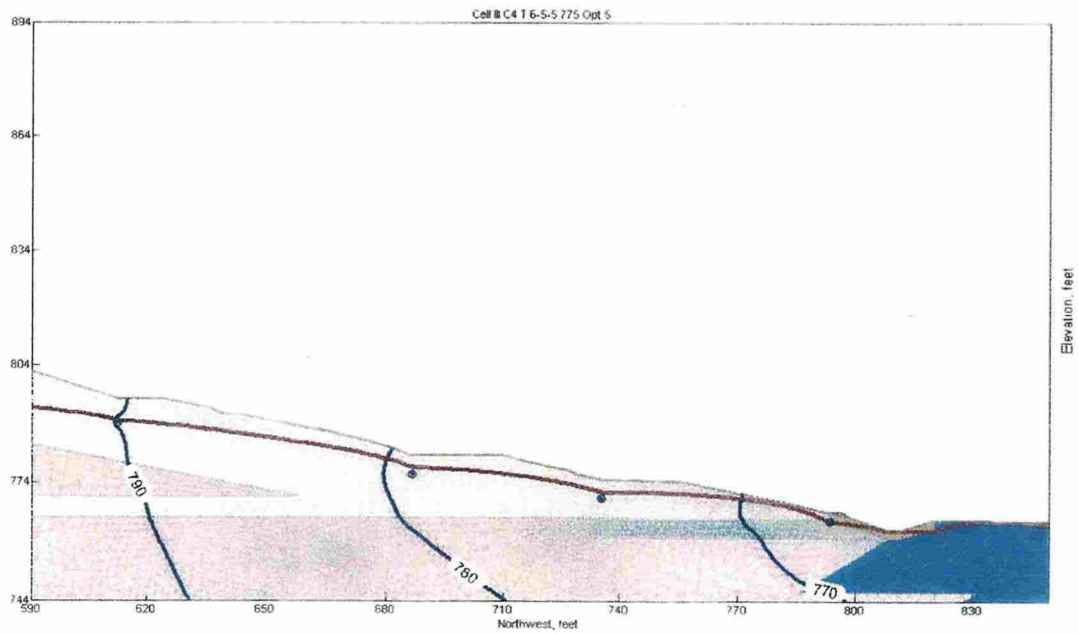
FINAL TRENCH AND TOE BUTTRESS CONFIGURATION FOR DREDGE CELL III SWAN POND ROAD

PARSONS E & C



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PARSONS E & C ROLE

- PERFORMED PRELIMINARY GEOTECHNICAL DESIGN FOR SLOPE STABILITY ANALYSIS 2004

- PERFORMED PERLIMINARY SEEPAGE MODELING (JUNE, 2004) TO SHOW THAT SEEPAGE FORCES, NOT SLOPE STABILITY CAUSED FAILURE.

- PARSONS E & C (JUNE, 2004) AND (JANUARY, 2005) RECOMMENDED A FOCUSED INVESTIGATION TO ACQUIRE INSITU HYROGEOLOGIC PROPERTIES BEFORE DEVELOPMENT OF CONSTRUCTION DRAWINGS.

- TO BRING MODELING AND DESIGN KNOWLEDGE THAT WOULD ADD TO THE DEFENSIBILTY OF THE SEEPAGE MODEL.

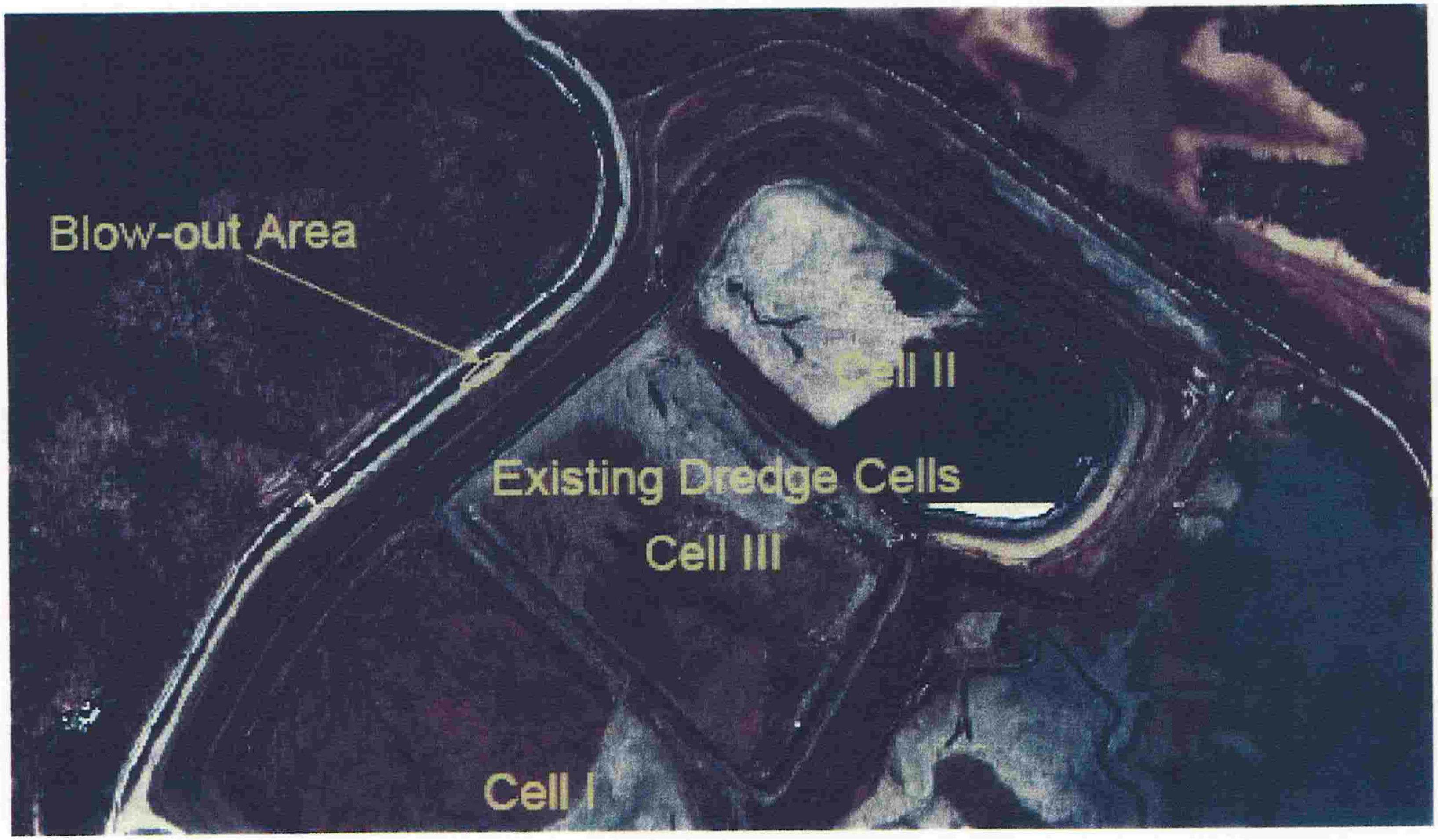
PARSONS E & C ROLE (cont)

- PARSONS E & C BRINGS YEARS OF EXPERTISE IN THE POWER INDUSTRY AND DESIGN OF IN GYPSUM AND ASH STACKS.
- PARSONS E & C WOULD WORK WITH THE TVA SEEPAGE TEAM TO DEFINE THE FOCUSED INVESTIGATION, MODEL PARAMETERS FOR THE PARALLEL CALCULATIONS, AND COMPARE RESULTS AS THEY DEVELOPED.
- TO KEEP SEEPAGE TEAM FOCUSED ON THE DESIGN EFFORT AT HAND.
- FINALLY, PARSONS E & C IS RESPONSIBLE FOR THE FINAL DESIGN OF THE TRENCH AND TOE BUTTRESS CONFIGURATION TO STABILIZE THE SEEPAGE CONDITIONS FOR THE DREDGE CELLS

Outline of Presentation

1. Introduction – Focused Investigation
2. Case 1 – Calibration to Existing Conditions and The Limitations of Calibration
3. Case 2 – Analysis of Seepage Conditions at Pool Elevation 806 feet for Blowout in November, 2003.
4. Case 3 – Analysis of Seepage Conditions at Future Projected Pool Elevation of 900 feet.
5. Slope Stability of Seepage Conditions at Permit Pool Elevation of 842 feet.
6. Summary and Conclusions

Site and Blow-Out Area



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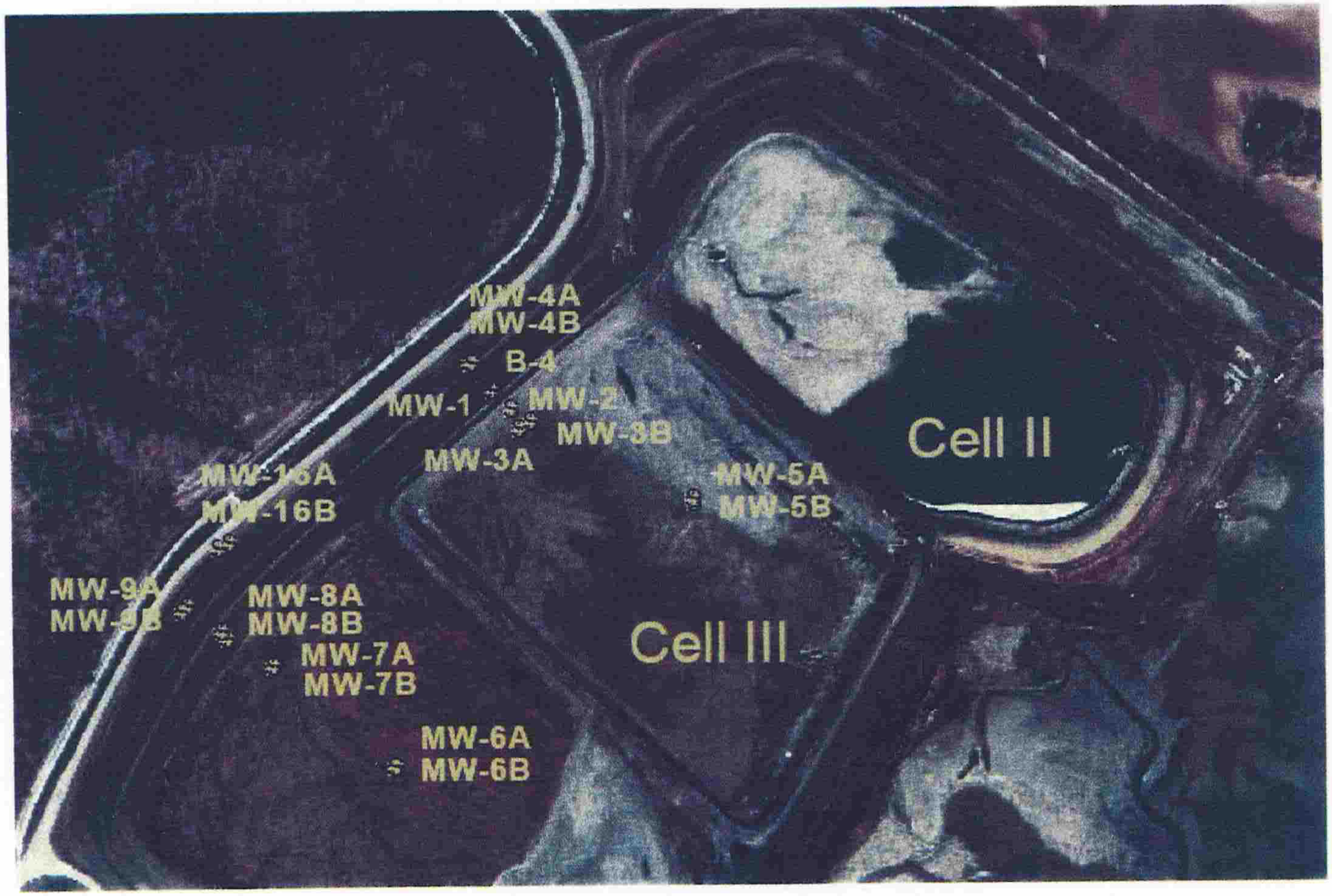
Focused Investigation Borings And Monitoring Wells



Cross Section for Cell III Analyses

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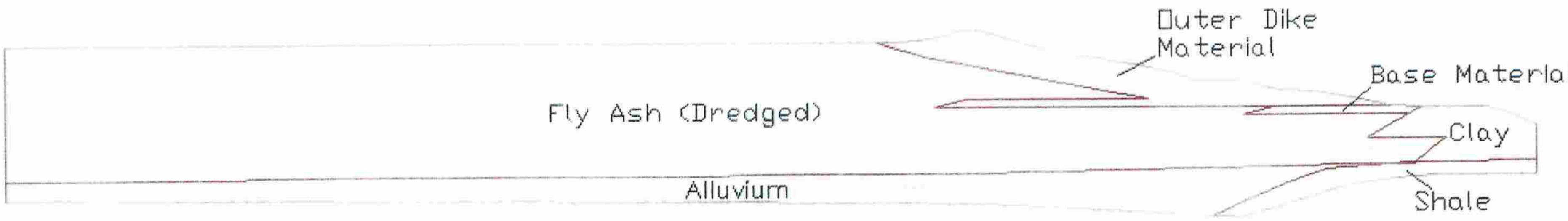
Dredge Cell III Cross Section Existing Conditions



SECTION A73 - CELL III

TVA-00029360

Aquifer Properties Each Layer –
Agreed to by Parsons E & C and Geosyntec

		Hydraulic Conductivity		Max/Min
Zone	**Material**	**cm/sec**	**ft/day**	**$K_{h/}K_v$**
1	Bottom Ash	1.0E-04	0.283	2
2	Firm Fly Ash Bottom Ash Base Material	1.73E-05	0.0490	2
3	Fly Ash	3.74E-05	0.106	2
4	Alluvium	1.29E-04	0.366	2
5	Clay	5.0E-06	0.0142	2
6	Shale	1.0E-06	0.00283	2

Unsaturated Zone Properties Fly Ash and Bottom Ash

- VG alpha = 0.01944/ft = 0.0030/cm
- VG n = 2.68
- θ_r = 0.104 (% Volume) (residual moisture)

Additional Properties Used by The TIMES Finite Element Model

1. **TIMES calculates seepage forces, piping, heave/uplift factors of safety at critical locations along the seepage face.**
2. **Consequently, TIMES uses additional data to perform these seepage force calculations.**
3. **SEEP/W cannot calculate seepage forces and therefore does not need these data.**
4. Because SEEP/W does not use these data, GEOSYNTEC declined Parsons E & C's request to develop an agreed to set of properties for porosity, specific gravity, and unit weight.
5. **Consequently, discrepancies exist among the calculated piping and uplift factors of safety by Parsons E & C and those calculated independently of SEEP/W by Geosyntec.**

TVA-00029363

Hydraulic Properties Used By TIMES To Calculate Seepage Forces, Piping and Uplift Factors of Safety

Zone	Material	Porosity	Residual Saturation	Specific Gravity	Wet Unit Weight pcf
1	Bottom Ash- Mactec (2003) Bull Run	0.589	0.104	2.37	97.6
2	Firm FA / BA Base- Mactec (2003) Bull Run	0.560	0.104	2.37	100.0
3	Fly Ash Mactec (2003) Bull Run	0.560	0.104	2.37	100.0
4	Alluvium Singleton (1994, US-9, T-1)	0.357	0.2	2.69	129.06
5	Clay Singleton (1994, US-1, T-1)	0.338	0.2	2.60	126.35
6	Shale Mactec (2003, Conf. Client)	0.169	0.14	2.69	150.0

Case 1 – Existing Conditions

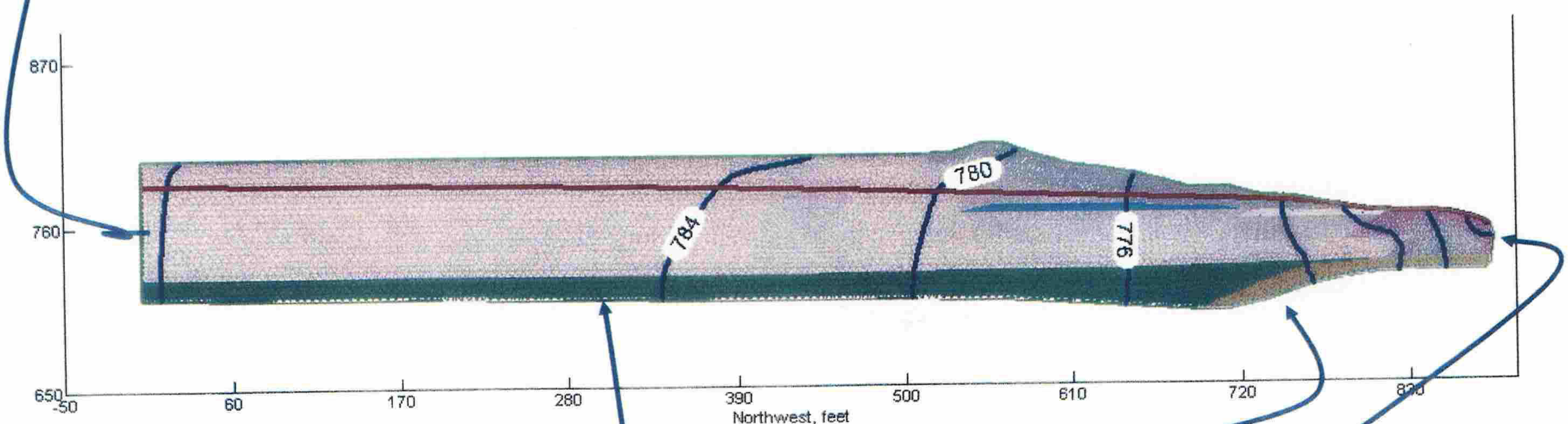
1. Existing conditions used for Calibration Exercise.
2. Calibration has limited validity as it represents an extremely small range of hydraulic stresses for the dredge cell aquifer (specifically, calibration used data from quiescent geohydrologic flow conditions, not flow representative of the seepage failure or as the stack and pond height increases).
3. Applicability of calibration to future conditions cannot be stated with certainty.
4. Therefore, Seepage model should be viewed **NOT AS PREDICTIVE TOOL** but as a **tool for comparison of design alternatives**. The National Research Council (1990) endorses this approach.

Prediction or Process?

Sherlock Holmes, the great detective (modeller) once said: "It is a capital mistake to theorize before one has data. Insensibly one begins to twist the facts to suit the theories, instead of theories to suit facts". Dealing with data deficiency means that we must never increase the complexity of our theories beyond the level of our data sufficiency and secondly, we have no possible solution without the liberal use of engineering judgment.

CASE 1 – CALIBRATION RUN - KINGSTON EXISTING DREDGE CELL III

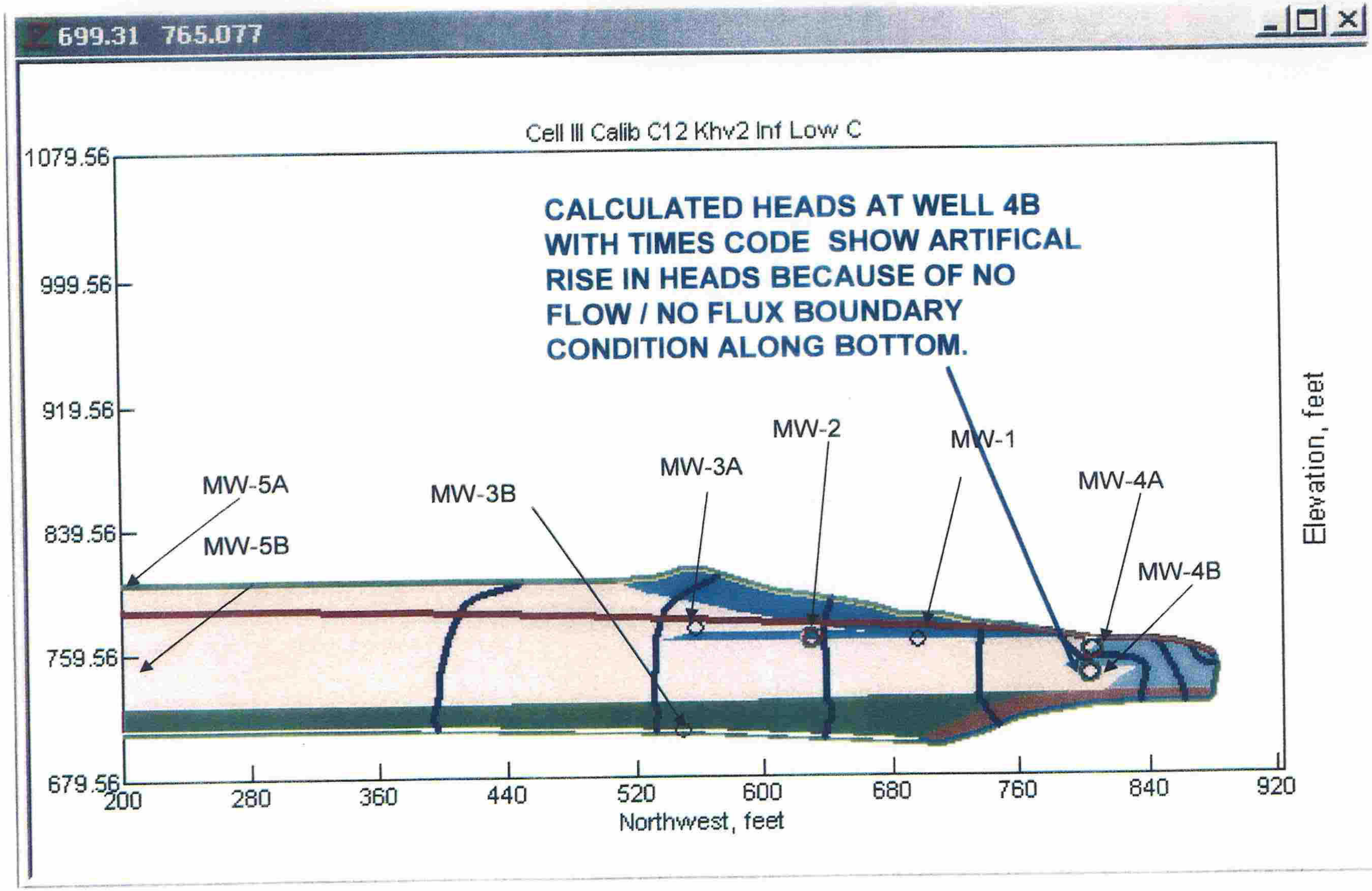
NO HEAD CHANGE PERIMETER
BOUNDARY CONDITION – DOES NOT HAVE
TO BE CONSTANT WITH ELEVATION



NO FLOW / NO FLUX BOUNDARY
CONDITION ALONG BOTTOM CAUSES
ARTIFICIAL RISE IN HEADS NEAR
ROAD THAT DO NOT EXIST IN FIELD.

CALIBRATION HEADS KH/KV =2,
INFILTRATION = 12% SURFACE, 17% SLOPE,
USED MARK BOGGS VAN G. PARAMETERS FOR KINGSTON ASH

KINGSTON EXISTING DREDGE CELL III CASE 1 – CALIBRATION RUN



CALIBRATION HEADS KH/KV =2,
INFILTRATION = 12% SURFACE, 17% SLOPE,
U[illegible] MARK BOGGS VAN G. PARAMETERS FOR KINGSTON ASH

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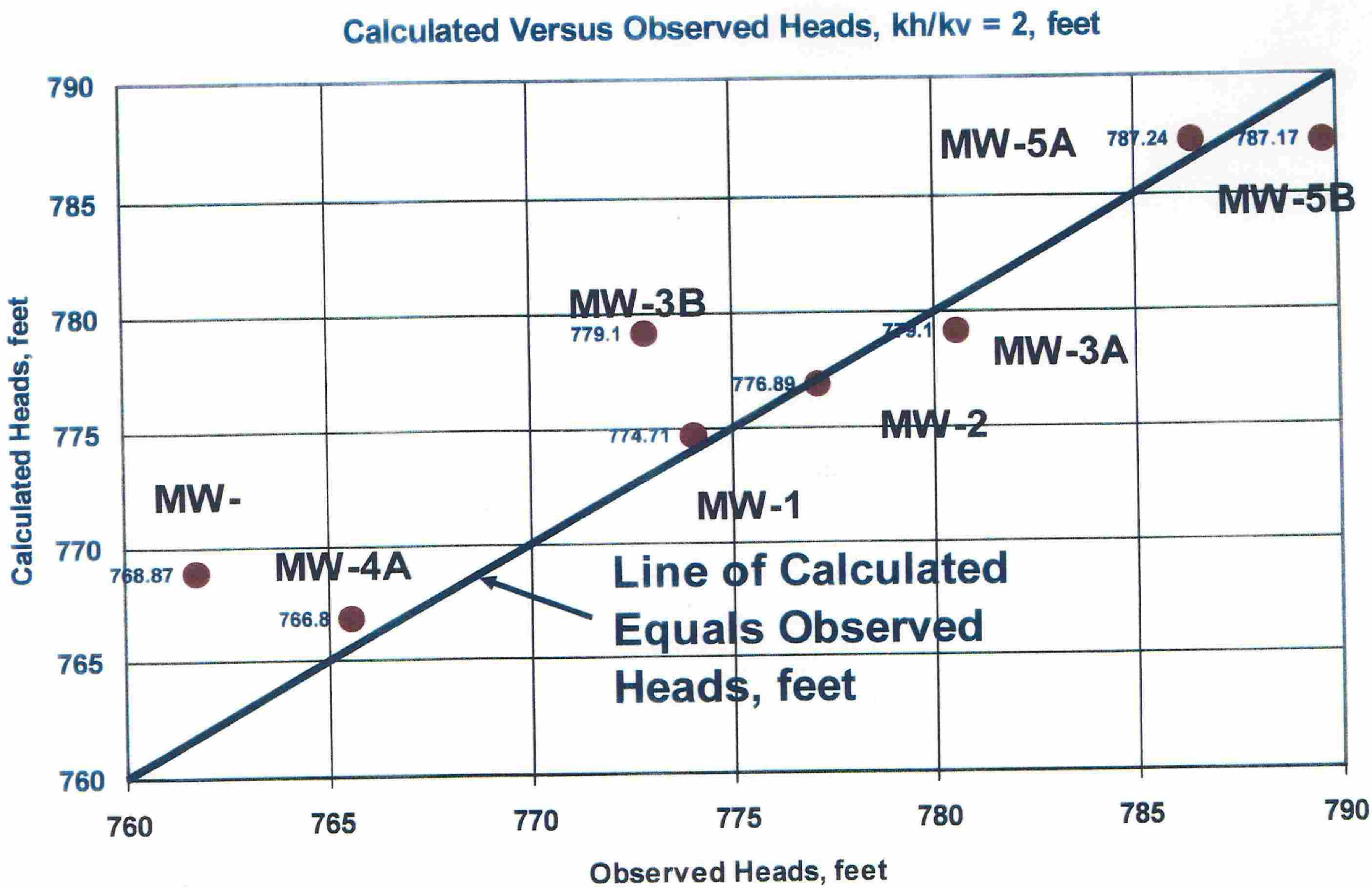


Calculated Versus Observed Heads, kh/kv = 2, feet
Calculated Heads, feet
Observed Heads, feet
760
765
770
775
780
785
790
MW-5A
787.24
787.17
MW-5B
MW-3B
779.1
MW-3A
776.89
MW-2
774.71
MW-1
MW-
768.87
MW-4A
766.8
Line of Calculated Equals Observed Heads, feet

The kh / kv = 2 for all soils gave the best calibration. The following monitoring wells show large calculated differences with the observed field heads because:

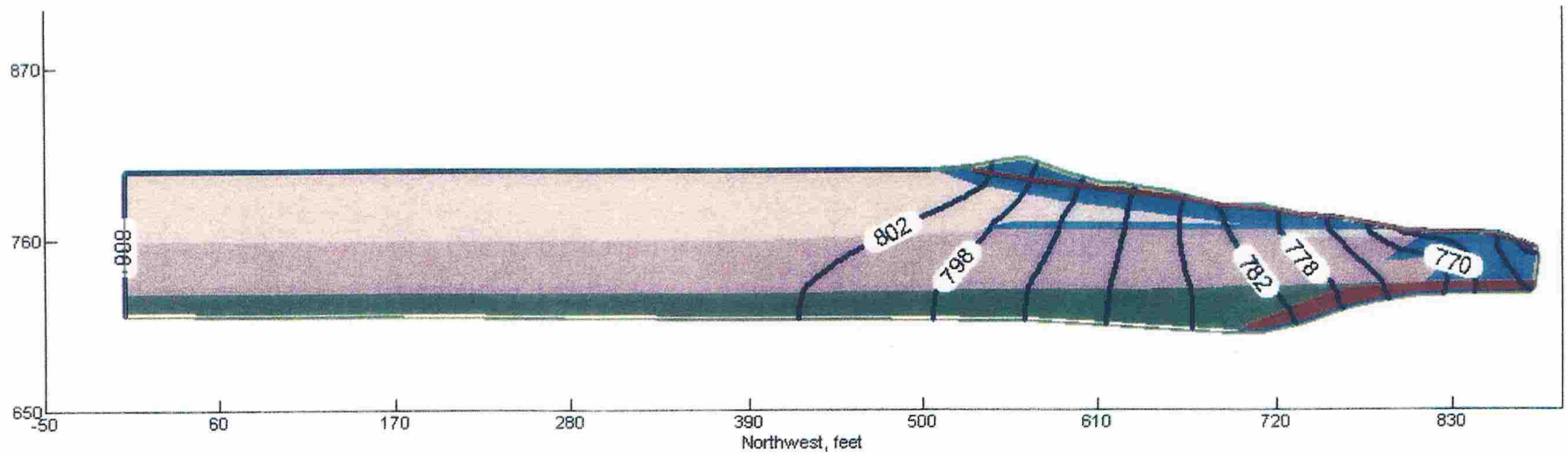
- MW – 3B measures lower heads than calculated because no flow boundary on the bottom increases heads. The downward head gradient reduces heads near the bottom in the field.
- MW - 4B measures lower heads than calculated because the no flow boundary increases the calculated heads where as the downward gradient in field reduces them.
- MW – 5B, by contrast, shows no increase in head with depth even though there is an upward gradient near MW – 5B.

Ignoring downward gradients near toe will

1. over predict uplift and seepage forces
2. under predict factors of safety for uplift / heave at toe and on benches of slope
3. under predict factor of safety for slope stability.

Thus the modeling approach is "conservative" results in a safer design.

CASE 2 – "BLOWOUT CONDITION" - KINGSTON DREDGE CELL III



TVA-00029371

Calculated Flow Rates at Seepage Faces Along Selected Benches

Seepage Face	Calculated Flow Rate	
	ft^3/day/ft	ft^3/sec/ft
765 to 775 Bench	0.884	1.026E-05
775 to 780 Bench	0.550	6.360E-06
781 to 784 Bench	0.440	5.089E-06

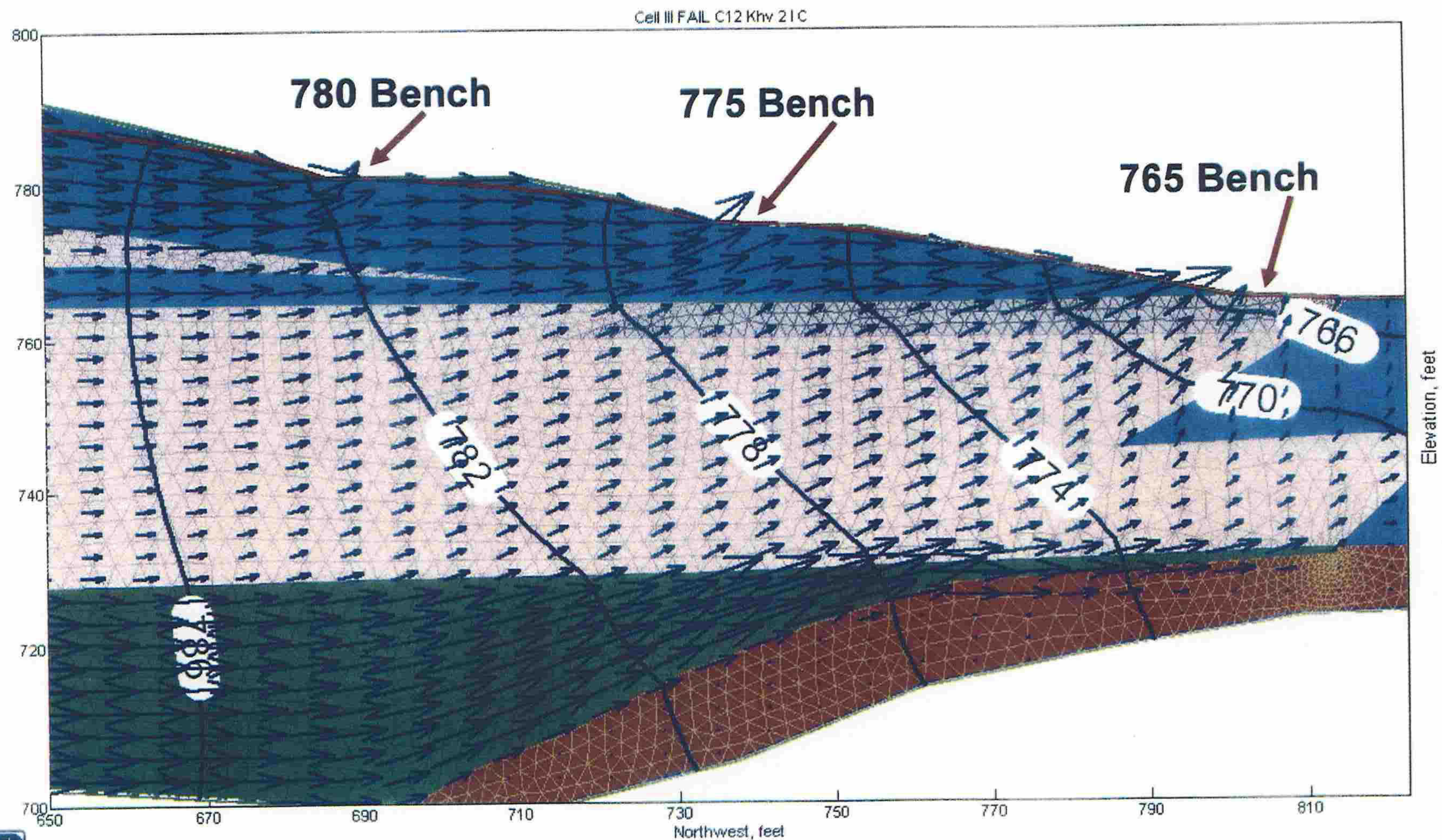
A NOTE ON FACTORS OF SAFETY

- *The US Army COE (1986, Pg. 4-24) recommends FS=1.5* ***up to 15 depending on knowledge of soil and seepage conditions*** *(NOTE THAT the* ***1.5 is solely*** *based on recommendation at a 1962 Missouri River Conference held in Omaha 27 November* ***based on the singular experience during Missouri River flood of 1952),***
- *Harr (1962) states that the FS should be 4-5, and*
- ***Cedergren states that Uplift FS for these calculations really should be 2 to 2.5 for boils (Pg. 227, Cedergren, 1967) AND 2.5 to 3.0 for uplift (Cedergren, Page 107, 1989, 3rd Edition). We meet the FS requirements of the US COE, Harr and Cedergren criteria.***
- ***Note that Cedergren 1967 cites as uplift as being APPLIED TO SOIL GRAINS Figure (3-2, b-2), not just on structures (See Pages 126 and 226) and Cedergren 1989, 3rd edition, Fig. 3.19, Page 102 and 227 shows this as the uplift term as well.***

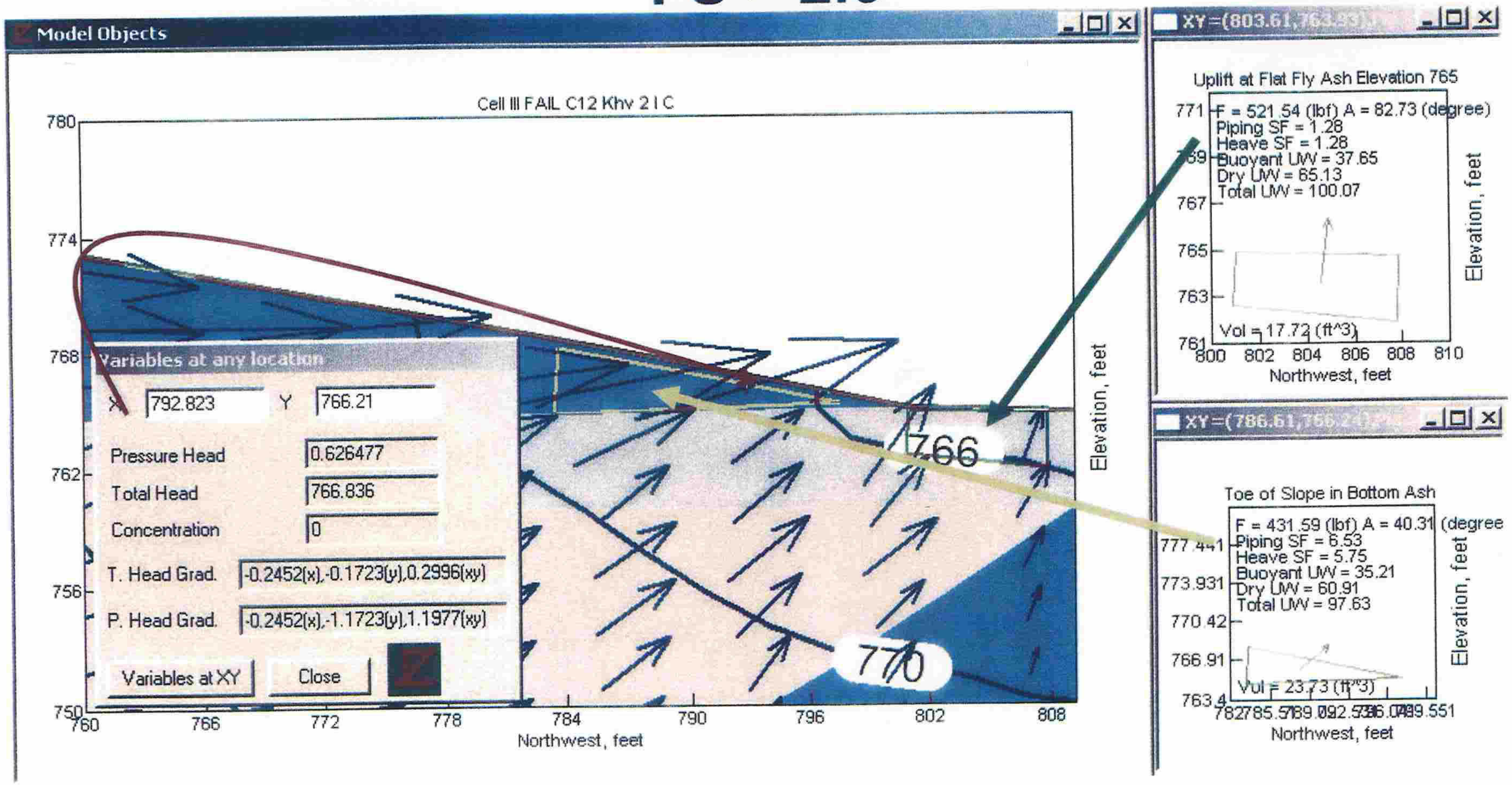
We have learned a lot since 1952, particularly, from Cedergren, Harr, and even the US COE that 1.5 FS is not a particularly safe factor of safety. Consequently, that is why we may be advised to use higher FSs.

TVA-00029373

Pore Water Velocity Vectors Shown on Close Up View of Lower Slope



Uplift Factors of Safety at 765 ft Bench Flat in Fly Ash Fall Below 2.0 (= 1.28) – But BA Slope FS > 2.0



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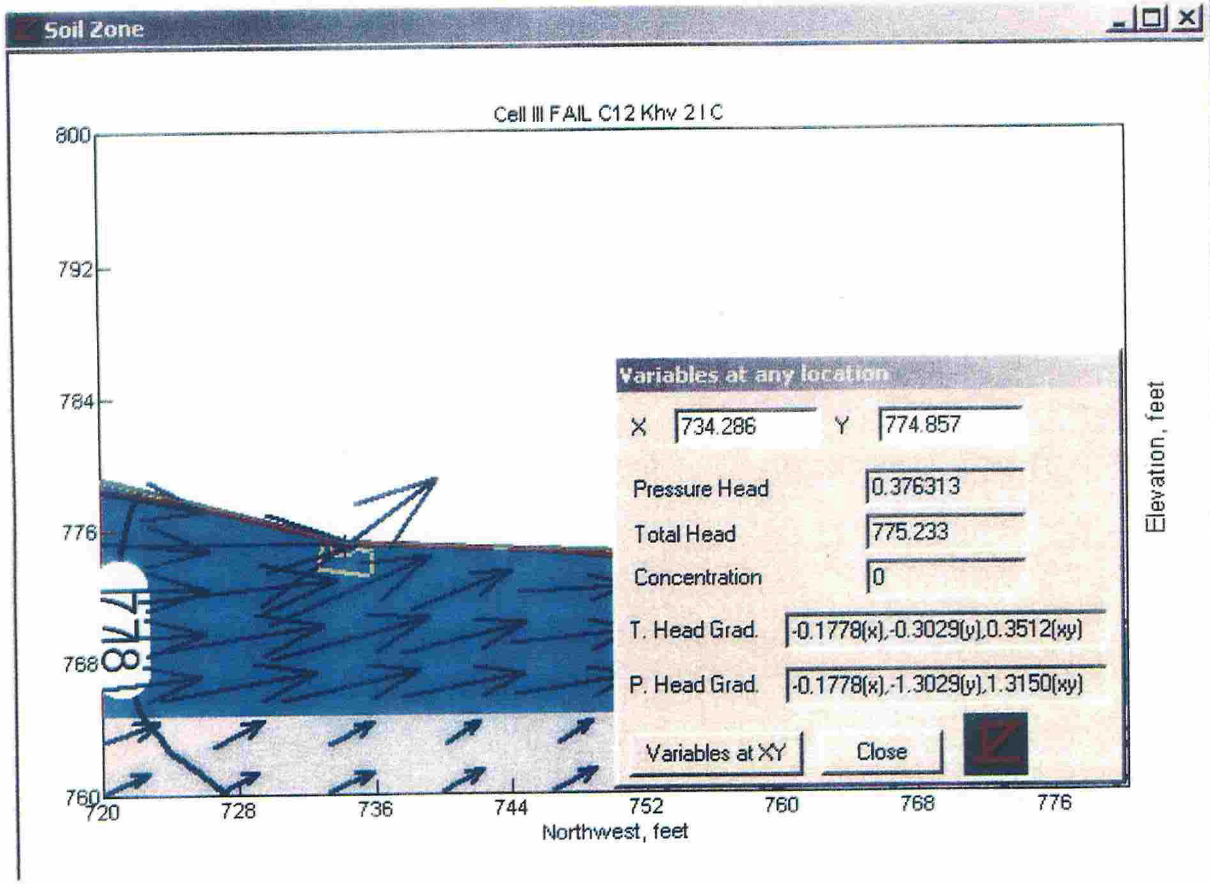
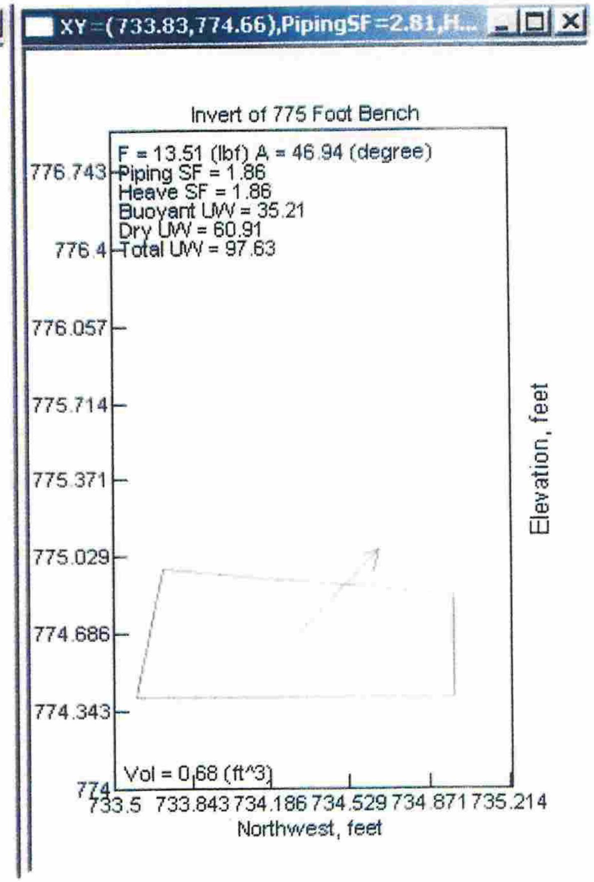
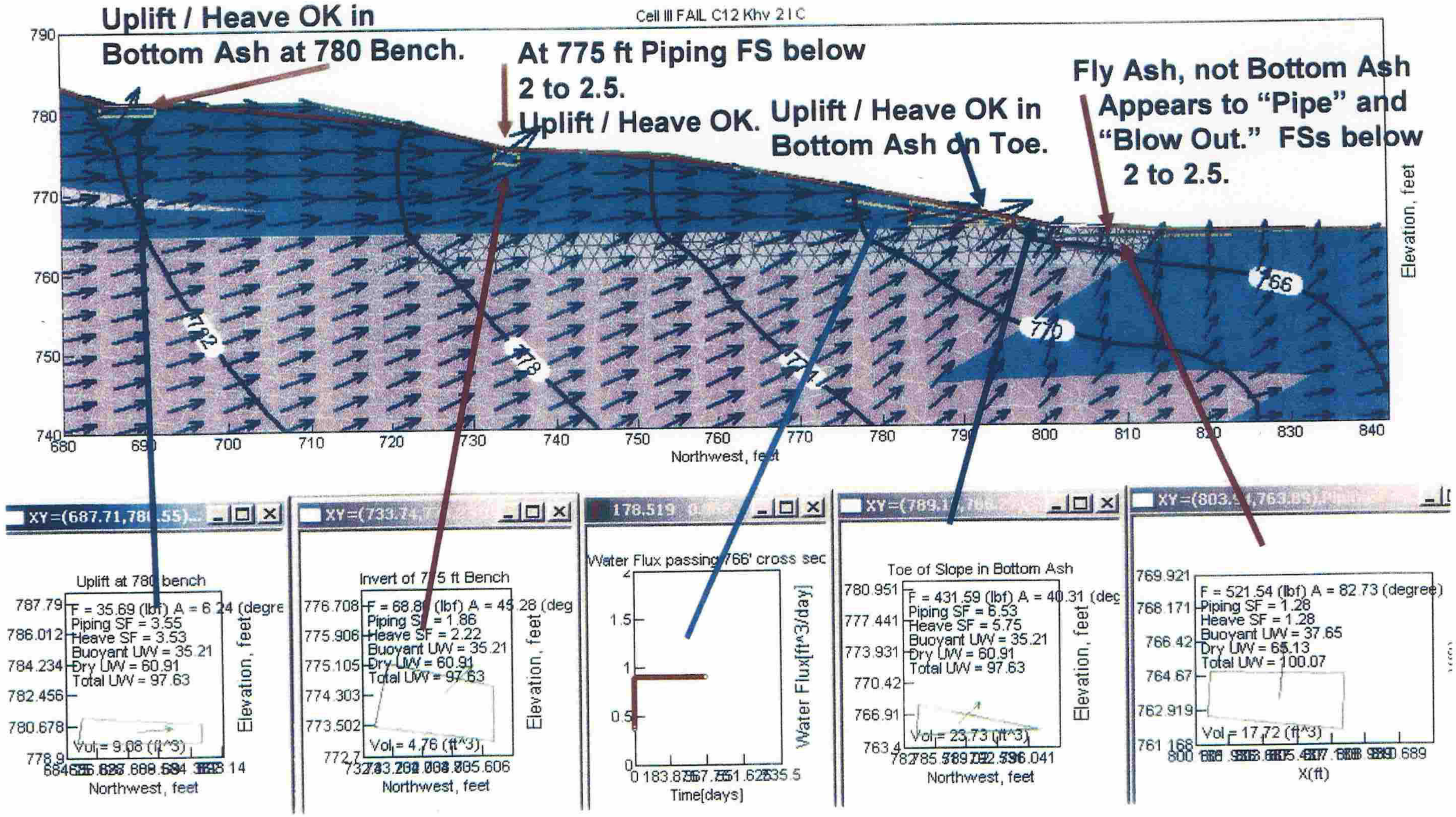
Toe of 775 ft Bench in BA – Piping and Uplift FS = 1.86; Below Requisite 2.0





TVA-00029376

UPLIFT FS AND FLOW VECTORS



CASE 2 – SEEPAGE FAILURE RESULTS

- Uplift FS is **1.28 < 2.0** at bottom of toe in the fly ash flat at Elevation 765 feet, approximately at the elevation observed in the field for the blowout.
- The slope above this point appears stable from seepage forces **except** the bench at the **775 foot elevation**. At this bench the factors of safety (**1.86**) fall below the requisite 2.0 (Boiling) to 2.5 to 3.0 (Uplift) required by Cedergren.

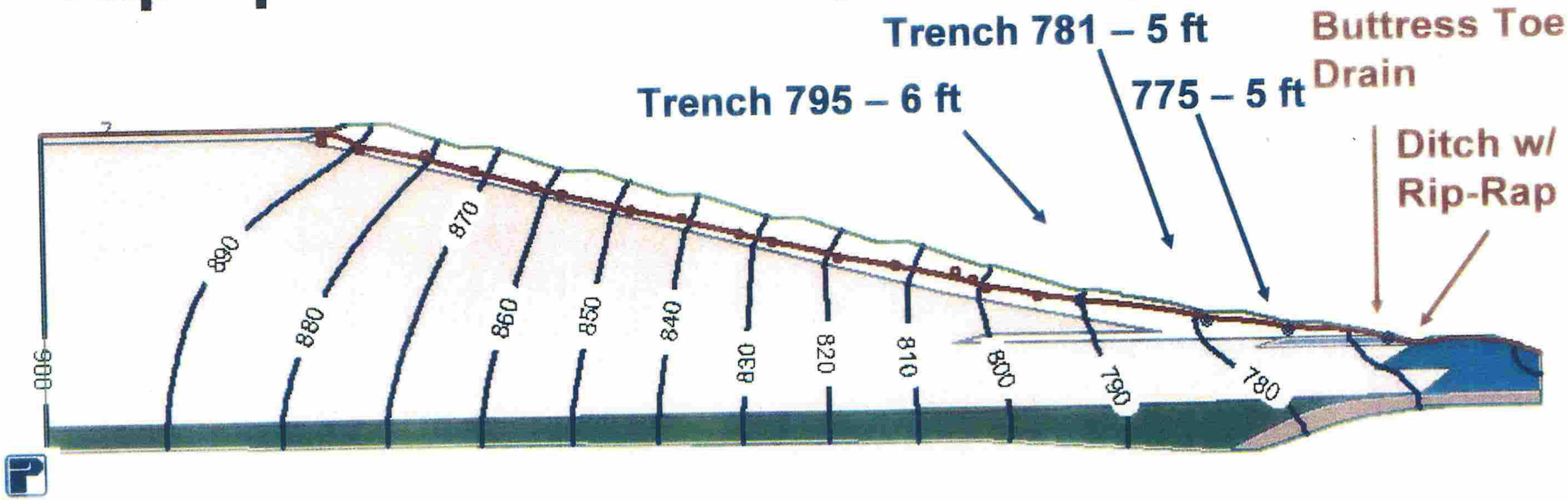
TVA-00029378

Case 3 – Looks at Future if Dredge Cell Raised to as High as 900 feet

1. Analyses evaluate the ifs of future vertical expansion of Dredge Cell goes to as high as 900 feet.
2. Analyses estimate what will the seepage conditions may be along the face of the unimproved lower slope.
3. Analyses evaluate alternatives to arrive at most the efficient solution to reducing seepage forces to requisite factors of safety of 2 to 2.5.
4. These solutions include trench and buttress drains parallel to the slope.
5. Parsons E & C prepares the final seepage design and construction drawings.
6. **Note that the permit currently sets the maximum height of the dredge cells to an elevation of 842 feet.**

CASE 3 - 900 Foot Pool
Parsons Proposed Design

- One 6-foot Trench at 795 feet, Two 5-foot Trenches at 781, and 775 feet
- Buttress Toe Drain for Seepage Uplift
- Riprap Channel to Stop Seepage Uplift



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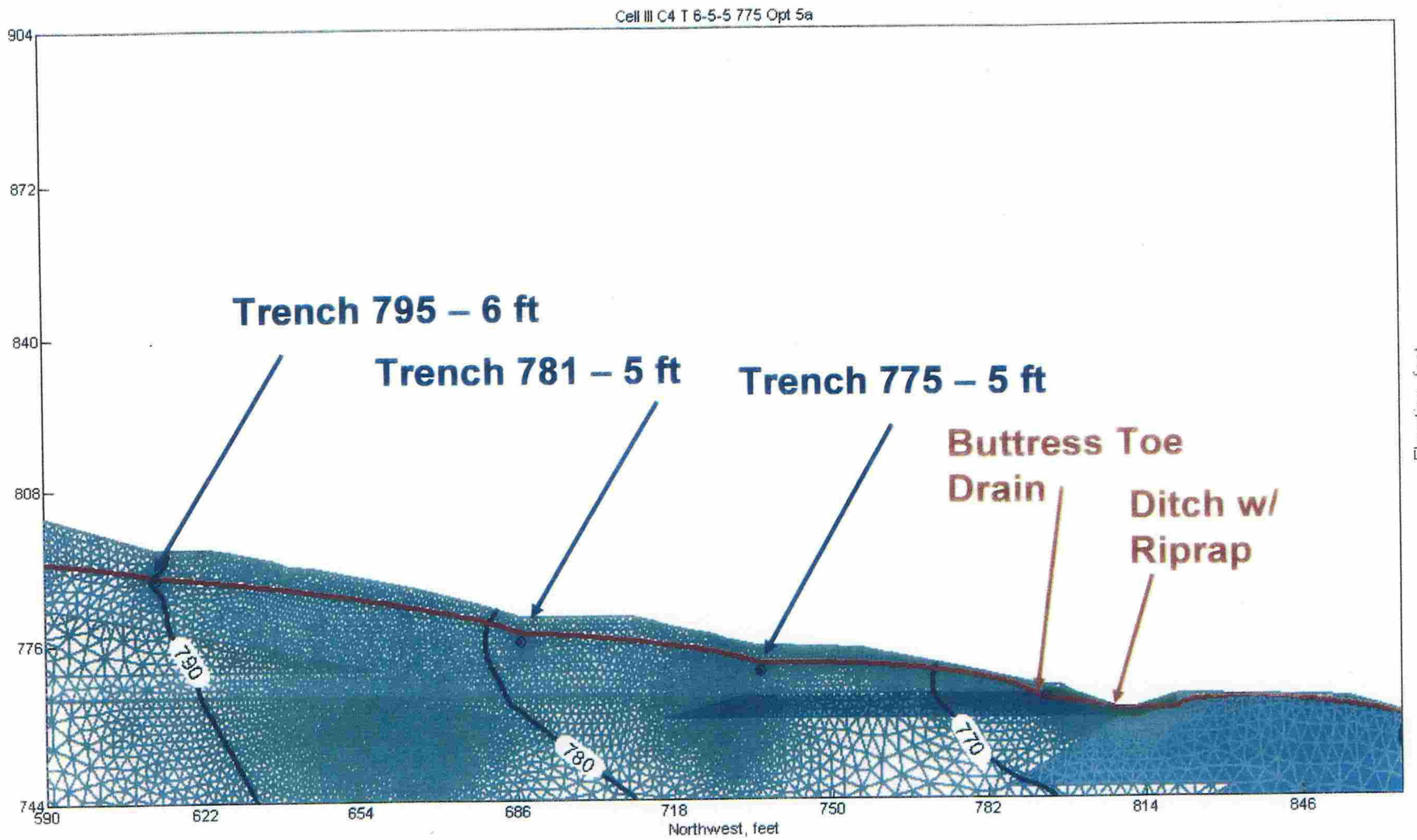
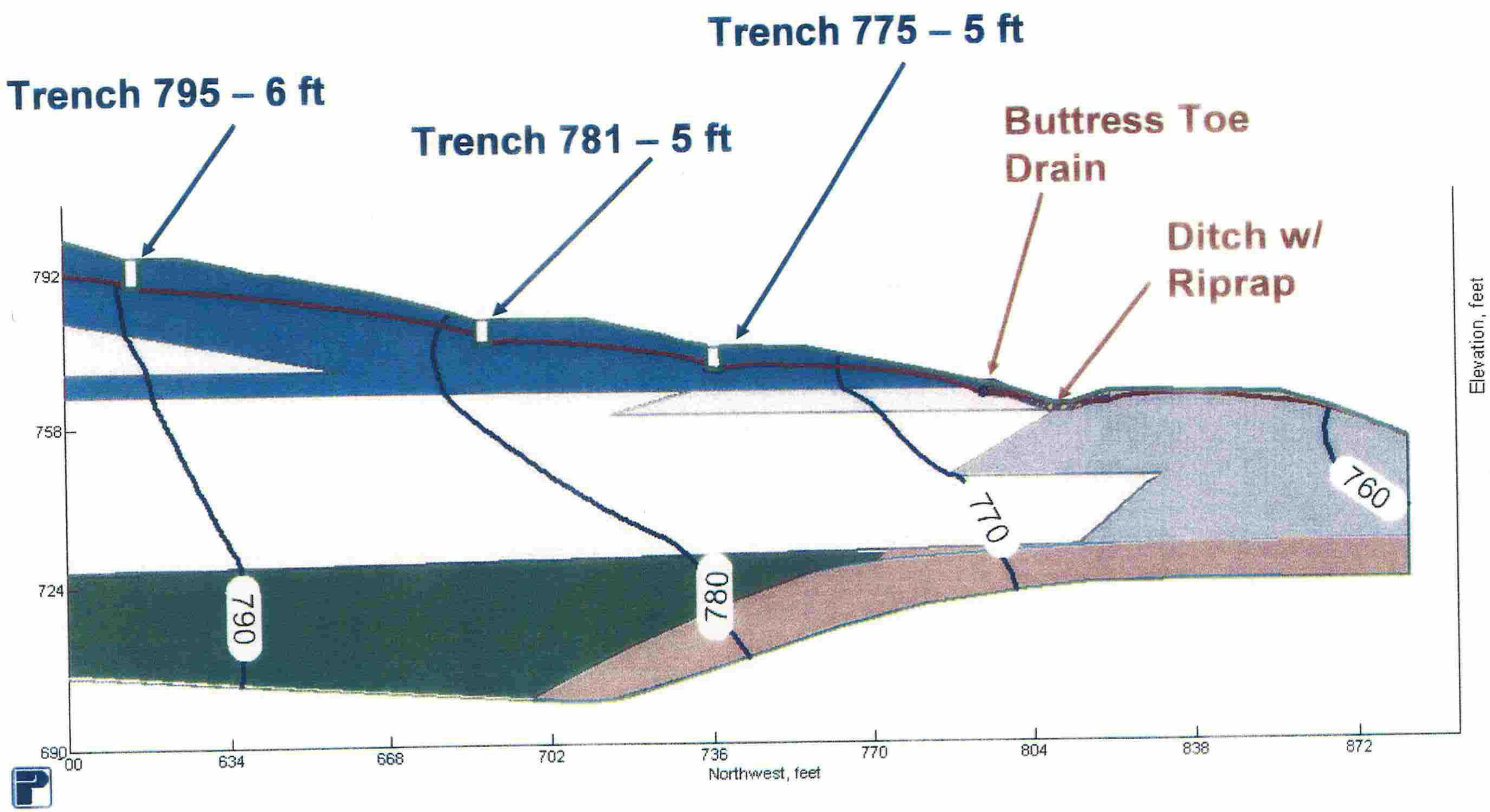
FINITE ELEMENT MESH NEAR TRENCH, BUTTRESS, AND DITCH AREAS



TVA-00029381

CASE 3 – CLOSEUP ON TRENCHES

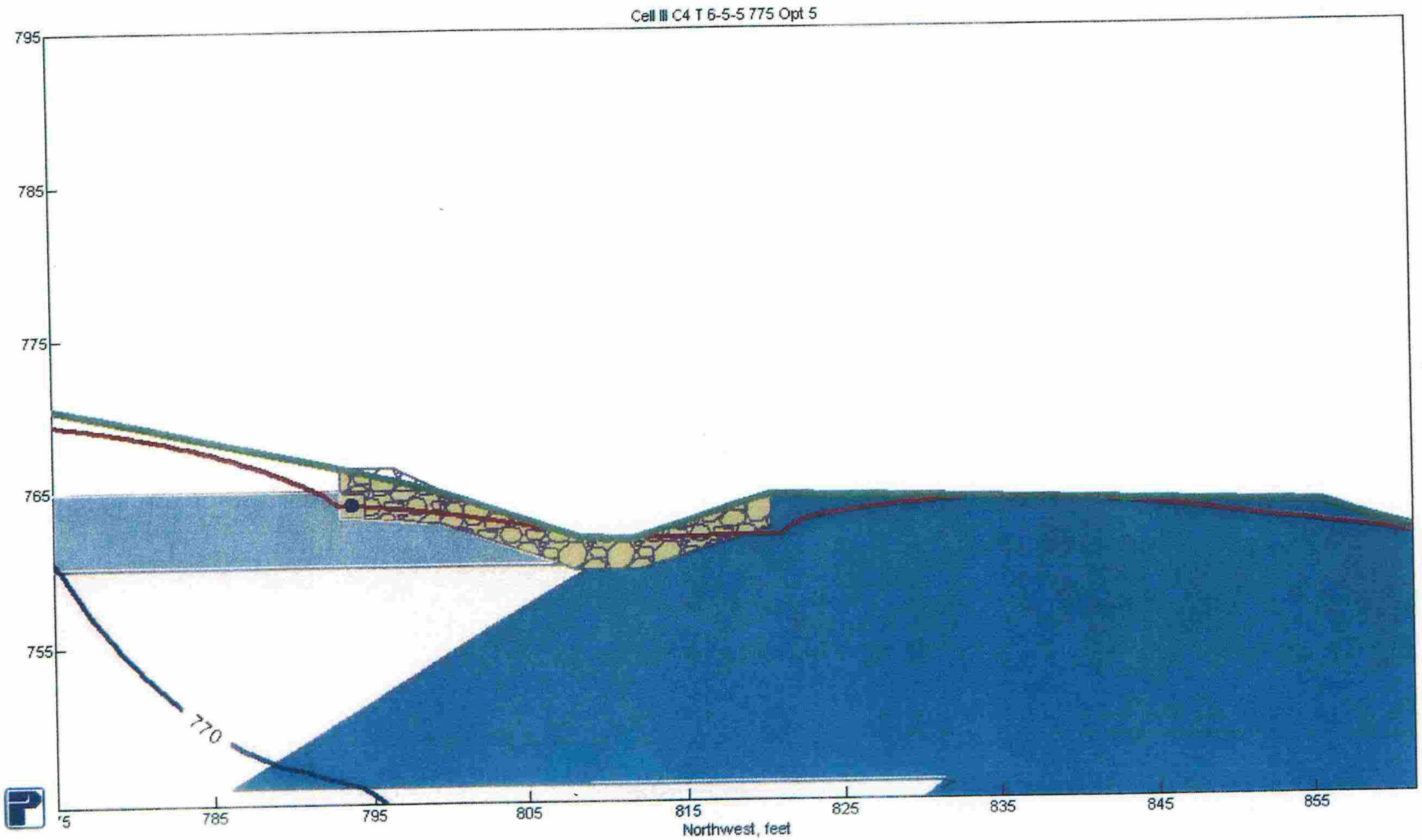


TVA-00029382

Calculated Flows for Future 900 ft Dredge Cell

Well /Trench	ft^3/day/ft	ft^3/sec/ft
Buttress Ditch	0.921	1.066E-05
Geocomposite Drainage	5.1	5.903E-05
8-Inch Pipe	0.592	6.852E-07
775 ft Elevation Bench 5-Foot Trench	1.13	1.308E-05
781 ft Elevation Bench 5-Foot Trench	1.26	1.458E-05
795 ft Elevation Bench 6-Foot Trench	0.38	4.398E-06
797 foot Elevation Pipe Drain	0.93	1.076E-05
802 foot "	0	0
807 foot "	0	0
812 foot "	0.0058	6.713E-08
817 foot "	0.59	6.829E-06
827 foot "	0.29	3.356E-06
832 foot "	0.29	3.356E-06
842 foot "	0	0
847 foot "	0.259	2.998E-06
857 foot "	0.172	1.991E-06
862 foot "	0.0269	3.090E-07
872 foot "	0	0
882 foot "	0	0
887 foot "	0.804	9.306E-06
892 foot "	1.21	1.400E-05

Riprap Design for Buttress and Ditch



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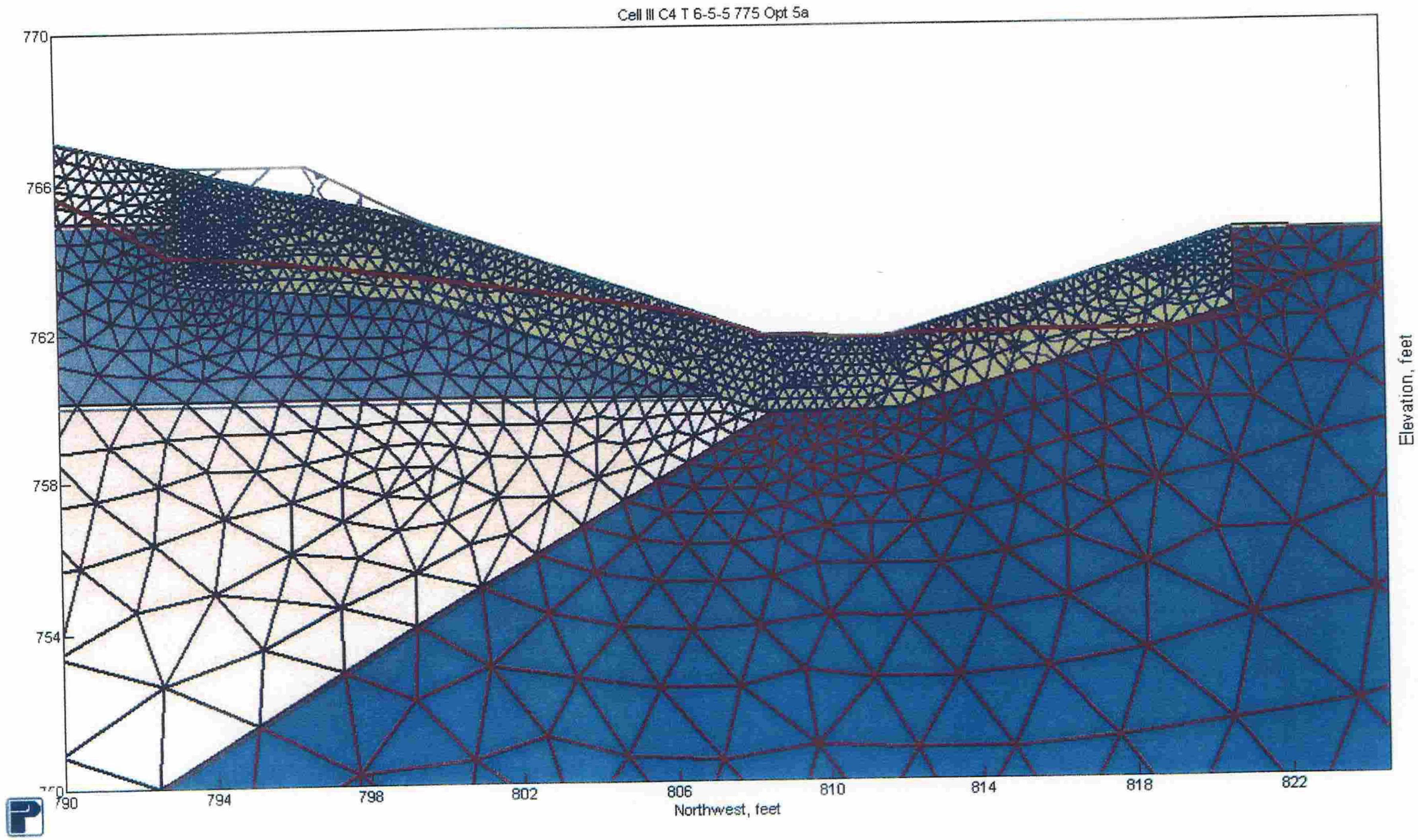
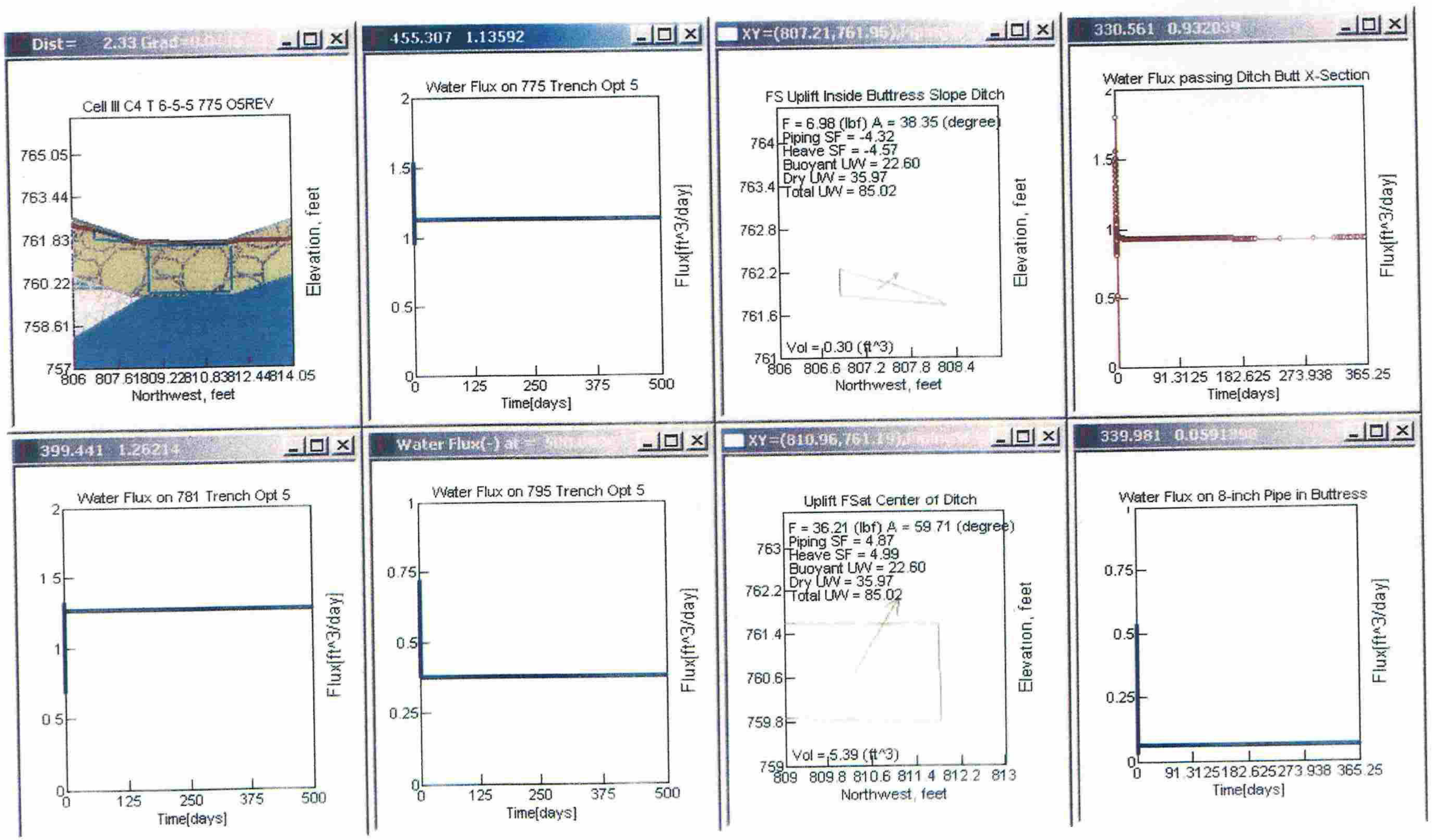
Hydraulic Properties of Buttress and Ditch Rip-Rap

- Hydraulic conductivity, k = 1.42 ft/day or 5.0E-04 cm/sec (at a minimum). **To assess uplift seepage forces on riprap under clogged conditions;**
- Actual k will be **> 120,000 ft/day** (Cedergren, 1989)
- VG alpha = 0.01944/ft
- VG n = 2.68
- Geotextile is assumed underneath the riprap.
- Bulk Unit Weight of Riprap equals 80 to 85 pcf (Source Red and Blue Steel Manuals, and the Pocket Reference (Glover,2001)

Finite Element Mesh At Buttress And Riprap Ditch



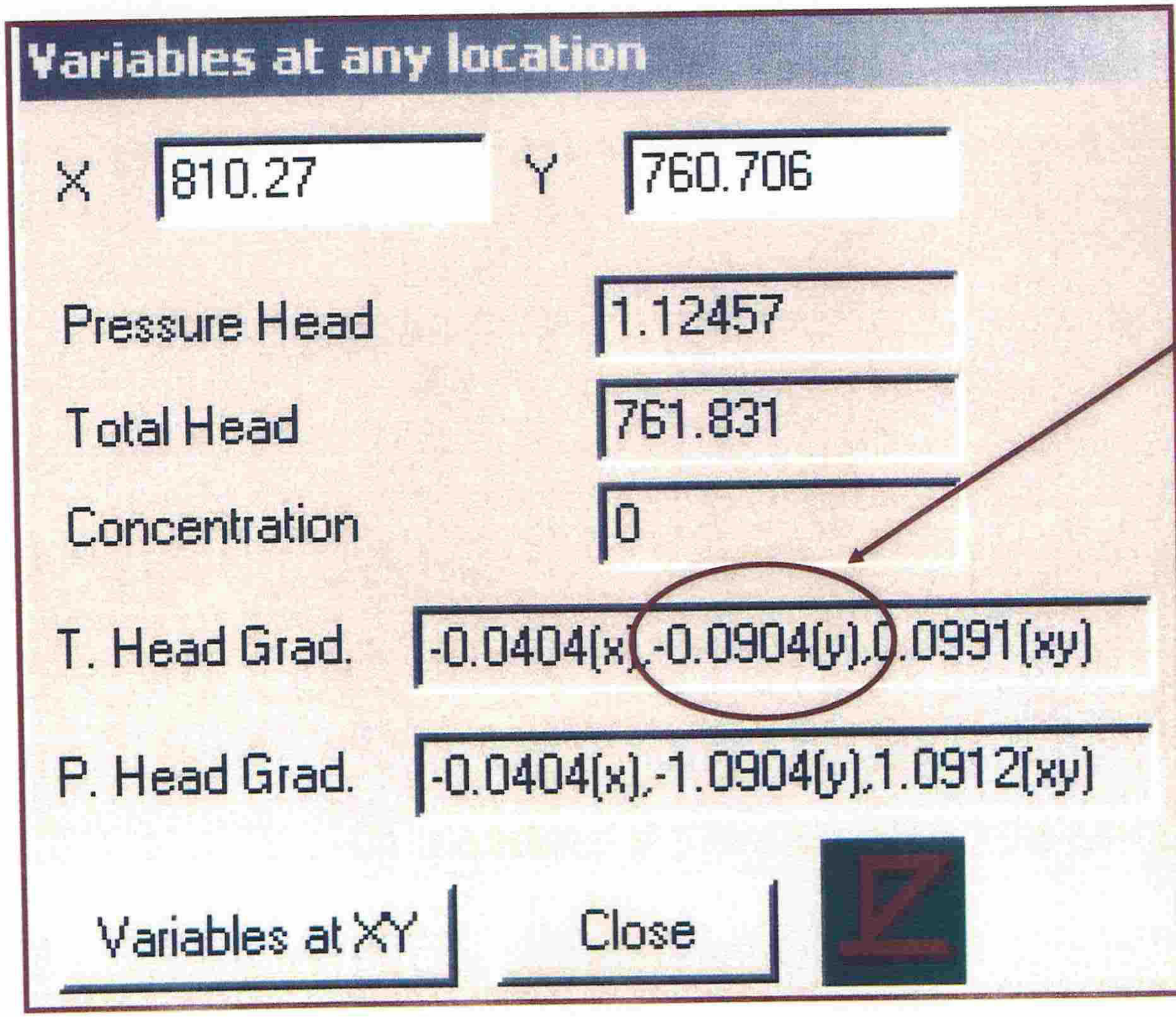
UPLIFT FS AND FLUXES



Results

- All Uplift Factors of Safety (FS) are calculated for below the water table **AT SEEPAGE FACE**. They do not take into account **SOIL OVERBURDEN**.
- Therefore, any uplift FSs calculated by the TIMES code for a water table below the ground surface will be greater than the calculated value. Addition of the weight of soil above the water table will increase the calculated UPLIFT FSs.

Variables at Any Location



Total Head Gradient in Y Direction,

Note Negative Sign Means UPWARD.

Positive Y direction is <u>DOWNWARD, as in water moving down hill is + Y.</u>

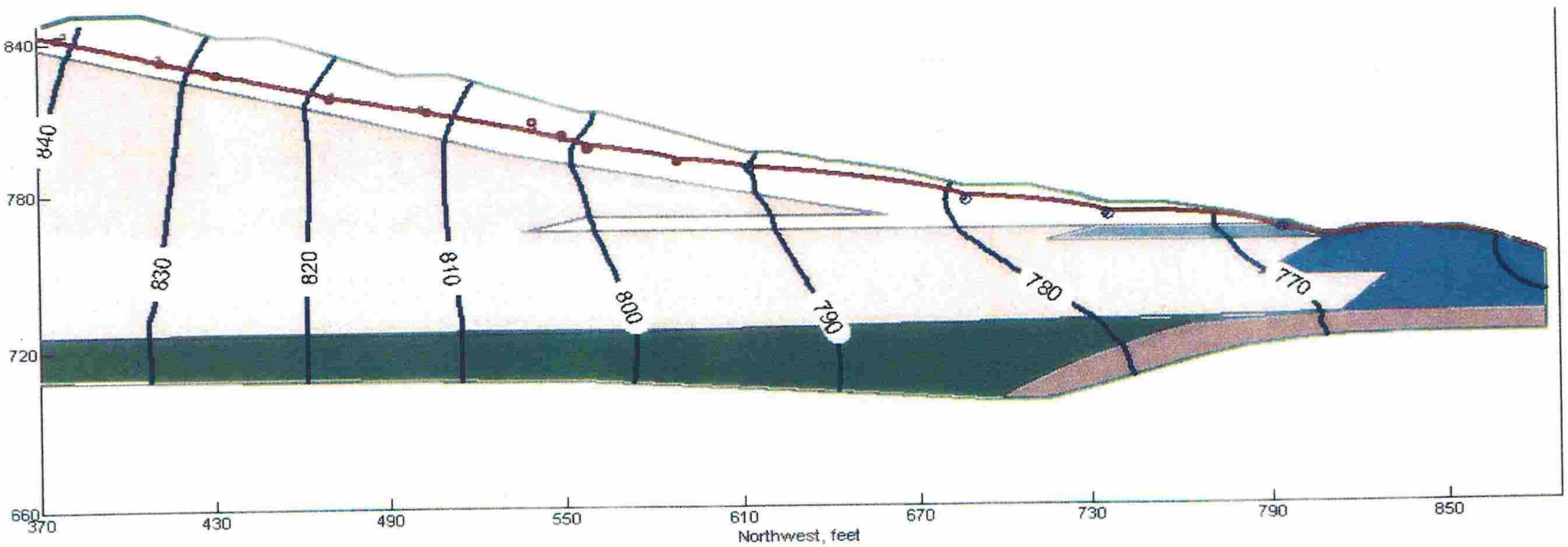
Case 3 - Conclusions

1. **Uplift Factors of Safety satisfy 2 to 2.5,** including the ditch with rip-rap when average bulk unit weight is consider (Average FS = 4.005).
2. **Use 3 Trenches – 795 trench 6 feet deep, the 781 and 775 trench 5 feet deep.**
3. Use the Buttress Toe and Drain as shown.
4. Use a Ditch with Riprap and Geotextile on the Bottom (optional, depends on Pond).

SLOPE STABILITY CHECK

- CHECKED FIRST THE **842 FOOT POND ELEVATION DESIGN** BECAUSE THAT WAS OUR ORIGINAL PERMIT PLAN.
- SETUP **TIMES RUN** FOR 842 FOOT POND ELEVATION.
- SETUP **END OF CONSTRUCTION** SLOPE STABILITY RUNS WITH UTEXAS3 AND SLOPE/W.

TIMES RESULTS
842 FOOT PERMIT ELEVATION



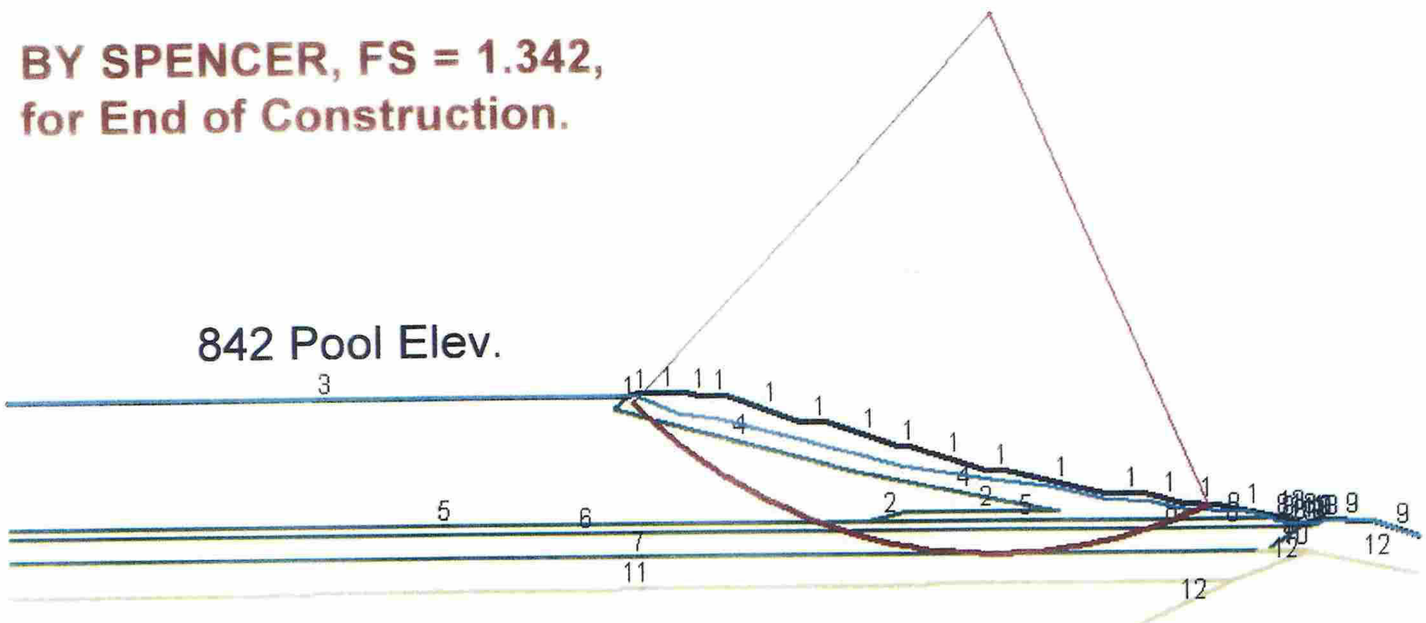
TVA-00029392

End of Construction – UTEXAS3

C:\UTEXAS3\KFAASR23.UT3
Kingston 8 Swan Road-Sect 4-4, End Of Construction
Fly Ash Option + EOC WT at 842 feet
KIF Wet +842 Pond Search Circles
F = 1.342, X = 618.0, Y = 1069.0, R = 322.8

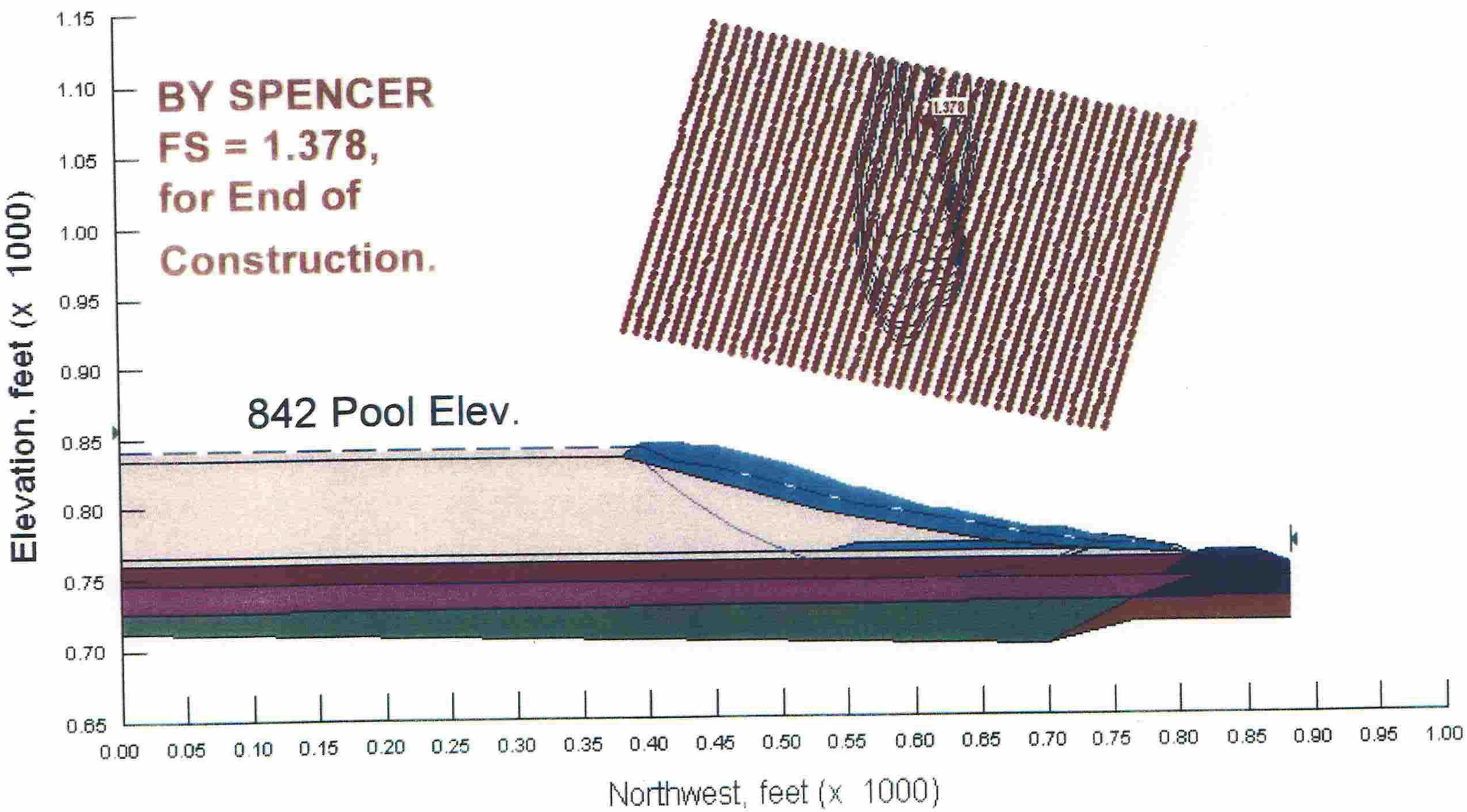
BY SPENCER, FS = 1.342, for End of Construction.

842 Pool Elev.



TVA-00029393

End of Construction – SLOPE/W



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SUMMARY AND CONCLUSIONS

1. End of Construction Factors of Safety barely exceed minimum requirements using effective stress analysis strength parameters. Total stress strength parameters yield slightly higher FSs for layers that may not drain during construction period.
2. Going to full 900 foot pool elevation may require drainage techniques other than deep trenches to remain economically feasible and effective.
3. Slope stability analyses confirm that current buttress and ditch configuration needs no modification.
4. An increase in the depth of trenches or buttress will yield only small increases in the stability of the slopes and the stacks against seepage / uplift forces.