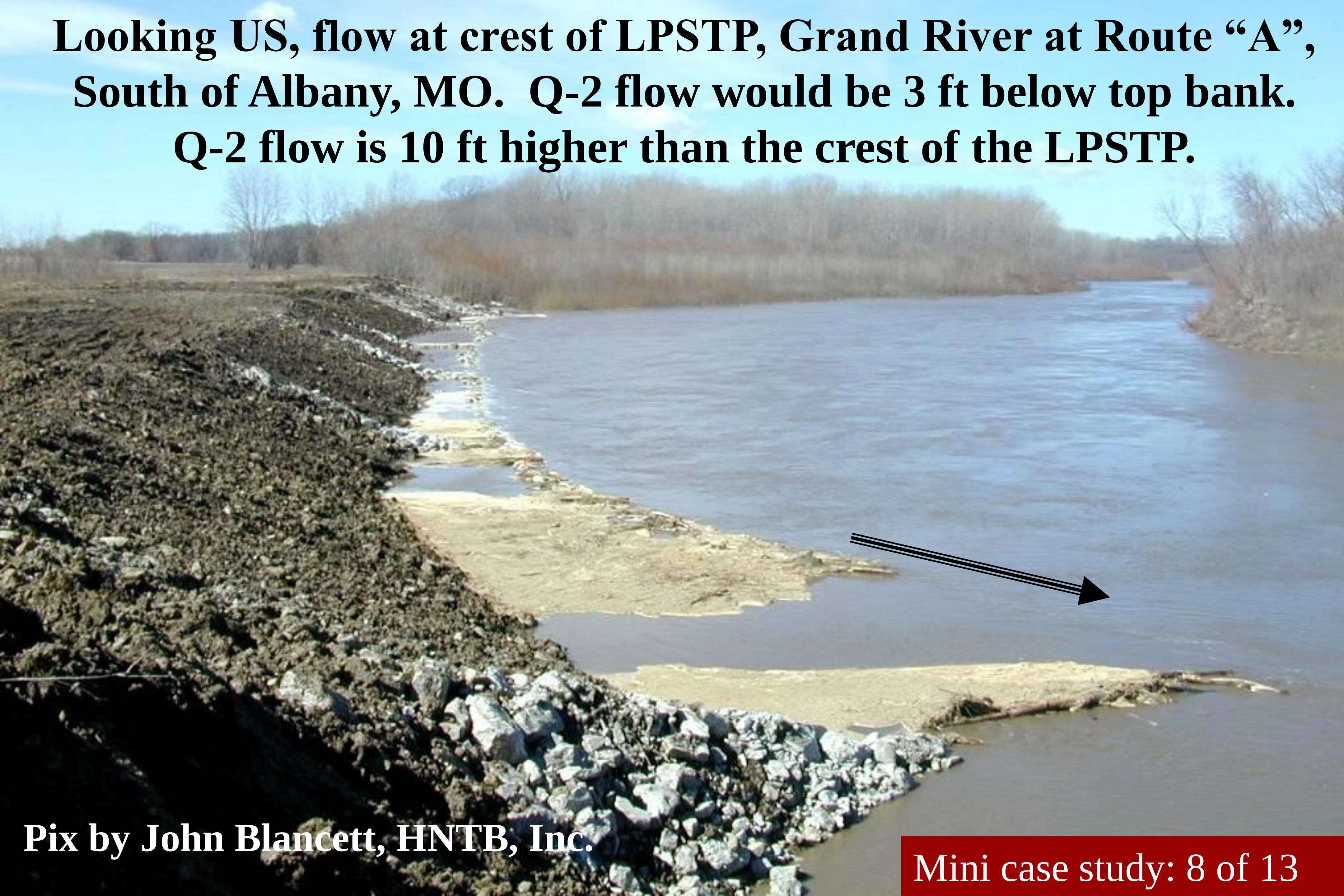
LPSTP was moved away from existing bank (false backline) so as to improve flow through the bridge opening and to reduce erosive pressure on opposite bank downstream of bridge.

Looking DS, Grand River, very poor flow alignment into Route "A" bridge opening, pre-project conditions

Pix by Derrick

Great shot Pix by John Blancett, HNTB, Inc., note old bank angle approach & new LPSTP flow approach angle into Route "A" highway bridge

Mini case study: 7 of 13


Looking US, flow at crest of LPSTP, Grand River at Route "A", South of Albany, MO. Q-2 flow would be 3 ft below top bank. Q-2 flow is 10 ft higher than the crest of the LPSTP.
Pix by John Blancett, HNTB, Inc.
Mini case study: 8 of 13


Looking US. Note deposition and veg within first year after completion. Grand River @ Rt. “A”, MO
Pix by John Blancett, HNTB, Inc.
Mini case study: 10 of 13


Oct 4, 2007 - After 6 years robust native vegetation results in a fully functional project, Grand River @ Rt. “A”, MO
Pix by John Blancett, HNTB, Inc.
Mini case study: 13 of 13

7 YEARS AFTER PROJECT COMPLETION

HIGH VELOCITY FLOW STRIPS LEAVES OFF OF PLANTS

Photos by Derrick

MAY 5, 2008

7 YEARS LATER - Looking US @ project. High velocity flow has stripped leaves off of almost all plants growing within the project.

7 YEARS LATER - Grand River @ Rt. “A”, MO -PIX BY DERRICK 5-1-2008

7 YEARS LATER – Close-up of bark & leaves stripped from PLANTS AT TOP BANK due to high flow velocities.

7 YEARS LATER - Grand River @ Rt. “A”, MO -PIX BY DERRICK 5-1-2008

8 YEARS LATER-Looking US @ willow recovery.

8 YEARS LATER- Grand River @ Rt. “A”, MO -PIX BY DERRICK 8-20-09

8 YEARS LATER-Looking DS of bridge, opposite bank. Was severely eroded pre-project, but redirection of flow thru bridge resulted in deposition & willow growth.

8 YEARS LATER- Grand River @ Rt. “A”, MO -PIX BY DERRICK 8-20-09

PIPELINE PROTECTION FOR TRANSCANADA ON THE THOMPSON RIVER NEAR LIMONI, IOWA

PROJECT CONSTRUCTED July 7, - Sept 15??, 2011

HIGH WATER CRESTED 3 FT OVER THE LPSTP, BUT NOW WATER JUST OVER THE BENDWAY WEIRS

HIGH WATER OVER THE WEIRS-Looking @ willows in perpendicular key caught debris, took a licking, still look great.

CONSTRUCTION-THOMPSON R. @ TRANSCANADA PIPE - DERRICK 8-17-2011

HIGH WATER OVER THE WEIRS-Close-up, looking US @ deposition on LPSTP, foam, & debris on willows.

CONSTRUCTION-THOMPSON R. @ TRANSCANADA PIPE - DERRICK 8-17-2011

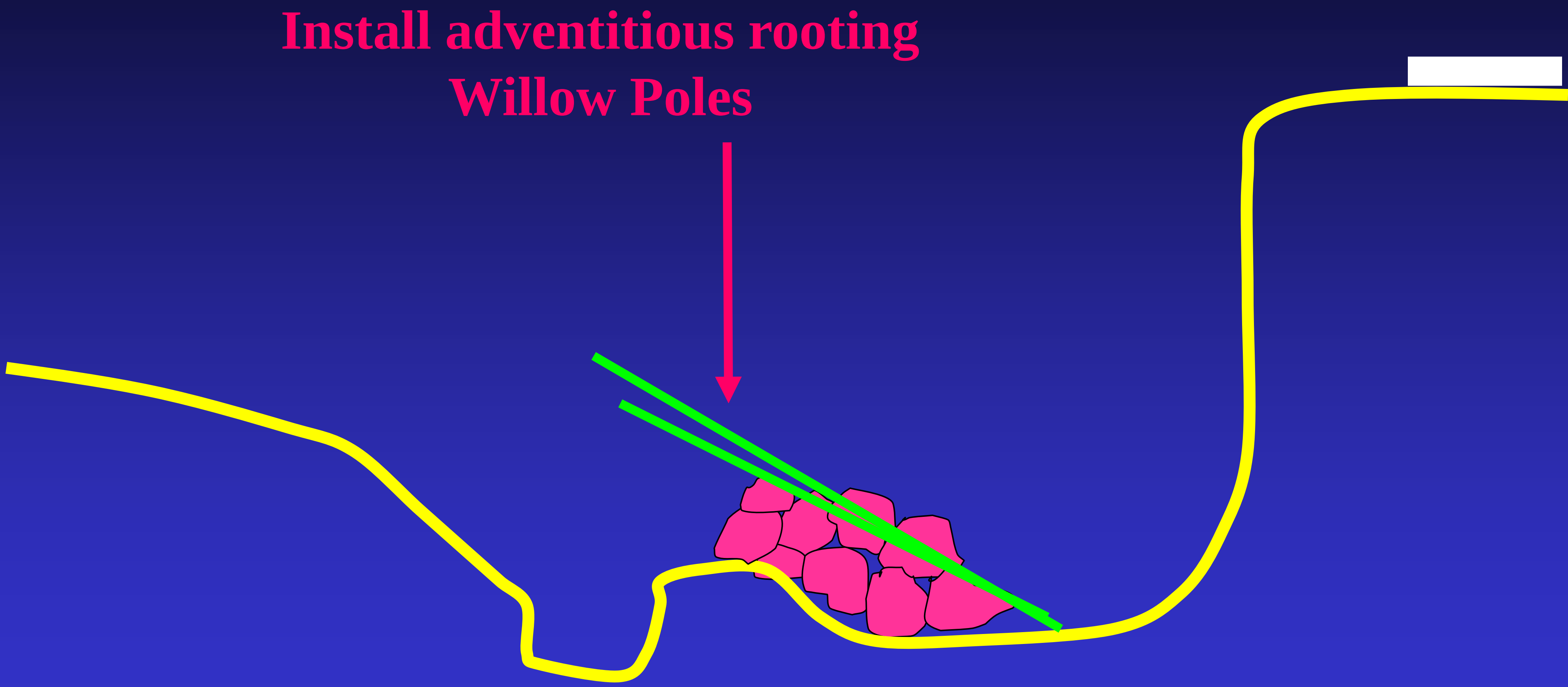
HIGH WATER OVER THE WEIRS-Looking DS @ no sediment on LPSTP. Foam line on bank shows flood height.

CONSTRUCTION-THOMPSON R. @ TRANSCANADA PIPE - DERRICK 8-17-2011

ELTON CREEK, FREEDOM, NY

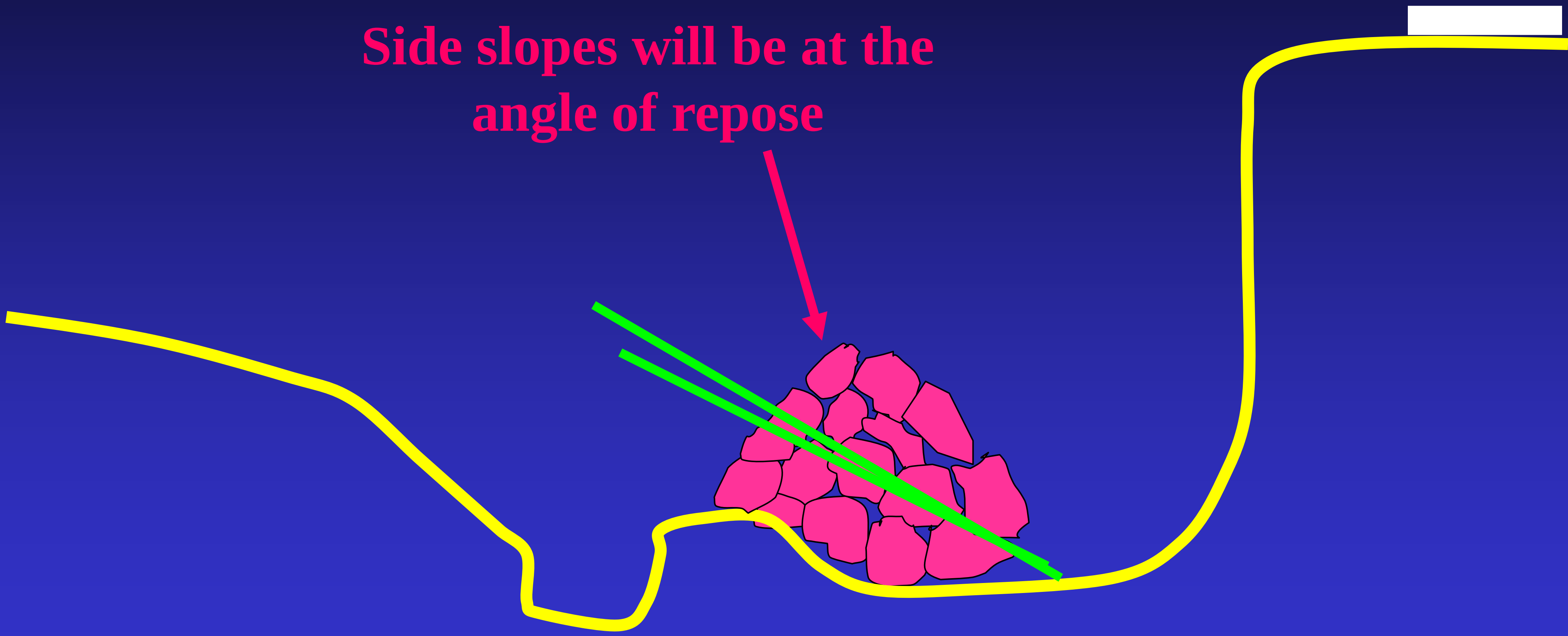
PLANTING ADVENTITIOUS ROOTING WILLOW & DOGWOOD POLES WITHIN THE STONE TOE PROTECTION

Elton Creek near Freedom 7 Bridge, Freedom, NY



Elton Creek near Freedom 7 Bridge, Freedom, NY

Install remainder of LPSTP.
Side slopes will be at the
angle of repose



Looking DS. Vegetation integrated thru LPSTP.

Under construction-Elton Creek DS of Freedom 7 Bridge-derrick-Oct 2007

2 years & 8 months after completion. Looking DS @ the apex of the bend. Live Siltation & transplanted willows & dogwood growing well. Nice deep pool to dissipate energy. WILLOW PLANTED WITHIN STONE TOE

32 MONTHS LATER-Elton Cr. DS of Freedom 7 Br.-Derrick-June 15, 2010

2 years & 8 months after completion. Close-up of stacked stone wall with Live Siltation behind & some planted willow & dogwood growing through the stone wall

32 MONTHS LATER-Elton Cr. DS of Freedom 7 Br.-Derrick-June 15, 2010

LSTP - CHAPTER 10:

Introduction to Longitudinal Fill Stone Toe Protection {LFSTP}

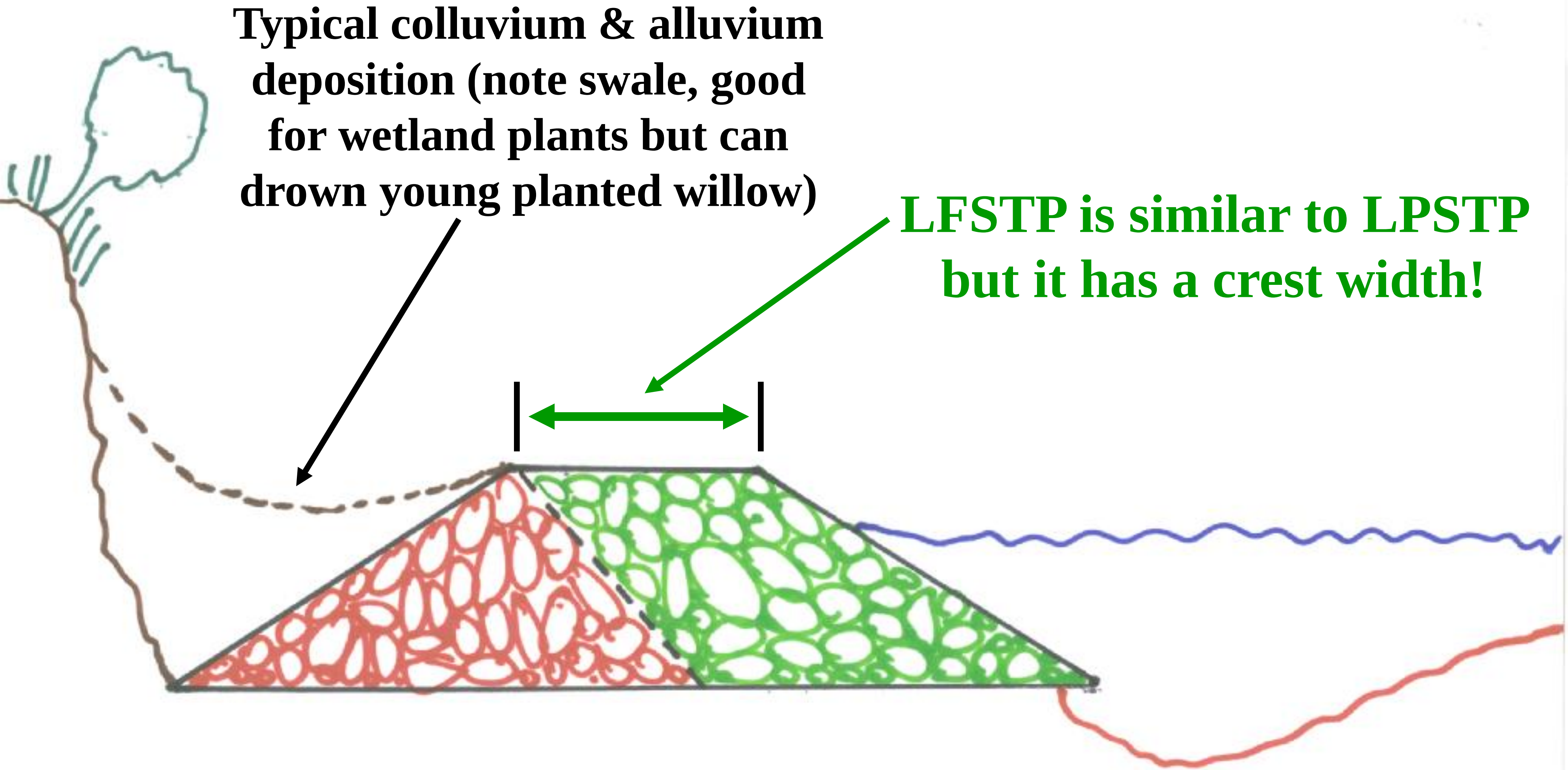
Longitudinal Fill Stone Toe Protection (LFSTP)

(also called a “Weighted Toe” or a “Reinforced Revetment”)

- **Description -** Longitudinal Fill Stone Toe Protection (LFSTP) is similar to LPSTP, except that instead of coming to a peak, the crest has a specified width. Therefore, LFSTP has a trapezoidal cross-section as compared to the triangular cross-section of LPSTP.

- **Advantages -** Same as LPSTP. In addition, in areas of deep scour LFSTP provides sufficient rock to self-adjust (launch) into the scour hole while still maintaining its original crest height.

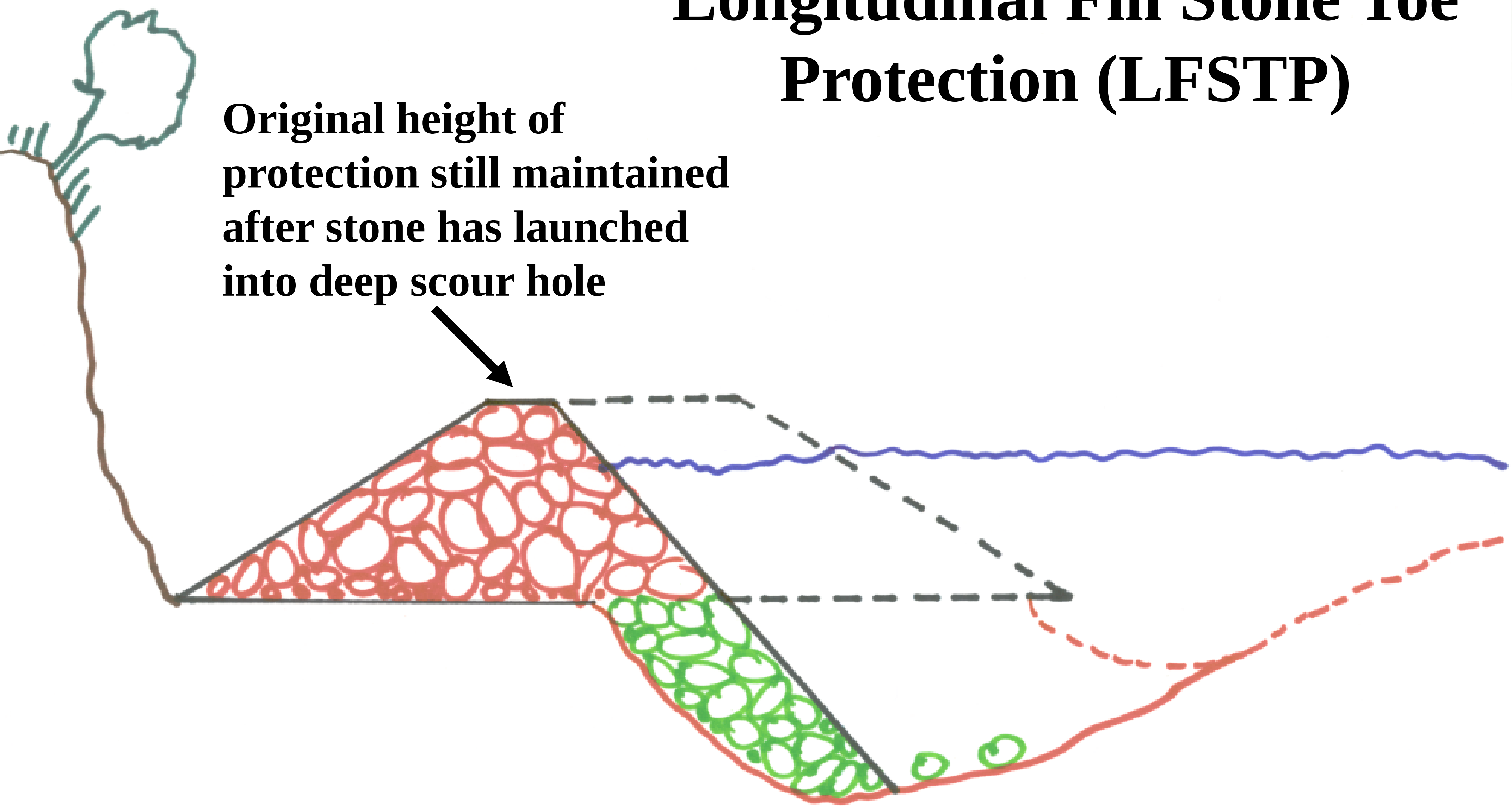
- **Design considerations -** The maximum scour depth should be calculated. The volume of stone required to launch into and armor the scour hole (with an appropriate margin-of-safety incorporated into the design) should be calculated. Based on these calculations, the crest width (volume of launchable stone needed from the LFSTP) can then be back-calculated.



Longitudinal Fill Stone Toe Protection (LFSTP)

WE WILL LET THE RIVER DO THE EXCAVATION FOR US!!!

Longitudinal Fill Stone Toe Protection (LFSTP)



LSTP - CHAPTER 11:

CASE STUDY- Missouri River @ Lewis & Clark Regional Water System, Vermilion, SD.

Constructed Nov. 2007-Apr. 2008

Longitudinal Fill Stone Toe Protection {LFSTP} with integrated Locked Logs

Aerial shot fall 2007. Looking US @ completed mile-long L & C project.

CONCEPTUALLY

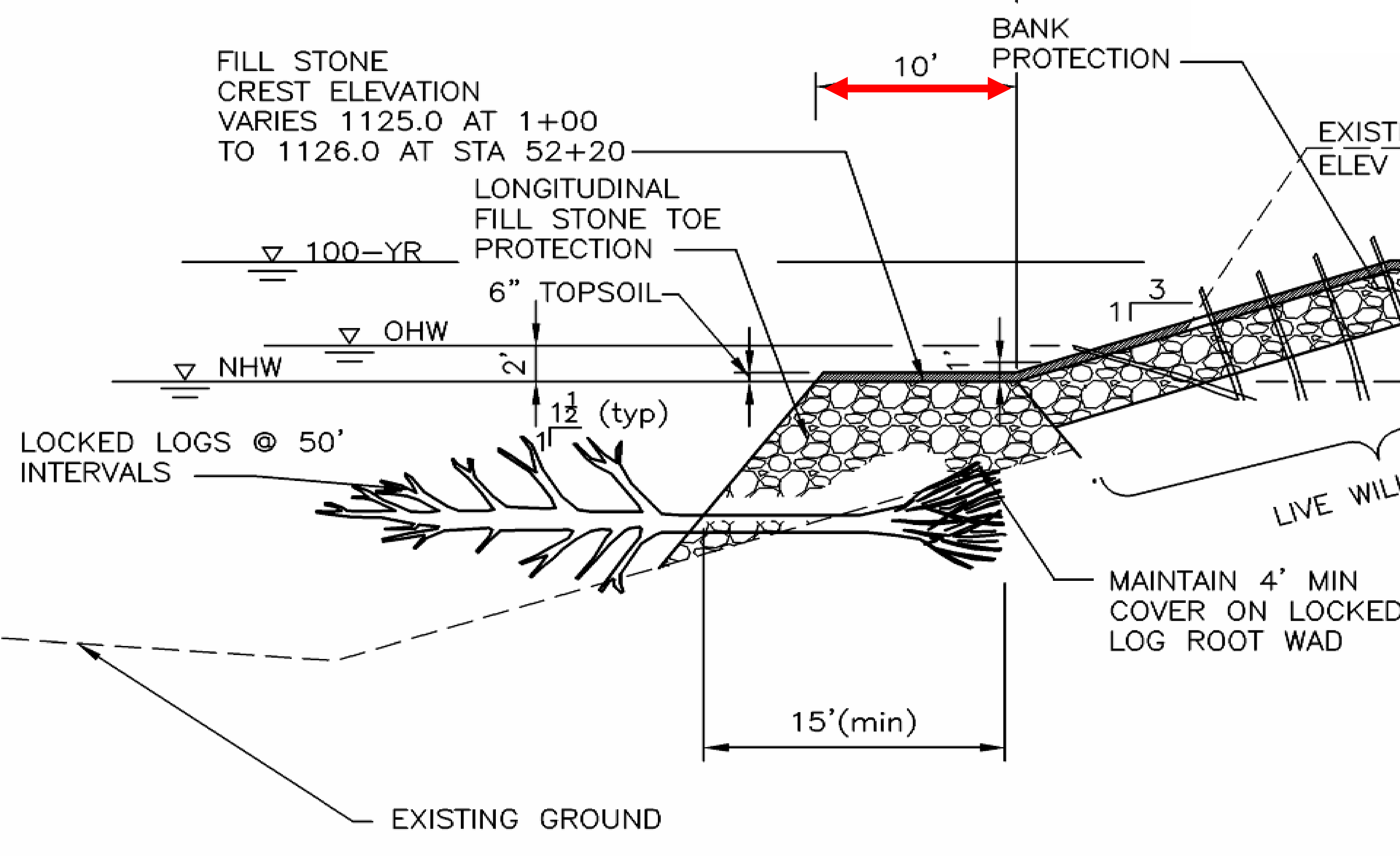
- **Start with a standard bank protection plan that is well understood, well designed, & time tested (low degree of risk)**
- **Add to this the hydraulically rough & environmentally desirable Extreme Locked Logs (113 logs spaced 50 ft apart) plus 49,000 unrooted willow pole plantings within & through the riprap, & 59,300 rooted stock plants for the mid & upper bank areas. Then cover (choke) all exposed stone with 1 ft of soil & seed !!**

LONGITUDINAL FILL STONE TOE PROTECTION {LFSTP}

{Self-adjusting & self-filtering stone. Minimum 10 ft wide by minimum 3 ft thick. Contractor placed 22,986 tons of stone for entire launchable toe.}

(Amounts in actual construction have varied from 3.2 to 4.6 tons/ft. in concave & straight sections, to 6.3 to 8.4 tons/per ft. at convex areas (juts).

Stabilization / habitat cross-section from HDR, Inc.



Looking US @ the 10 ft wide Longitudinal Fill Stone Toe Protection. The bank will be graded to 3 on 1 with riprap & integrated veg

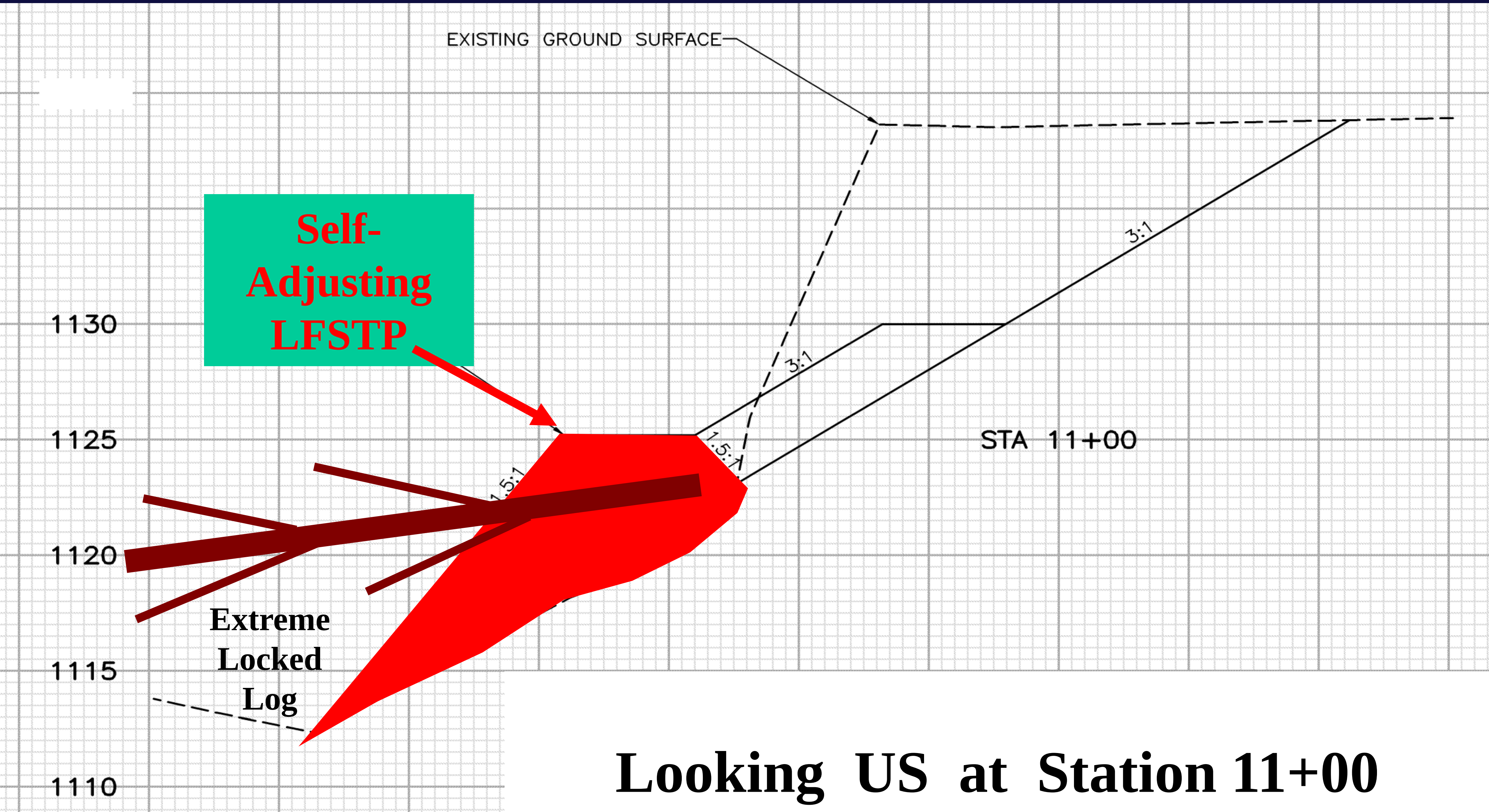
CONSTRUCTION-MISSOURI RIVER @ L & C-TERRY STOLTENOW-11/8/07

Looking US. Smoothing choke soil with the Bobcat. Minimum of 6 inches of soil choke, but contractor applied 12 inches almost everywhere. Some settling will occur.

CONSTRUCTION-MISSOURI RIVER @ L & C-TERRY STOLTENOW-12/5/07

INSTALLATION OF THE EXTREME LOCKED LOGS

BANK CROSS-SECTION FROM HDR., INC



Looking US at Station 11+00

LONGITUDINAL FILL STONE TOE PROTECTION WITH INTEGRATED EXTREME LOCKED LOGS (Fuzzy Locked Log shown next)

Looking US. A cedar Fuzzy Extreme Locked Log

CONSTRUCTION-MISSOURI RIVER @ L & C-DERRICK-NOV 15, 2007

Looking US. Scraping branches off of the lower 15 ft of the Fuzzy Extreme Locked Log so stone to trunk contact is made, & then the Locked Log is truly locked in place.

CONSTRUCTION-MISSOURI RIVER @ L & C-DERRICK-NOV 15, 2007

Looking US. Note calm water between Locked Logs.

CONSTRUCTION-MISSOURI RIVER @ L & C-DERRICK-NOV 15, 2007

Looking US @ self-adjusting toe stone & Extreme Locked Logs, note natural bank with wood upstream.

CONSTRUCTION-MISSOURI RIVER @ L & C-DERRICK-NOV 15, 2007

Looking DS. Irregular bankline mimics natural shore

CONSTRUCTION-MISSOURI RIVER @ L & C-DERRICK-NOV 15, 2007

EXTREME LOCKED LOGS WITH ICE

Ice surrounding ExLL fends off moving ice floes.

CONSTRUCTION-MISSOURI RIVER @ L & C-DERRICK-DEC 11, 2007

PLANT PLANTS

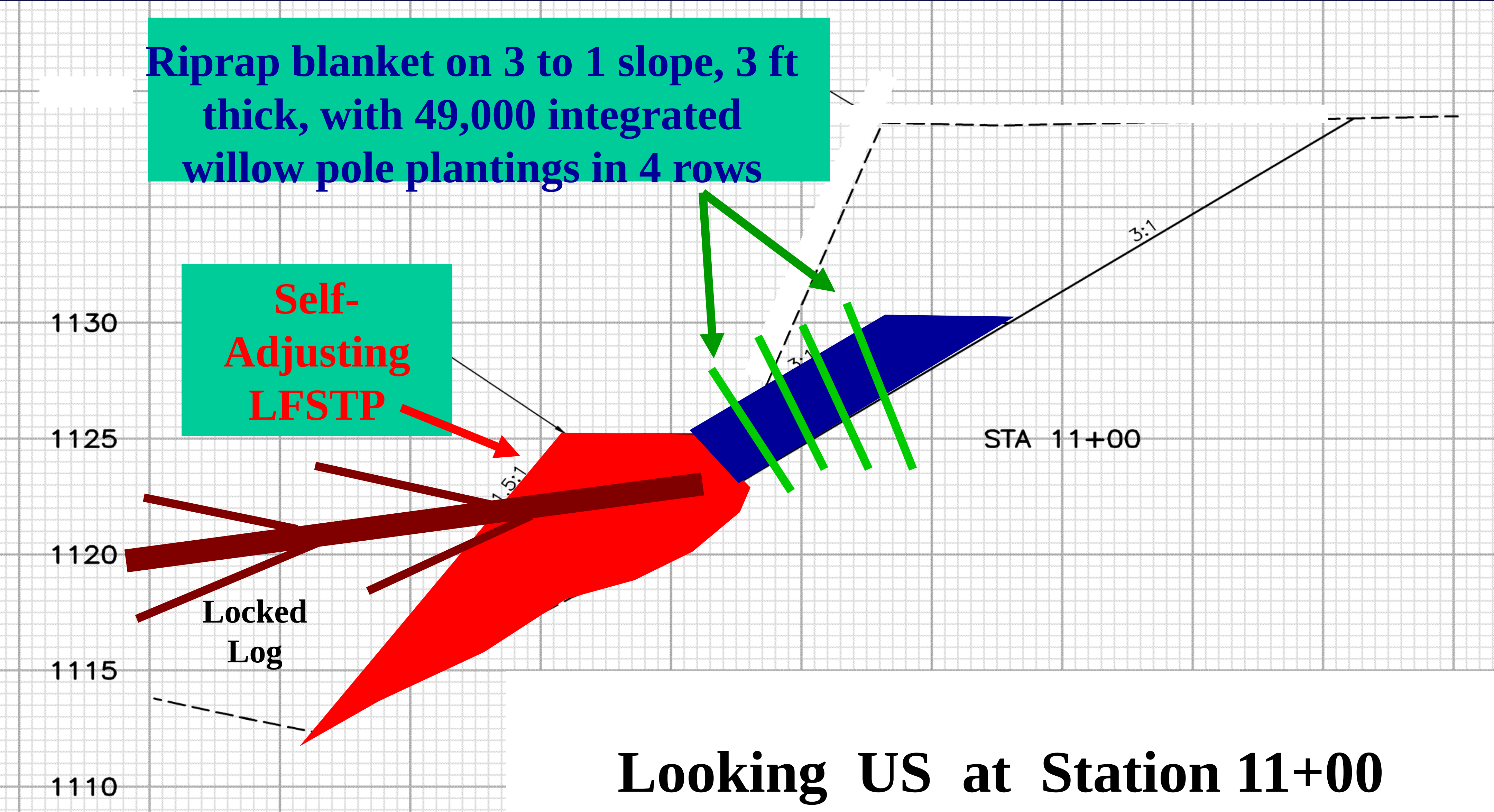
WITH VERY

LARGE

YELLOW

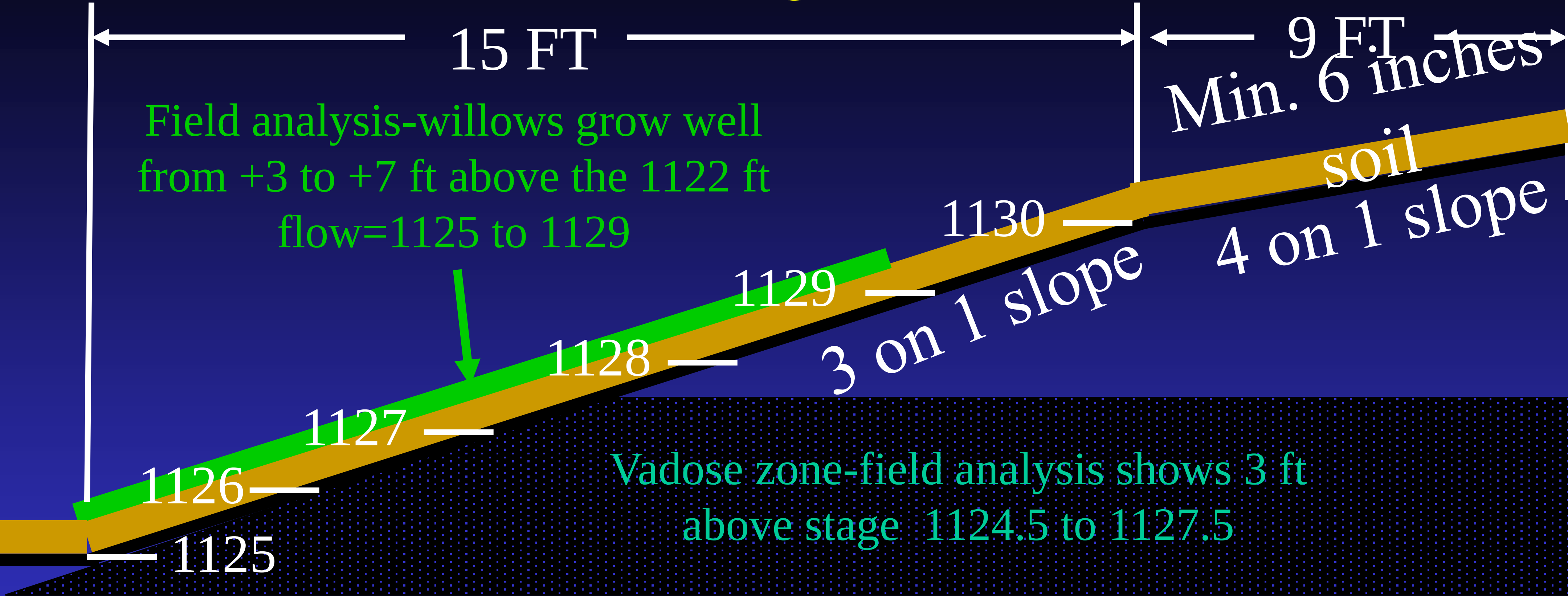
MACHINES

BANK CROSS-SECTION FROM HDR., INC



Looking US at Station 11+00

MISSOURI RIVER @ LEWIS & CLARK



River flow elevations during growing season

June-Sept 2002-2008 24K= 1124.5 June-Sept 2008 26K= 1124.7 Target nav. stage 31K= 1125.3 June-Sept 1967-2004 34K= 1125.5 Height of toe stone 28K= 1125.0

Use this one

Basal ends of willows should be at ele. 1125

Terry Stoltenow, construction inspector with HDR, Inc. with 6-7 ft long bundled willows.

CONSTRUCTION-MISSOURI RIVER @ L & C-DERRICK-DEC 11, 2007

Pull bucket back 8”, lean willow poles against stone.

CONSTRUCTION-MISSOURI RIVER @ L & C-DERRICK-Dec 13, 2007

Looking US. All 4 rows of willows

CONSTRUCTION-MISSOURI RIVER @ L & C-DERRICK-Dec 12, 2007

Looking US at willows & stone.

CONSTRUCTION-MISSOURI RIVER @ L & C-DERRICK-DEC 11, 2007

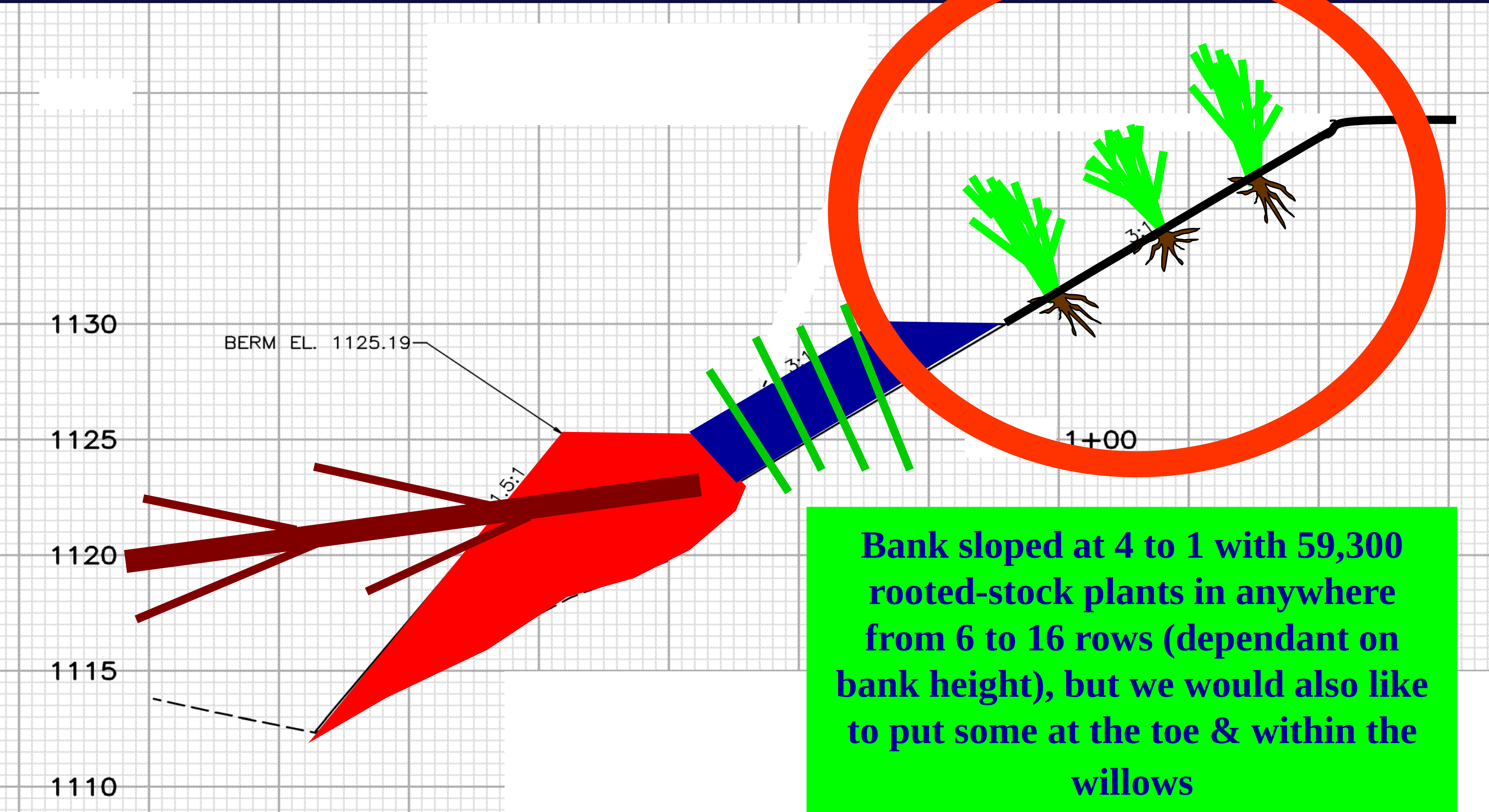
Looking US. Nature is curvaceous, us too !!

CONSTRUCTION-MISSOURI RIVER @ L & C-DERRICK-Feb 25, 2008

PLANT PLANTS WITH A MUCH SMALLER MACHINE

59,300 bare root plants {even amount of cottonwood & red osier dogwood} were installed on a 4 to 1 slope from elevation 1130 up to top of bank during March 26 - May 4, 2008 .

BANK CROSS-SECTION FROM HDR., INC



Bank sloped at 4 to 1 with 59,300 rooted-stock plants in anywhere from 6 to 16 rows (dependant on bank height), but we would also like to put some at the toe & within the willows

Ancient two seat single row planter was used to plant 8,000 rooted stock plants per day, finished 4/28/2008, 3 months ahead of schedule.

CONSTRUCTION-MISSOURI RIVER@L & C-TERRY STOLTENOW-4/3/08

3 MONTHS AFTER PROJECT COMPLETION

Photos by Derrick

August 1, 2008

3 months after completion, looking DS @ L & C project & highway bridge.

3 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 8-1-2008

From upper section of project looking DS toward bridge. Willow, cottonwood & dogwood growth 3 months after planting is robust. Some erosion of soil at water’s edge & slight launching of stone.

3 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 8-1-2008

Close-up of willow pole plantings 3 months after installation.

3 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 8-1-2008

Mid to upper bank plantings. Cottonwoods 22" to 48" tall, Red Osier Dogwoods 16" to 31" tall. 3 ft between rows, from 12" to 18" spacing between plants in a row.

3 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 8-1-2008

THIS PROJECT WON THE DEPARTMENT OF THE INTERIOR'S "PARTNERS IN CONSERVATION" AWARD IN 2009

16 MONTHS AFTER PROJECT COMPLETION

(1.5 GROWING SEASONS)

Photos by Derrick

AUGUST 6, 2009

16 MONTHS LATER-Looking DS @ willow & cottonwood growth (up to 6 ft for both).

16 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 8-6-09

16 MONTHS LATER-Looking DS @ dense & robust willow growth. Coverage of ground is excellent here.

16 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 8-6-09

39-40 Months After Project Completion

GREAT FLOOD OF 2011

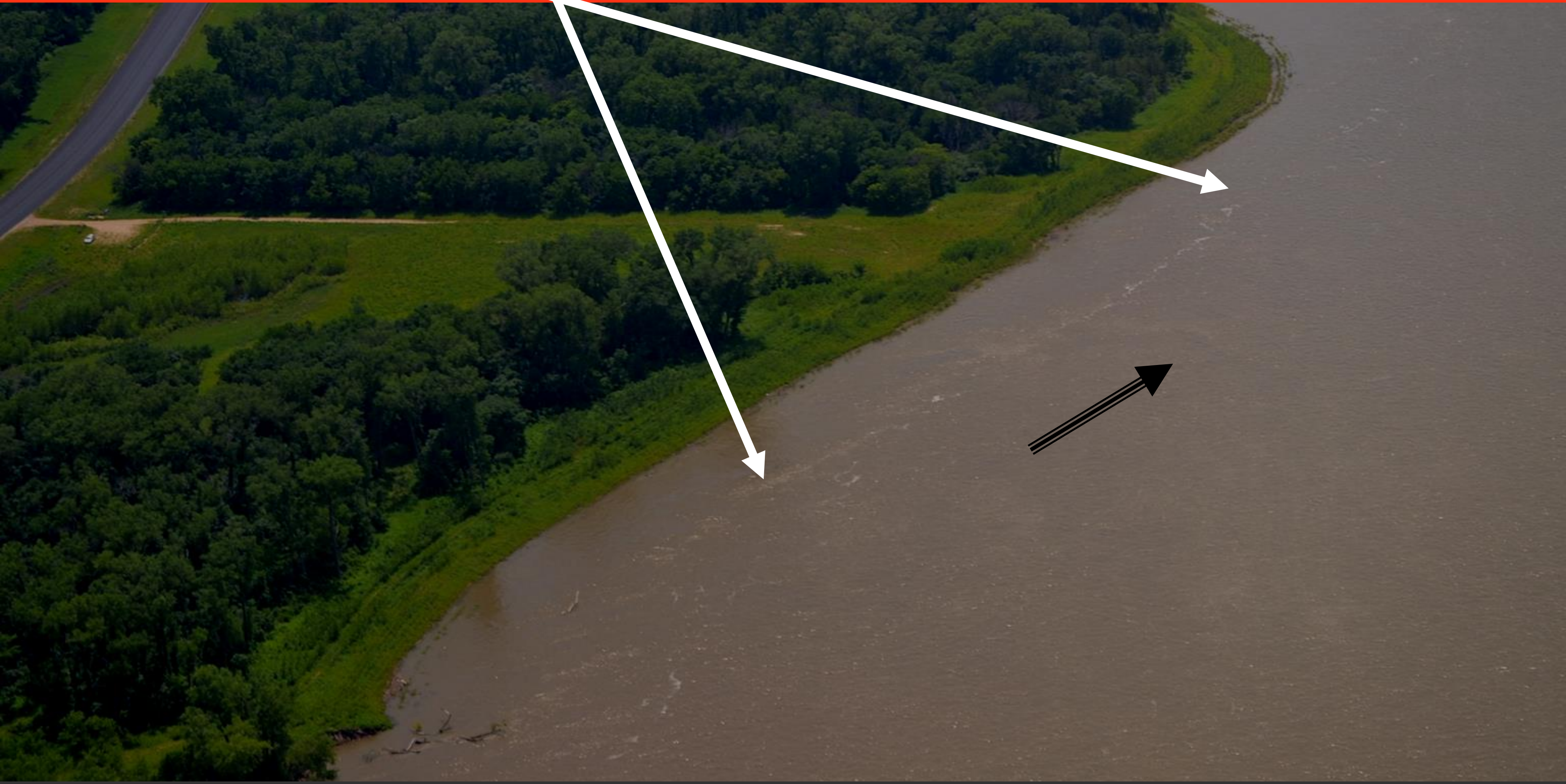
AERIAL PHOTOGRAPHS

Different dates

GREAT FLOOD OF 2011-Looking DS. Reach between arrows is the project. Straight section US of bridge is eroding.

37 MONTHS LATER- MISSOURI R.@L & C-FROM TED HALL 5-31-11

GREAT FLOOD OF 2011-Looking DS. Clearly visible foam line indicates the influence of the Locked Logs, (slower water nearer bank). Logs are submerged at least 8 to 10 ft.



38 MONTHS LATER- MISSOURI R.@L & C-FROM TED HALL 6-29-11

40 Months After
Project Completion

GREAT FLOOD OF 2011
PIX TAKEN TWO FOOT
BELOW FLOOD CREST

Photos by Derrick

JULY 30, 2011

2 FT BELOW GREAT FLOOD OF 2011 CREST-Looking @ foam line approx. 100 ft. into channel caused by the reduction in flow velocity due to the Locked Logs

40 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 7-30-11

2 FT BELOW GREAT FLOOD OF 2011 CREST-Looking DS @ foam line delineating the outermost effect of the Locked Logs in reducing flow velocity. Logs 8-10 ft under water.

40 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 7-30-11

2 FT BELOW GREAT FLOOD OF 2011 CREST-Looking DS @ debris on bank. All 4 rows of willows under water. No erosion!

40 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 7-30-11

2 FT BELOW GREAT FLOOD OF 2011 CREST-Close-up of recently flooded plants showing very little ill effects.

40 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 7-30-11

2 FT BELOW GREAT FLOOD OF 2011 CREST-Almost all of project had very dense & robust veg at the flood stage elevation & above. No erosion! Wave wash not an issue.

40 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 7-30-11

2 FT BELOW GREAT FLOOD OF 2011 CREST-Looking DS @ dense forest of dogwood & cottonwood. Typical.

40 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 7-30-11

2 FT BELOW GREAT FLOOD OF 2011 CREST-Looking @ 2.5 inch base diameter of planted cottonwood. 14-16 ft tall.

40 MONTHS LATER- MISSOURI R.@L & C-PIX BY DERRICK 7-30-11

I am ready at this time to listen to your questions.