NRC – Callaway / Wolf Creek Public Meeting

GL 2004-02 Response RAIs

November 20

2009

Introduction

- The purpose of this presentation is to address GL 2004-02 RAIs for Union Electric Company (Callaway) and Wolf Creek Nuclear Operating Corporation (Wolf Creek).

Order of Presentation

- RAIs common to both Wolf Creek and Callaway:
  - RAIs 3-13 &16, 14, 26, 24, 29, 30, 21, 35, 17, 28, 33, 32, 27, 22, 37, and 39
- RAIs for Callaway only:
  - RAI 2

Major Hardware Modifications

Major Hardware Modifications

RAI #3 - #13 & 16

- Mid-December NRC-Owners group meeting to resolve ZOI issues
- <u>Contingency Plan</u>:
  - Callaway and Wolf Creek are confident that NRC and industry will successfully resolve the ZOI issues
  - If the NRC does not accept WCAP-16710, Callaway and Wolf Creek would implement fiber reduction by various means

RAI #14 – Wolf Creek

- Wolf Creek
  - Not applicable since not installed inside containment

RAI #14 – Callaway

- The steam generator replacement project at Callaway replaced limited amounts of NUKON™ insulation with Thermal-Wrap™ on portions of the piping systems connected to the steam generator such as the steam generator nozzles.
- The Thermal Wrap insulation system installed at Callaway has the same stainless steel jacketing (22 gauge with circumferential and longitudinal overlap) and buckle / latch configuration (very similar dimensions) as the Nukon insulation testing performed for Callaway and Wolf Creek.

RAI #14 – Callaway (cont'd)

- As stated by Wolf Creek in their December 22, 2008 submittal with regard to the Wolf Creek and Callaway Nukon jet impingement testing:
  - For the 8D (25.4 L/D) ZOI test of jacketed NUKON insulation system, all of the stainless steel jacketing was observed to remain in place following this test.

RAI #14 – Callaway (cont'd)

- Since the stainless steel jacketing remained in place at a distance of 8D (25.4 L/D), and the jacketing system is equivalent for the Thermal Wrap insulation, the use of an 8D ZOI for the Transco Thermal Wrap insulation system at Callaway is appropriate and justified.
- Sensitivity calculations have been performed and indicate that the increase of a ZOI from 7D to 8D does not increase the fibrous debris quantities for any of the bounding piping breaks at Callaway.

RAI #14 – Callaway (cont'd)

- In addition, with regard to the referenced testing for ANO (ADAMS Accession No. ML080710544) for RAI #14 indicating damage at 12D (45.7 L/D) and 7D (22.7 L/D), the test specimen utilized a non-jacketed Thermal Wrap insulation system as opposed to the stainless steel jacketing used at Callaway.

RAI #26

- Miscellaneous debris transport testing was conducted following the clean strainer head loss test with the test flume recirculation pump running, while the test flume water was clear providing good visibility
- The various types of miscellaneous debris used in the testing were inserted at the surface of the water in the drop zone
  - When the debris was inserted into the flume, it was oriented parallel to the surface of the water to maximize the potential for floating and transport

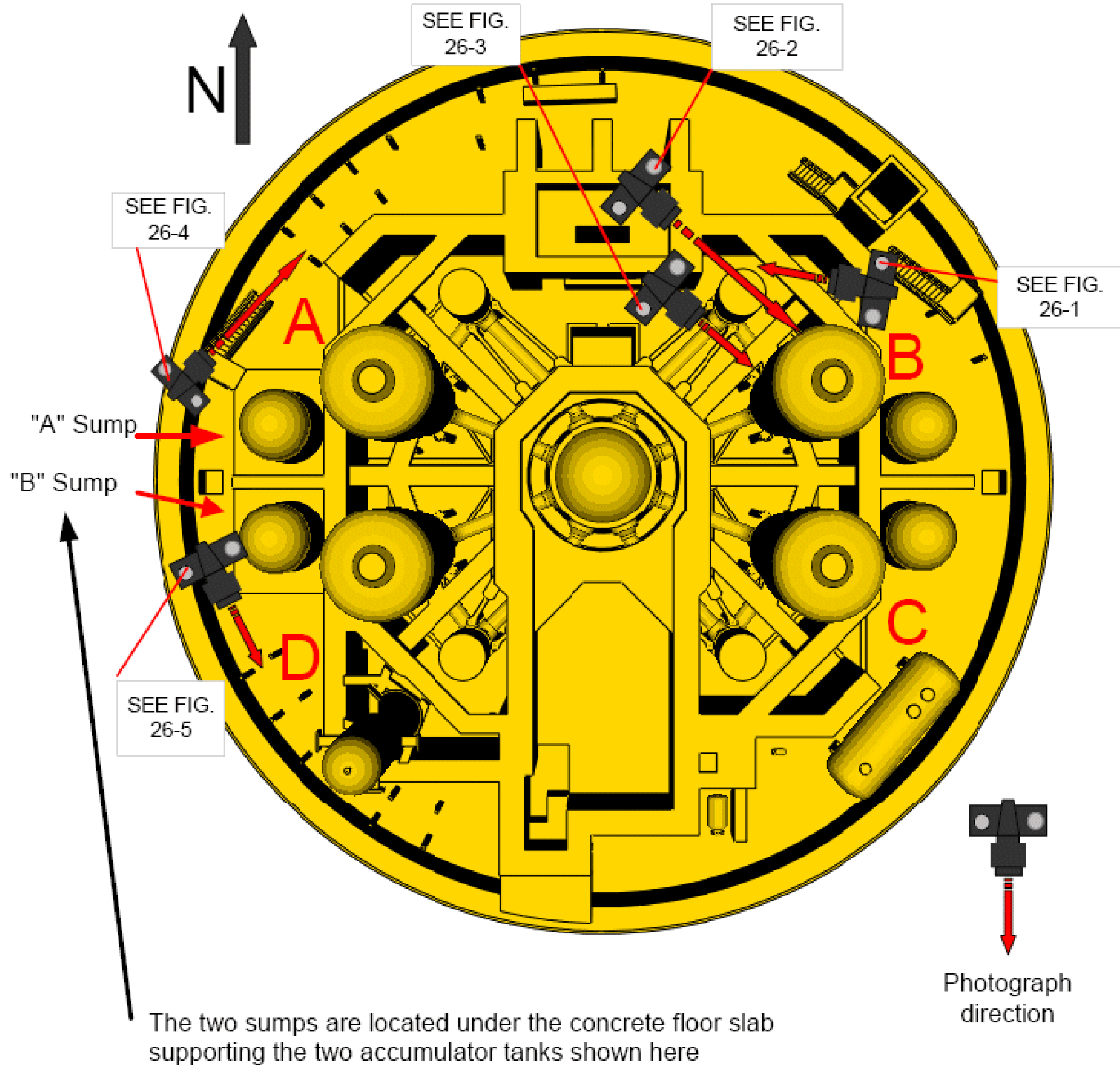
RAI #26 (cont'd)

- Of all of the miscellaneous debris tested, only two materials were found capable of floating.
  - These two materials represent 1.4% of all miscellaneous debris assumed.
    - The maximum surface area of miscellaneous debris postulated to float is only 4.6 ft^2 total if all debris generated that floats reaches the screen. Applying the 75% area reduction criteria for equipment labels and tape (SE, "Staff evaluation of GR Section 3.5.2.2.2"); only 3.45 ft^2 is postulated to float to the top of screens.
    - 3.45 ft^2 represents 0.1% of one strainer assembly surface area; which is not significant when compared to the total area available
  - All other miscellaneous debris (~98%) was found to not float.

RAI #26

- 95% of the miscellaneous debris (313.8 ft^2 of 330.2 ft^2), all non-porous is initially located inside the secondary shield wall, would be subjected to pipe break conditions (100% humidity)
- Pre-soaking the debris is prototypical since the miscellaneous debris will be wetted (surface air bubbles removed) by direct exposure to the LOCA break and long transport time due to tortuous path to the strainers

RAI #26 (cont'd)


N
SEE FIG. 26-3
SEE FIG. 26-2
SEE FIG. 26-4
SEE FIG. 26-1
SEE FIG. 26-5
A
B
C
D
"A" Sump
"B" Sump
Photograph direction
The two sumps are located under the concrete floor slab supporting the two accumulator tanks shown here

RAI #26 (cont'd)

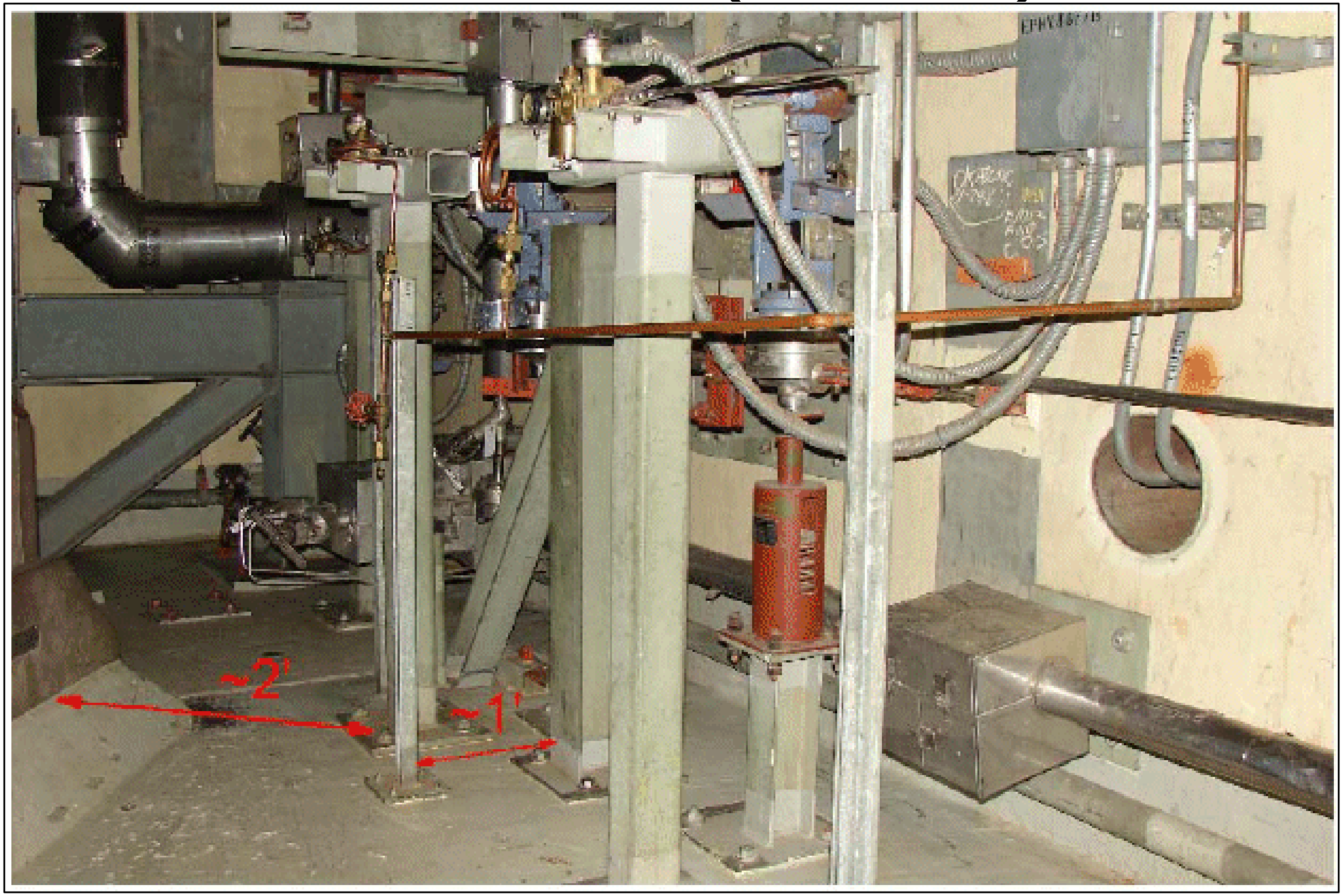
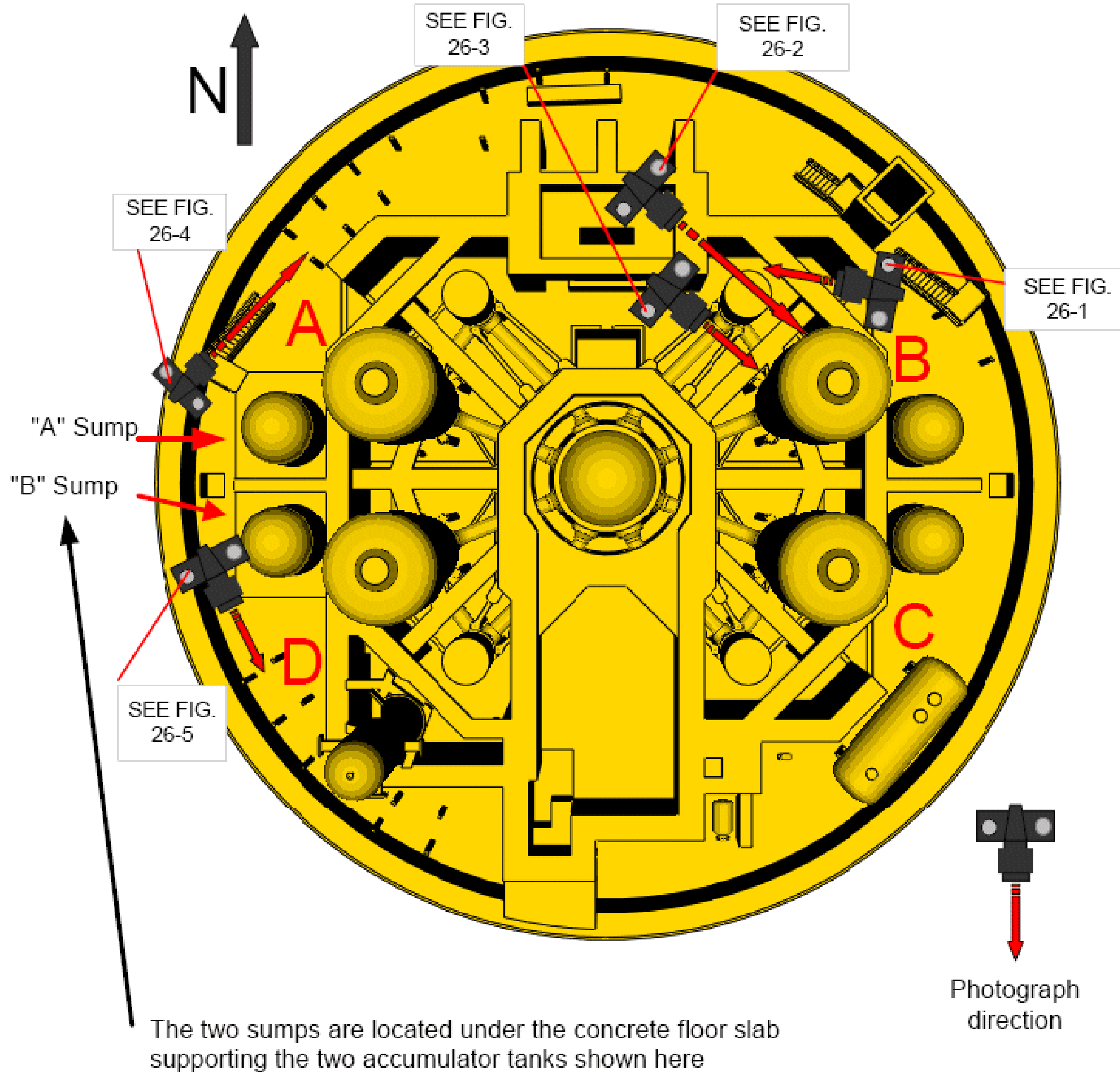


Figure 26-1

RAI #26 (cont'd)


N
SEE FIG. 26-3
SEE FIG. 26-2
SEE FIG. 26-4
SEE FIG. 26-1
A
B
C
D
"A" Sump
"B" Sump
SEE FIG. 26-5
Photograph direction
The two sumps are located under the concrete floor slab supporting the two accumulator tanks shown here

RAI #26 (cont'd)

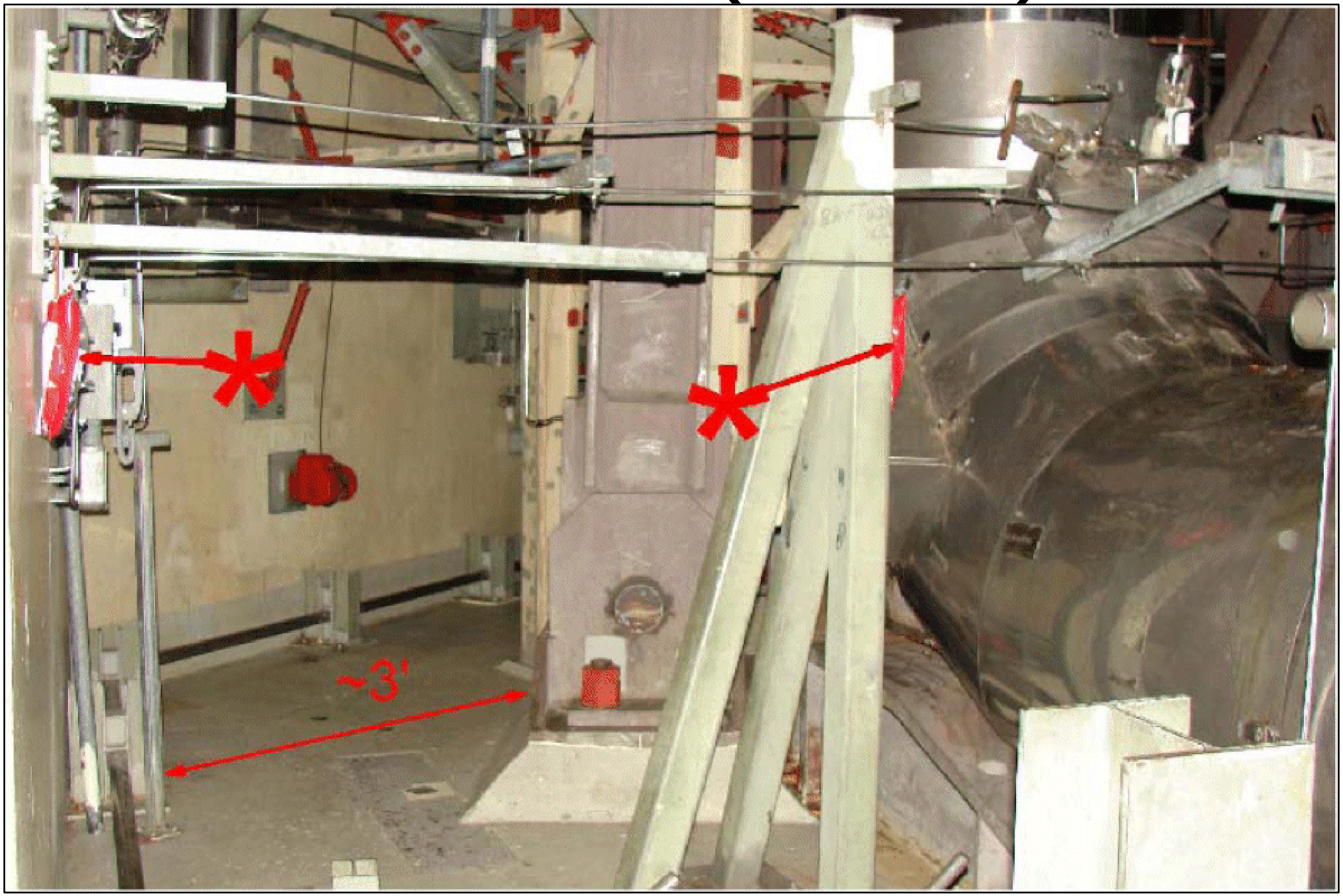
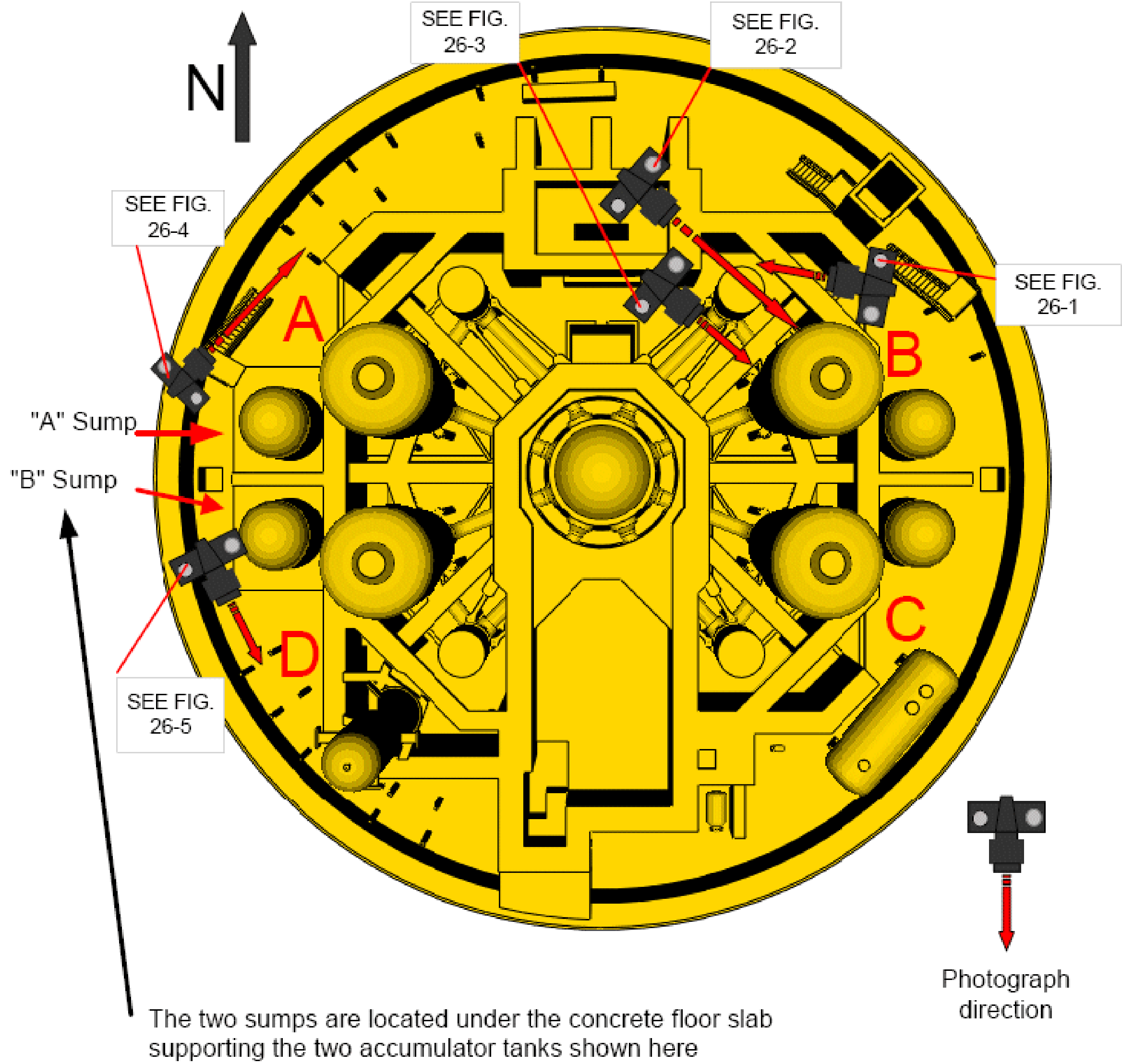


Figure 26-2

RAI #26 (cont'd)


SEE FIG. 26-3
SEE FIG. 26-2
N
SEE FIG. 26-4
SEE FIG. 26-1
A
B
"A" Sump
"B" Sump
C
D
SEE FIG. 26-5
Photograph direction
The two sumps are located under the concrete floor slab supporting the two accumulator tanks shown here

RAI #26 (cont'd)

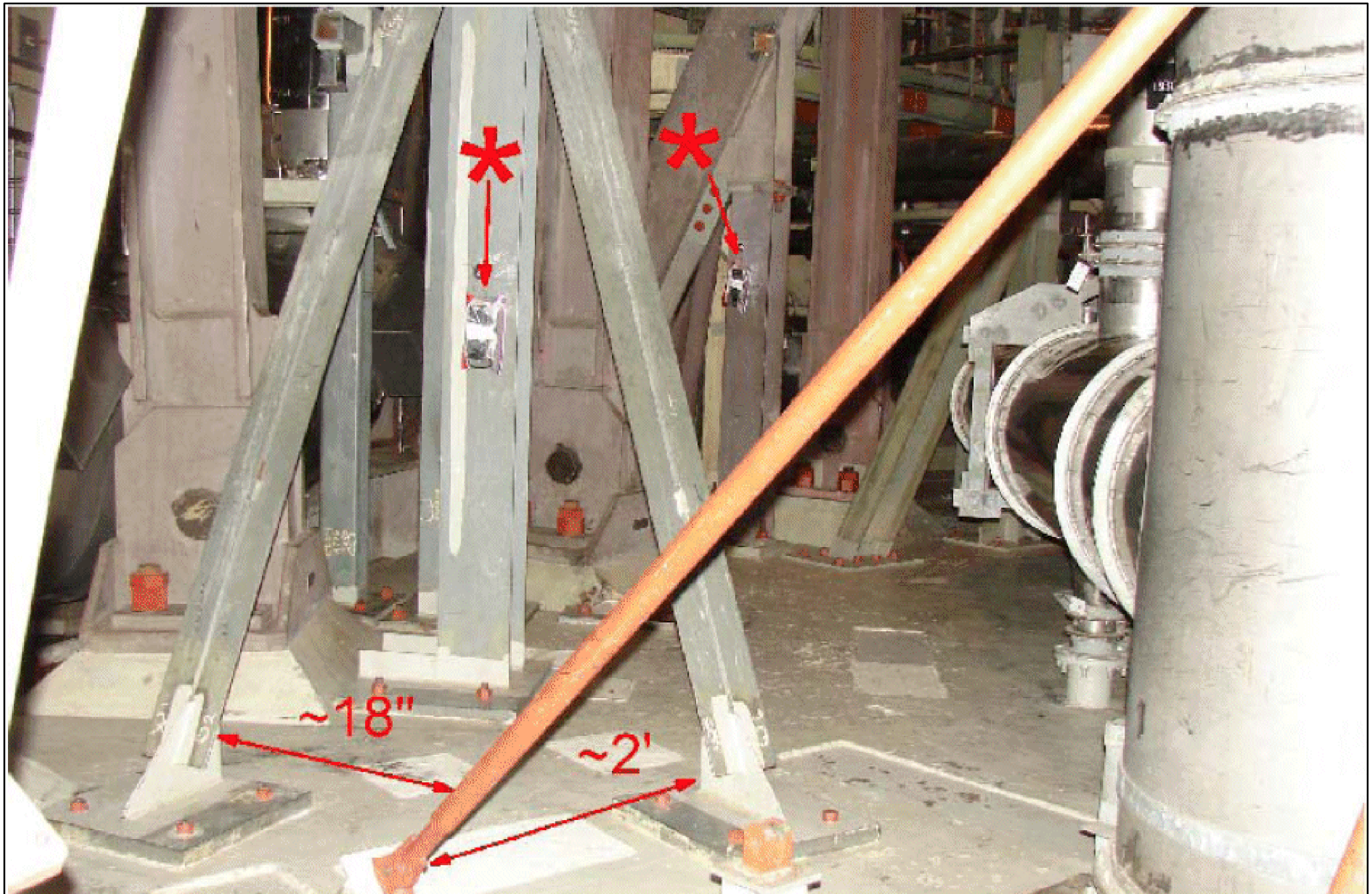
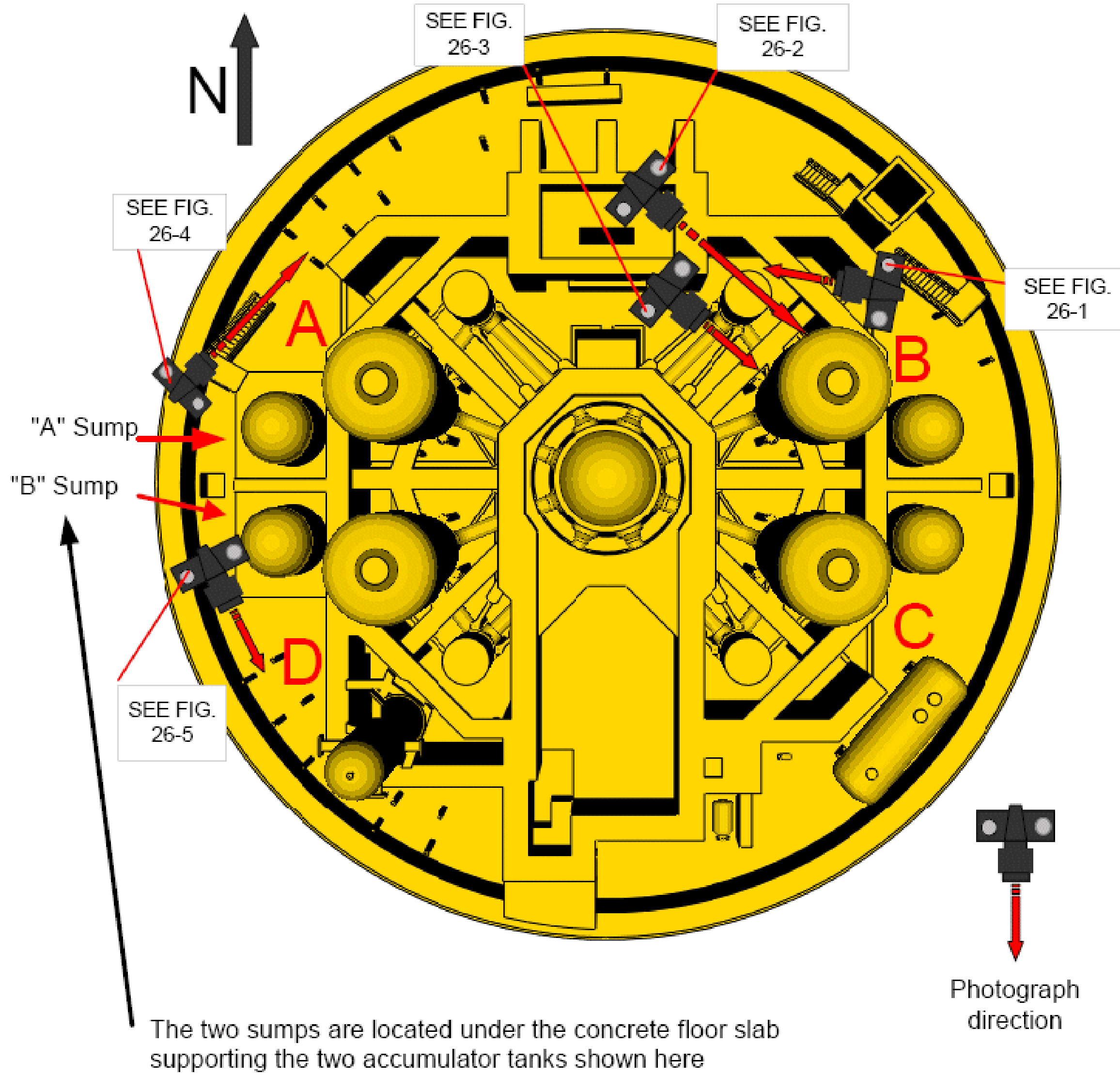


Figure 26-3

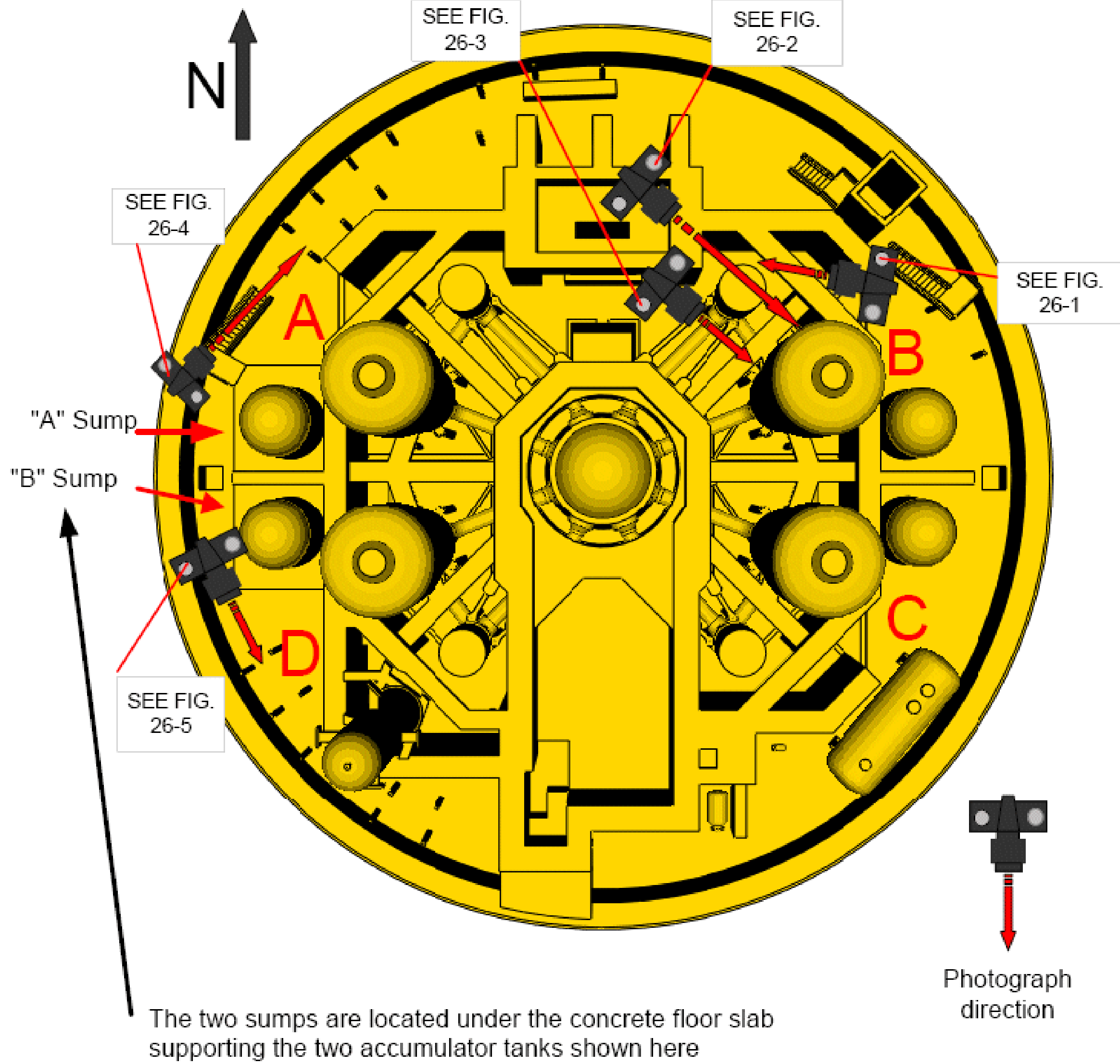
RAI #26 (cont'd)


N
SEE FIG. 26-3
SEE FIG. 26-2
SEE FIG. 26-4
SEE FIG. 26-1
A
B
C
D
"A" Sump
"B" Sump
SEE FIG. 26-5
Photograph direction
The two sumps are located under the concrete floor slab supporting the two accumulator tanks shown here

RAI #26 (cont'd)

Figure 26-4

RAI #26 (cont'd)


N
SEE FIG. 26-3
SEE FIG. 26-2
SEE FIG. 26-4
SEE FIG. 26-1
SEE FIG. 26-5
A
B
C
D
"A" Sump
"B" Sump
Photograph direction
The two sumps are located under the concrete floor slab supporting the two accumulator tanks shown here

RAI #26 (cont'd)

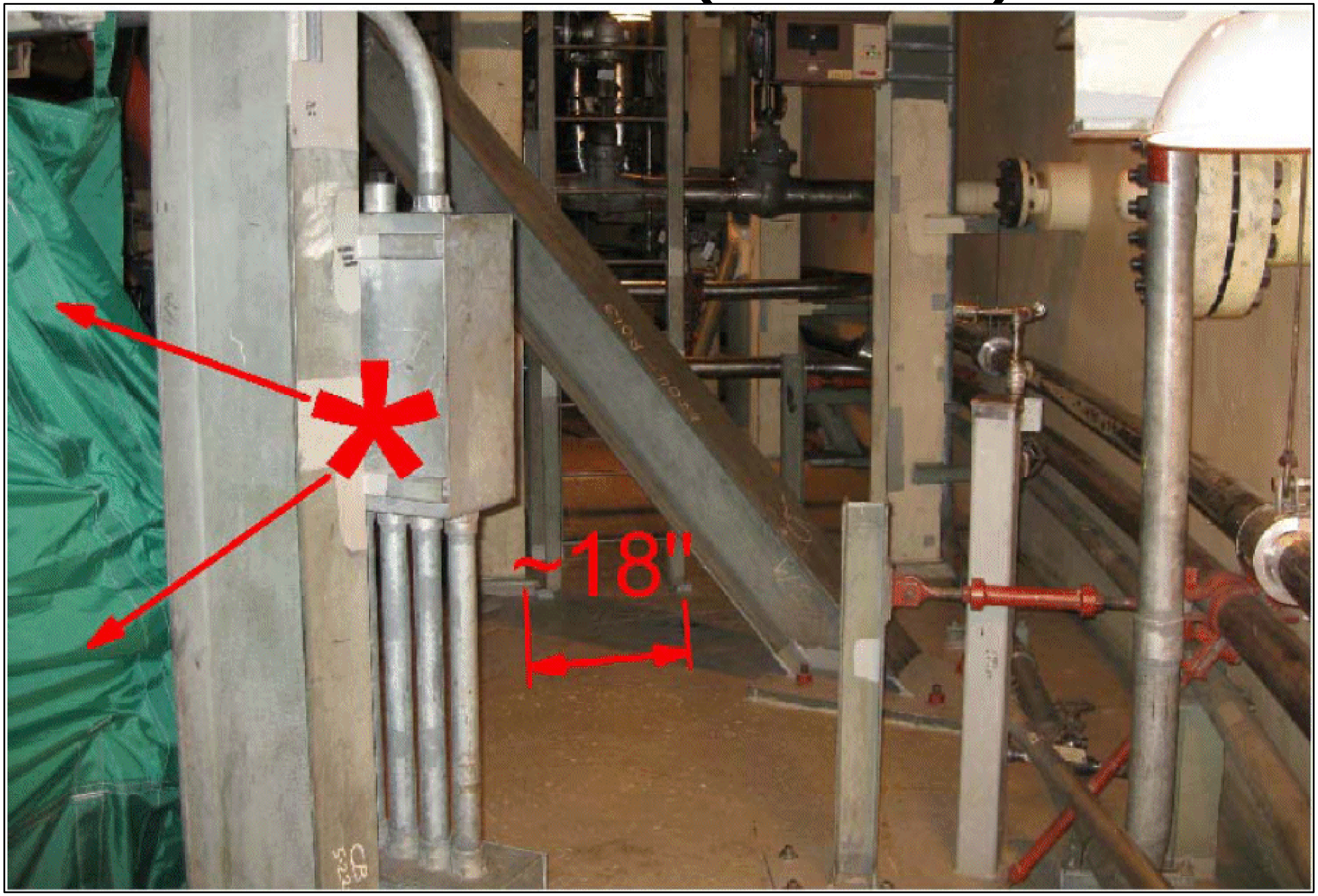
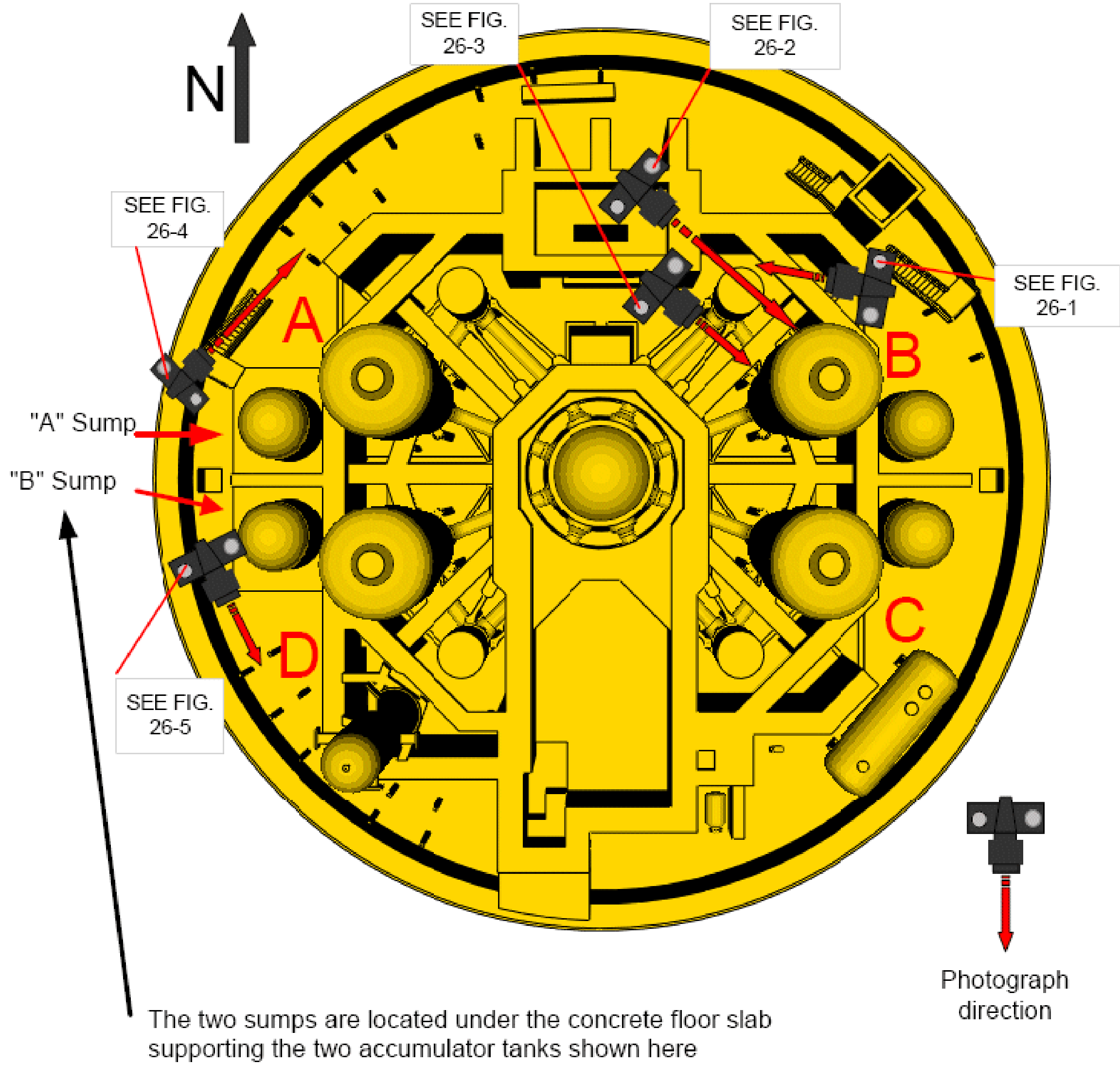


Figure 26-5

RAI #24

- There are numerous obstructions within the bioshield and the containment annulus that would serve to capture large debris during pool-fill phase of a LOCA.
  - Refer to RAI #26

RAI #24 (cont'd)



N
SEE FIG. 26-3
SEE FIG. 26-2
SEE FIG. 26-4
SEE FIG. 26-1
A
B
C
D
"A" Sump
"B" Sump
SEE FIG. 26-5
Photograph direction
The two sumps are located under the concrete floor slab supporting the two accumulator tanks shown here

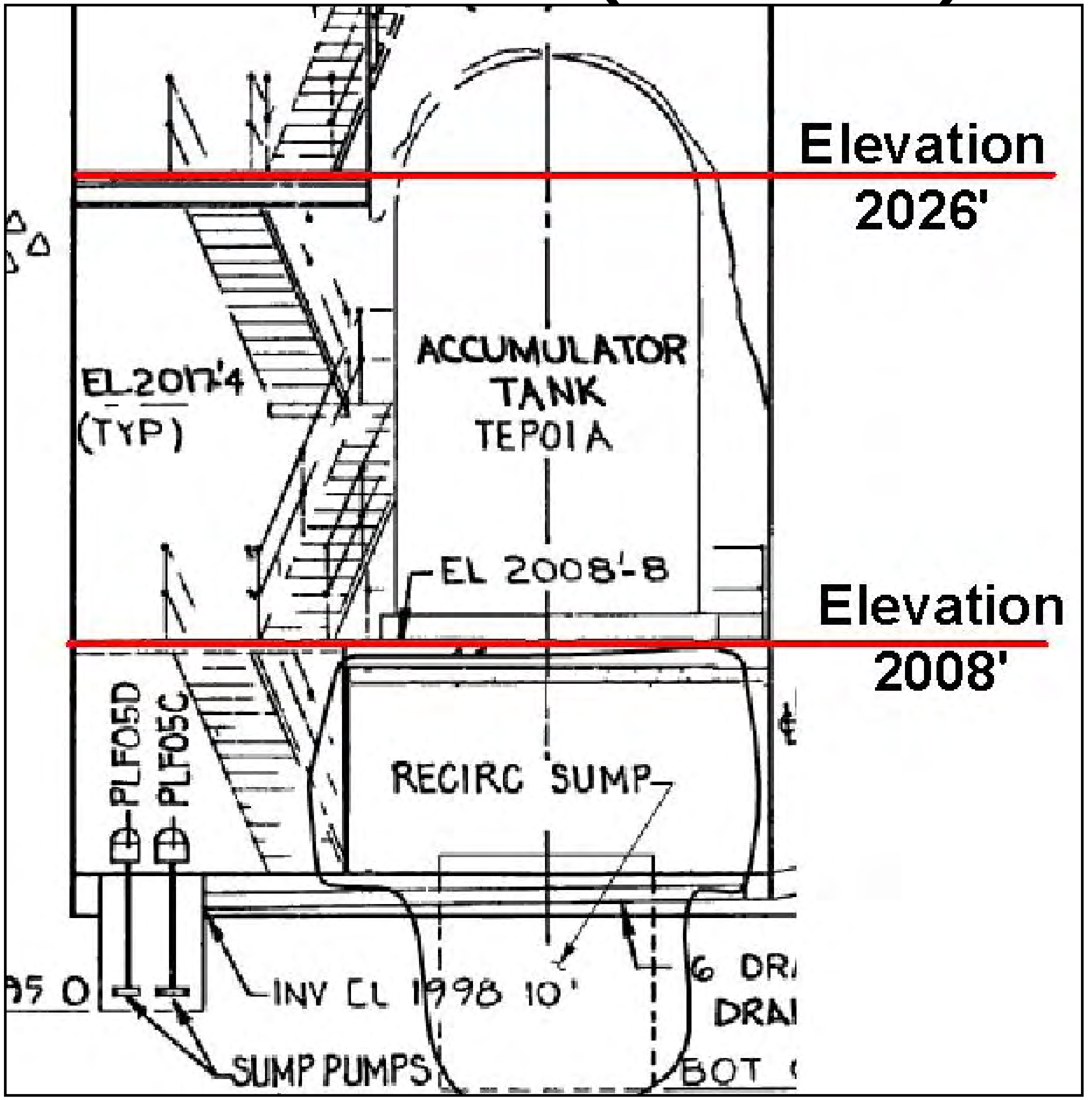
RAI #24 (cont'd)

- The barrier doors, made from 1/8" perforated plate, installed in Loops A and D would stop pieces of debris from transporting directly to the ECCS sump cavities during pool fill
  - Large debris would have to travel out of the SG compartments through the Loop B and C entrances and around the torturous length of the annulus during the short amount of time it would take to fill these cavities.

RAI #29

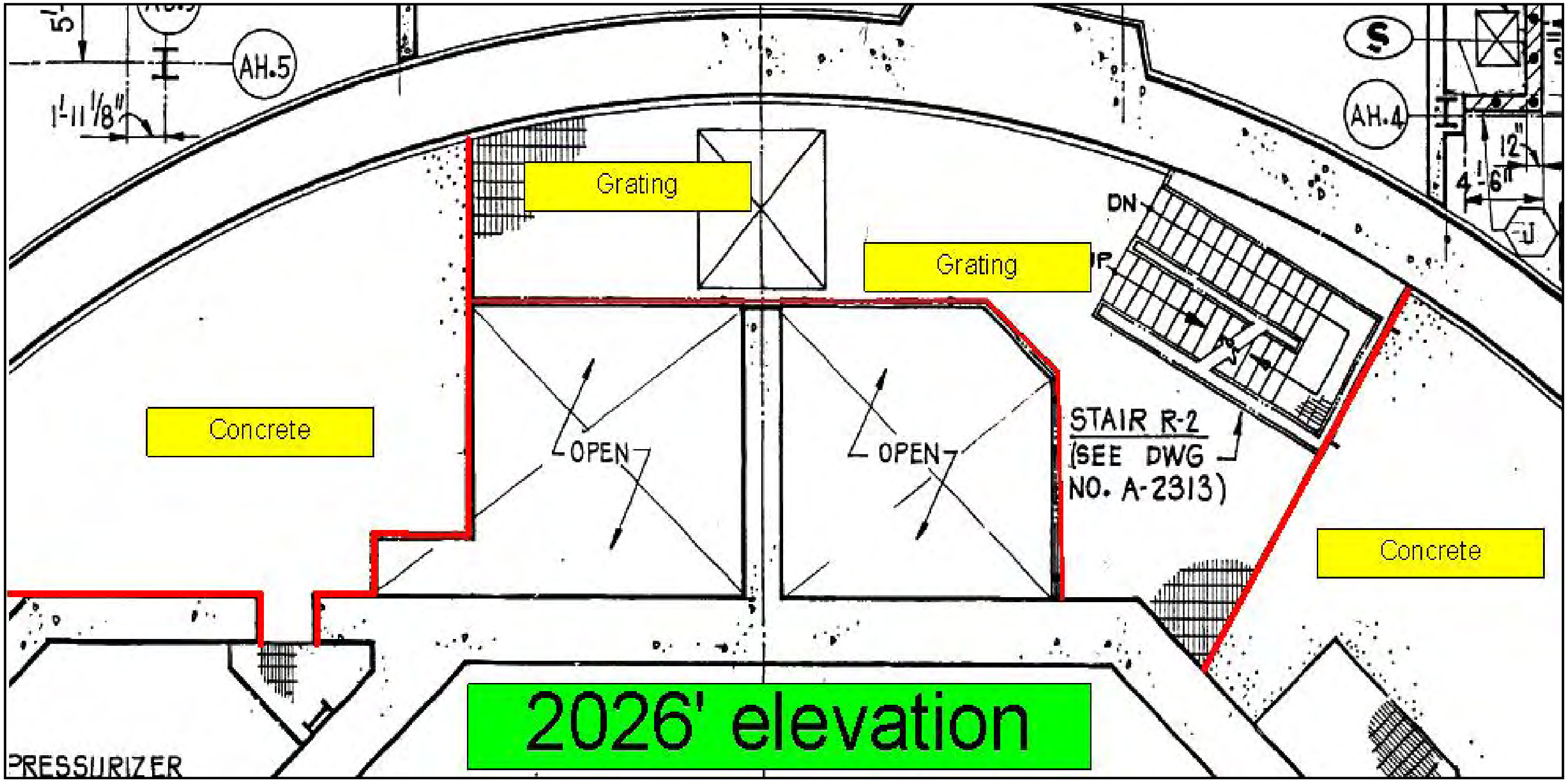
- Drainage sources from Containment Spray near the sump strainers enters in the form of droplets through grating and as run-off from concrete floors
- Turbulence was not modeled in the test flume from either direct spray or from run-off quantities because the impact of these quantities is small in areas near the strainer
- Flume testing showed that there was sufficient kinetic energy and turbulence to transport all debris within 23 ft of the sump
- See graphics on next few slides

RAI #29 (cont'd)



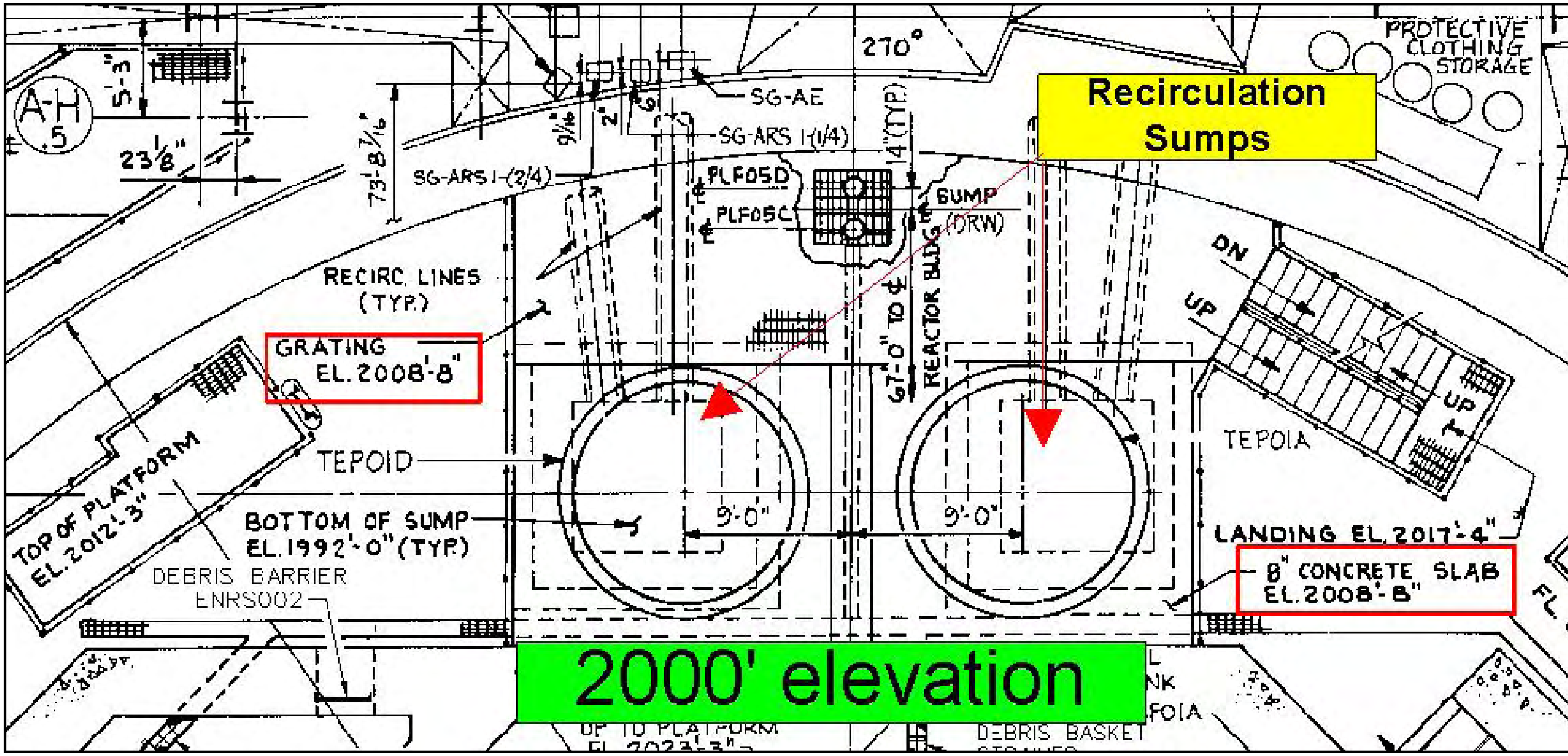
Elevation 2026'
Elevation 2008'
ACCUMULATOR TANK TEP01A
EL 2017'4 (TYP)
EL 2008'-8
RECIRC SUMP
PLF05D
PLF05C
INV EL 1998 10'
SUMP PUMPS

RAI #29 (cont'd)



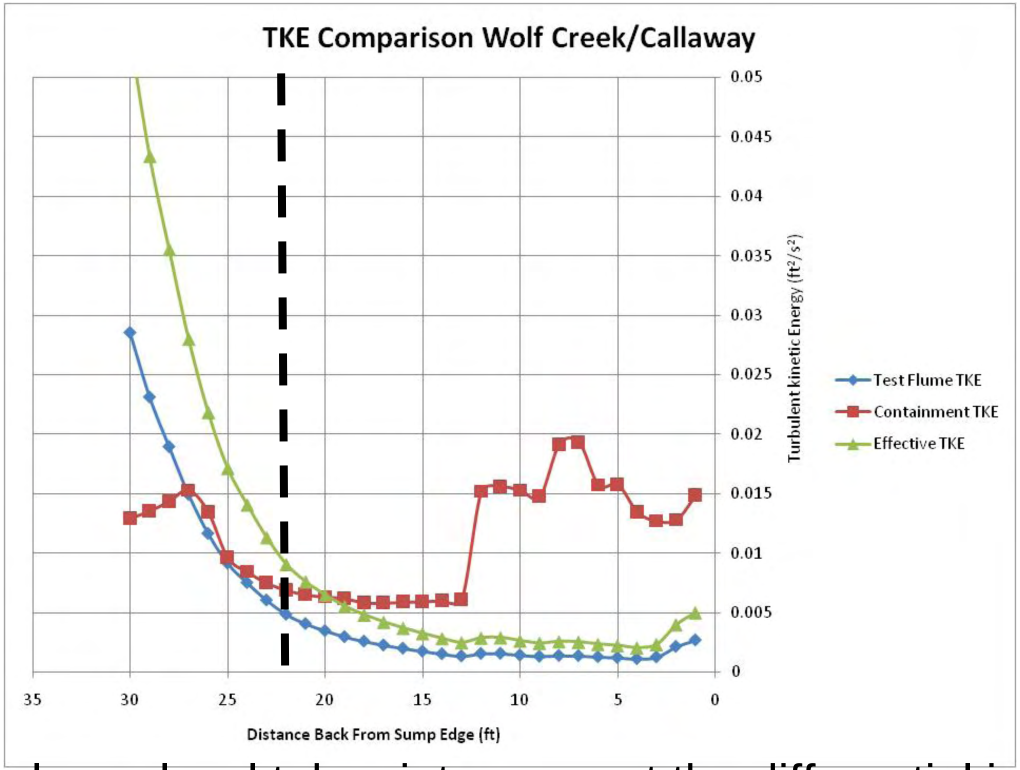
AH.5
AH.4
1'-11 1/8"
Grating
Grating
DN
Concrete
OPEN
OPEN
STAIR R-2
(SEE DWG
NO. A-2313)
Concrete
2026' elevation
PRESSURIZER

RAI #29 (cont'd)



Recirculation Sumps
GRATING EL.2008'-8"
8" CONCRETE SLAB EL.2008'-8"
2000' elevation
270°
PROTECTIVE CLOTHING STORAGE
SG-AE
SG-ARS 1-(1/4)
SG-ARS 1-(2/4)
PLF05D
PLF05C
SUMP (DRW)
RECIRC. LINES (TYP.)
TEPOID
TEPOIA
BOTTOM OF SUMP EL.1992'-0" (TYP.)
TOP OF PLATFORM EL.2012'-3"
DEBRIS BARRIER ENRS002
LANDING EL.2017'-4"
DEBRIS BASKET
9'-0"
9'-0"
67'-0" TO ℄ REACTOR BLDG.
14" (TYP.)
73'-8 7/16"
23 1/8"
DN
UP
UP

RAI #29



- Effective turbulence level takes into account the differential in flume and containment water temperatures and is a correction of the flume TKE to containment temperatures.
- ***Higher turbulence predicted by the debris transport containment CFD simulations within 20 ft of the sump pit did not affect the flume test results since no debris deposition was observed in the test flume within 23 ft of the test strainer modules.***

RAI #30

- Note that paint chips generated represents only approximately 3% of the total particulate debris generated for Wolf Creek and approximately 5% of the total particulate debris generated for Callaway. Considering the amount that did not transport:
  - For Callaway, only 4% of the total particulate (including chips) debris generated was credited to settle
  - For Wolf Creek, only 2% of the total particulate (including chips) debris generated was credited to settle
- Callaway/Wolf Creek applied the NUREG/CR-6916 test data
  - Chip settling and tumbling velocities were calculated using NUREG/CR-6916 test data based on correlations for thickness, length and density
  - The values used in the NUREG/CR-6916 correlations were based on a water density at room temperature (62.4 lbm/ft^3), while the pool temperature at the start of recirculation is predicted to be approximately 260 degrees F with a water density of 58.5 lbm/ft^3
  - Lower water density enables the chips to settle more quickly
- Paint chips were included in testing
  - Chip sizes used were 1/64" and 1/8" to 1/4"

RAI #21

- All fine fibrous debris was assumed to transport 100%
  - Erosion testing results were not used for fine fibrous debris since all fine fibrous debris transported
- Large pieces of fiber were subject to erosion
  - 10% erosion only assumed for large pieces that did not transport

RAI #21a

- Details of the generic erosion test can be found in ALION-PLN-LAB-2352-77, “Test Plan for the Erosion Testing of Low Density Fiberglass Insulation and High Density Fiberglass Insulation,” Revision 3, which has been submitted to the NRC Staff by Alion [ADAMS Document Number ML092080573]
- With respect to chemical conditions, the erosion tests were performed in tap water and not buffered or borated water that would be present in the Callaway/Wolf Creek containment pool

RAI #21a (cont'd)

- The fibrous material tested was NUKON® low density fiberglass. Wolf Creek applied the fiber erosion fraction to NUKON® fiberglass insulation and Callaway applied the fiber erosion fraction to NUKON® and Transco's Thermal Wrap (which is treated identically to NUKON®)
- Therefore, the tested material compares well to Callaway/Wolf Creek insulation materials

RAI 21b

- RAI 22 addresses the erosion of pieces of fiberglass debris that settled out in the test flume

RAI 21c

- The generic testing analysis for erosion of non-transported fiber debris is based on a mission time of 30 days
- The generic testing was performed at a number of different durations, up to and including approximately 30 days and the erosion factor of ten percent was based on the average of all of the small piece sample erosion values regardless of test duration, so it was not time-based
- The generic testing data trends indicate that the large majority of the erosion occurred in the beginning hours of the testing
  - **The large piece sample erosion is bounded by the small piece sample erosion.**

RAI #35

- The amount of fine fibrous debris in the small fines mixture is discussed in RAI #17
- Small agglomerations of fiber or “clumps” could be seen entering the water column during introduction of the debris
- During the observations of the large flume head loss testing, the “clumps” did not float and “clump” dispersal could not be observed due to the dark, particulate debris-laden water

RAI #35 (cont'd)

- Small flume testing was conducted
  - Video documentation and test descriptions were submitted to the Staff on November 4, 2009
  - Velocity during the small flume test was equal to the minimum velocity sections of the large flume strainer head loss testing
- The video of the small flume test has confirmed separation of the fine fibrous debris upon introduction of small fines mixture did occur in a manner that did not affect transport to the strainers

RAI #35 (cont'd)

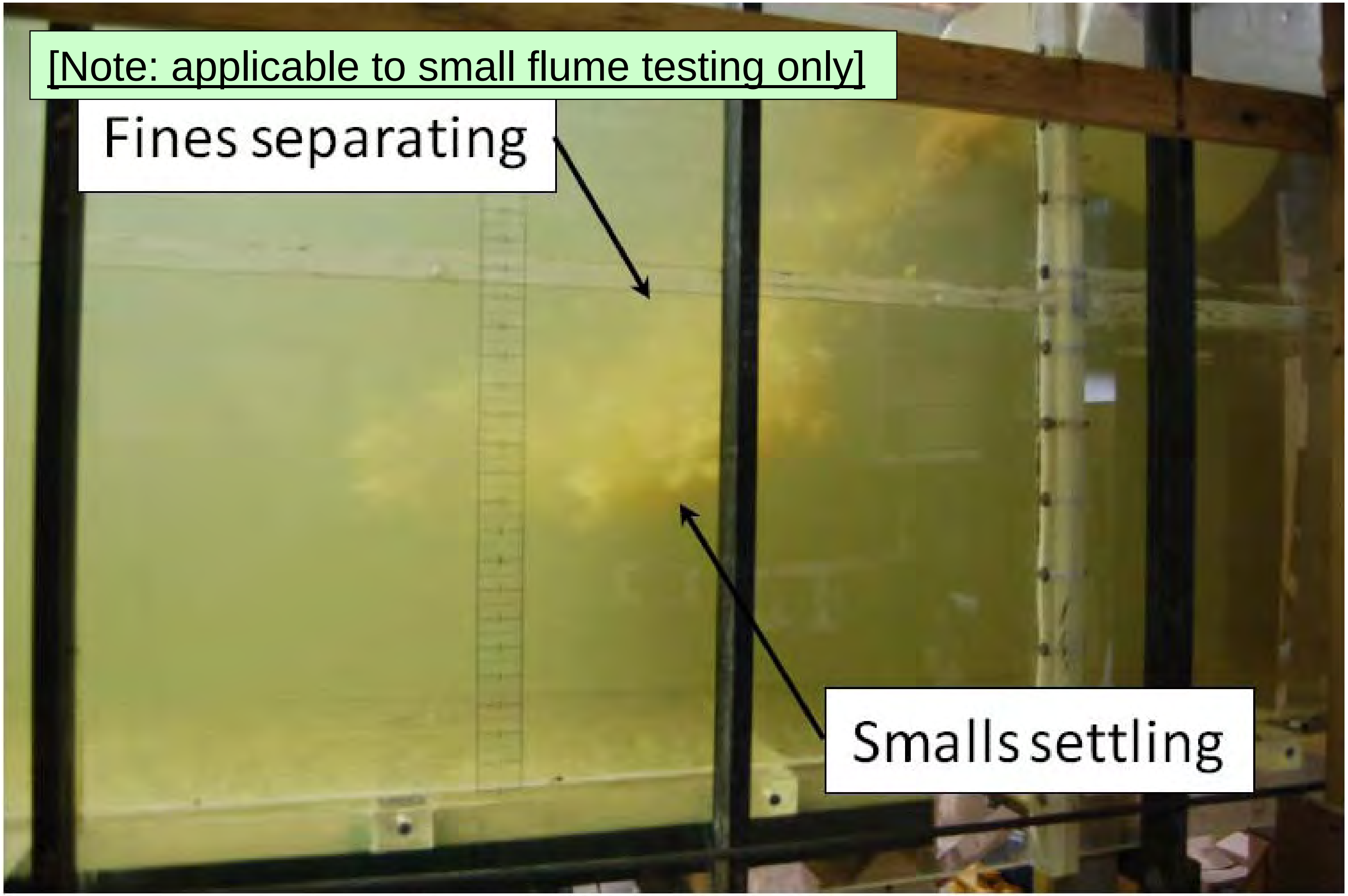


Figure 9. Smalls fiber addition

RAI #35 (cont'd)

[Note: applicable to small flume testing only]

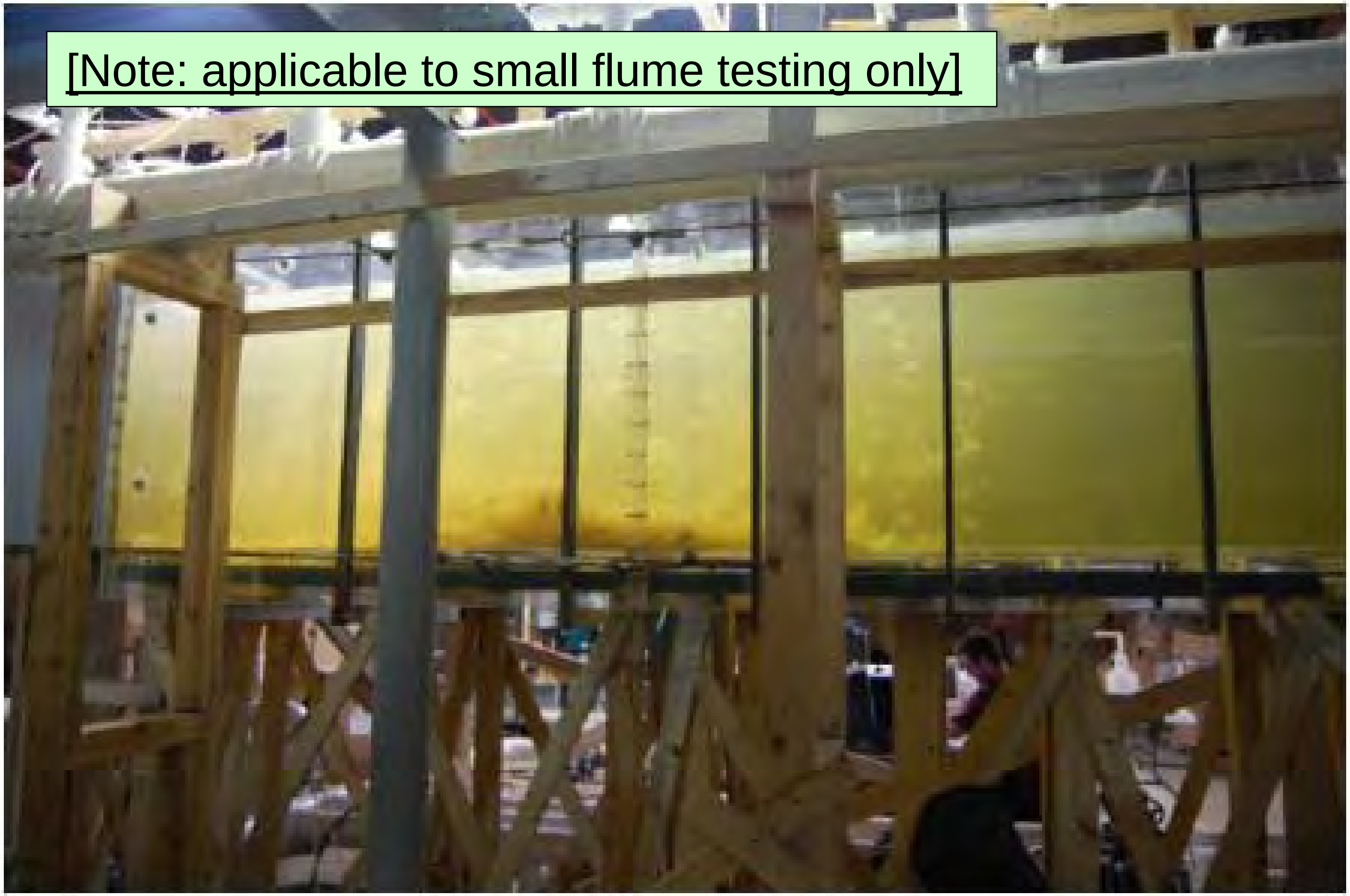


Figure 10. Fibers settling in flume downstream of introduction

RAI #35 (cont'd)

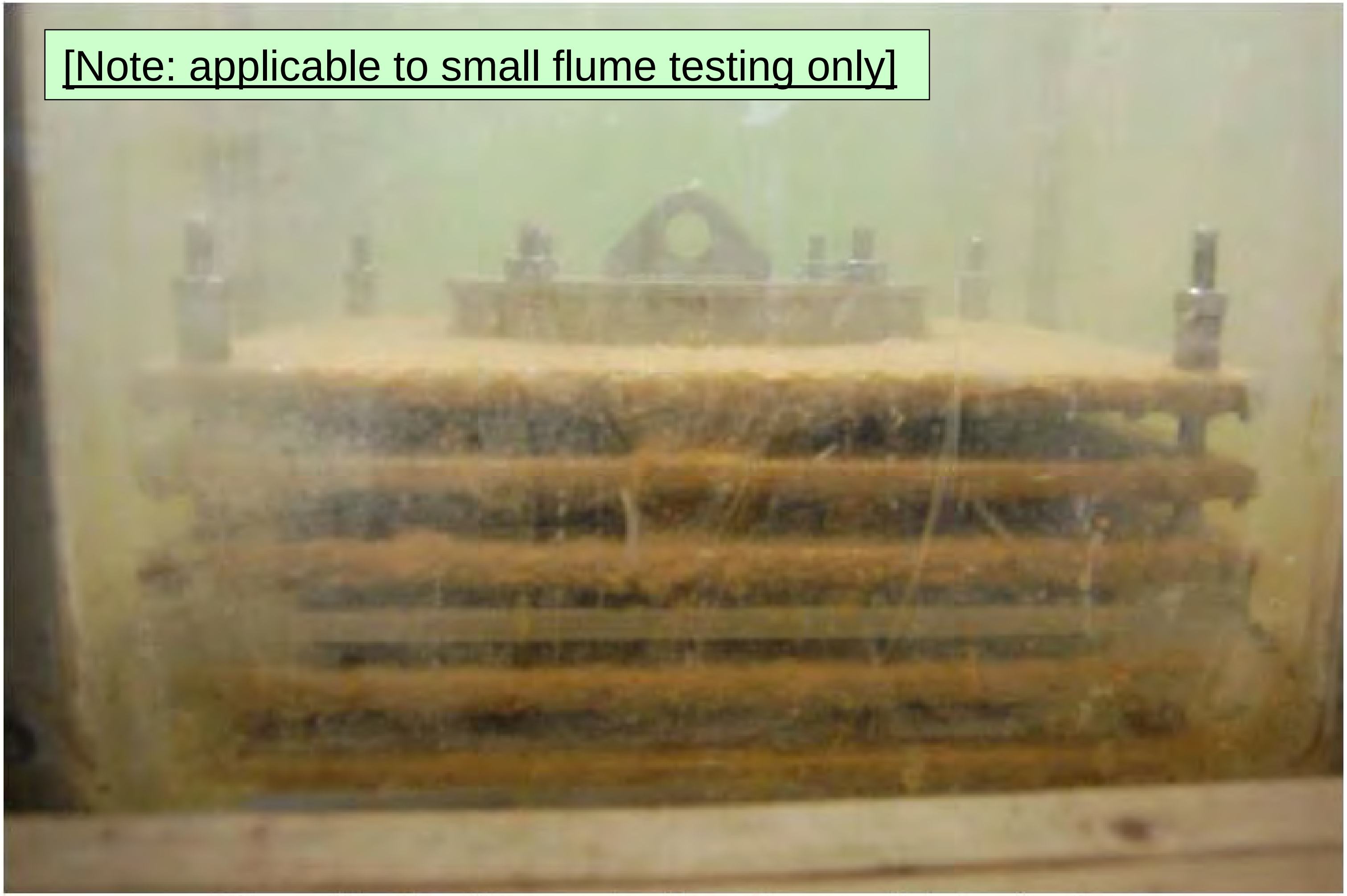


Figure 11. Fine fiber on strainer after smalls introduction

RAI #17

- As previously discussed on 8/27/09 phone call and supplemental responses, a sampling of the small fines mixture determined that 30% of the small fines mixture were fine fibrous debris
- PCI prepared fibrous insulation in accordance with PCI document, SSFS-TD-2007-004, *Sure-Flow Suction Strainer – Testing Debris Preparation & Surrogates* (transmitted by PCI to the NRC, see ML090900476).

RAI #17

- More detailed evaluation by PCI supports the above stated amount.
- The results of the PCI's detailed evaluation are documented in PCI document, SSFS-TD-2007-004, Supplement 1, Rev. 1, *Sure-Flow Suction Strainer – Testing Debris Preparation & Surrogates* (transmitted by PCI to the NRC, see ML092430056)
  - The processed fibrous insulation debris was mechanically separated by PCI and it was determined that the percentage of fine fibrous debris 'contained' in the small fines mixture was 41% by mass.
  - The fine fibrous debris were mixed with and/or loosely trapped in the small fines mixture, and easily released.

RAI #17 (cont'd)

- Wolf Creek and Callaway, as well as other Licensees, implemented a number of clean water tests (i.e., no particulate or chemical debris) at Alden Research Laboratory, Inc. (ARL) to observe the transportability and potential release/separation of fine fibrous debris from the NUKON small fines mixture.
- The use of clean water without particulate debris was utilized for the subject tests to enable viewing of the small fines mixture being introduced into the test flume.
- Since higher velocities would disperse more of the fine fibrous debris from the small fines mixture, the tests utilized licensee specific flow velocities that represented the slowest velocity section of the flow stream that was implemented in the ARL Large Flume Test.

RAI #17 (cont'd)

- During the clean water small flume testing, the Nukon small fiber mixture was added in the same manner as the fiber mixture was added in the large flume testing.
- The video from the small flume testing shows that the amount of fine fibrous debris released upon introduction of the small fines mixture supports the previously completed sampling data that at least 30% fine fibrous debris are contained in the small fines mixture
  - Video documentation and test descriptions were submitted to the Staff on November 4, 2009

RAI #28

- Aspects of this RAI are addressed in the following RAIs:
  - RAI #17 => Percent of fine fibrous debris in small fines mixture
  - RAI #35 => Agglomeration
  - RAI #37 => Debris introduction and sequencing

RAI #33

- As requested in the September 28, 2009 letter summarizing the August 27, 2009 public meeting, aspects of this RAI are being addressed by, and therefore cross referenced to, RAI #17 and #28

RAI #32

- The quantity of debris at the strainer is much higher during single train operation than for a two-train operation.
  - Small fine debris transports at approximately 100% in the recirculation pool regardless if one or two trains are operating.
- Single train operation results in approximately:
  - 110 ft^3 (99.6%) more small fines mixture and 189 lb (85%) more particulate at the strainer at Wolf Creek
  - 55 ft^3 (97.7%) more small fines mixture and 2150 lb (98%) more particulate at the strainer at Callaway.

RAI #32 (cont'd)

- For the single train case, a significantly greater amount of fine debris was placed in the flume and was able to reach the screen and contribute to the tested head loss
  - This more than offsets the impact of the higher local sump approach velocities for the two-train case, which may result in greater transport of the large debris
  - Also, TKE in the test flume drop zone is approximately double that expected in the recirculation pool
- Thus, single train operation represents the worst case and bounding condition.

RAI #27

- Current computational capabilities allowed for more detailed refinement of flow patterns near sump pit in response to RAI 27.
- Flow patterns and velocities near sump sensitive to representation of strainer boundary condition.
  - Test flume CFD assumed equal velocity along the vertical planes defining the sides of the sump pit (no specific representation of modules).
- Subsequent CFD simulations conducted in response to RAI #27 further detailed strainer configuration and obstacles near sump pit.
  - Modeled each individual strainer module in sump
  - Modeled strainer module support structures
  - Wolf Creek – Modeled additional instrument support stand
  - Callaway – Modeled TSP baskets and additional instrument support stand

RAI #27 (cont'd)

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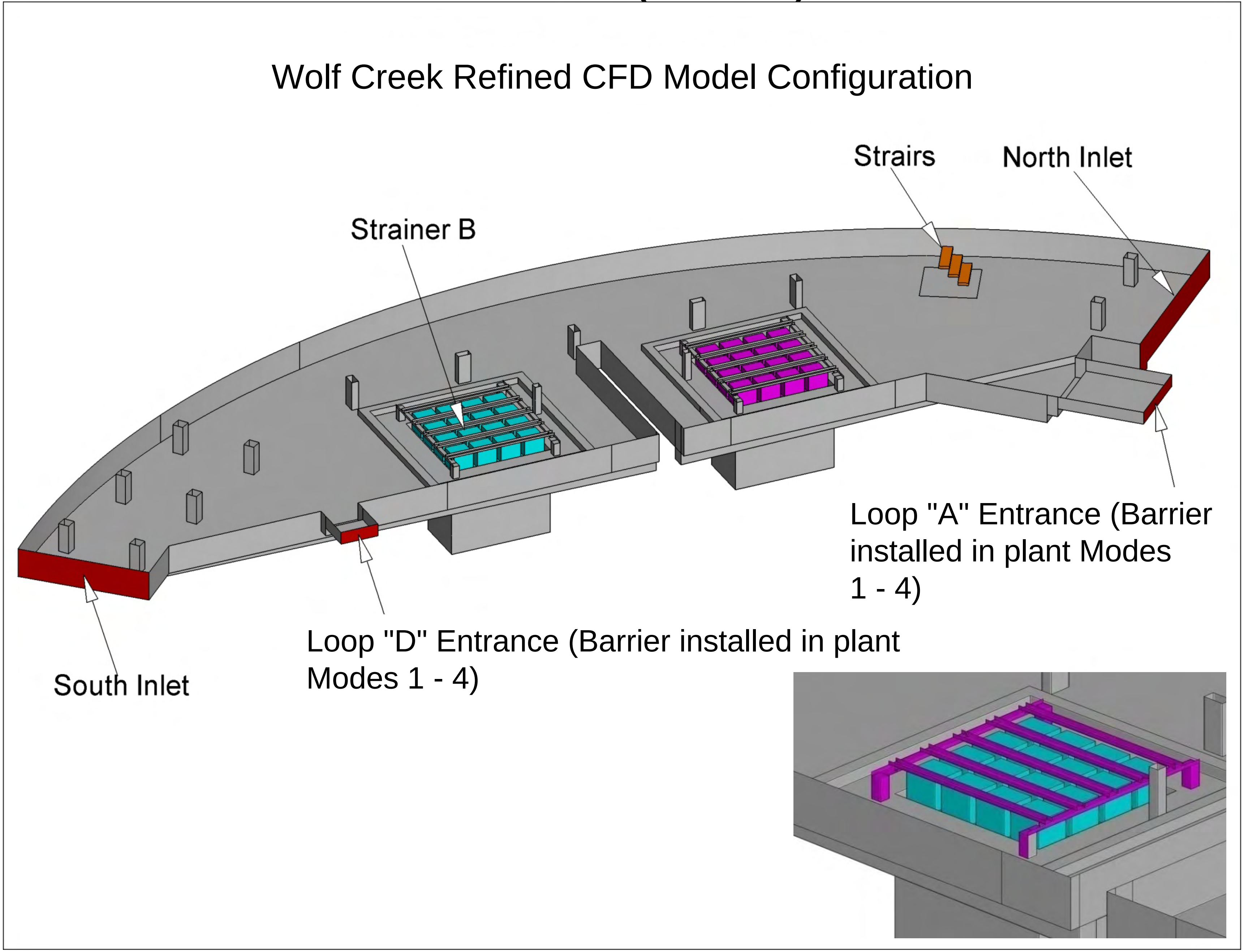
  - Modeled each individual strainer module in sump
  - Modeled strainer module support structures
  - Wolf Creek – Modeled additional instrument support stand
  - Callaway – Modeled TSP baskets and additional instrument support stand

RAI #27 (cont'd)

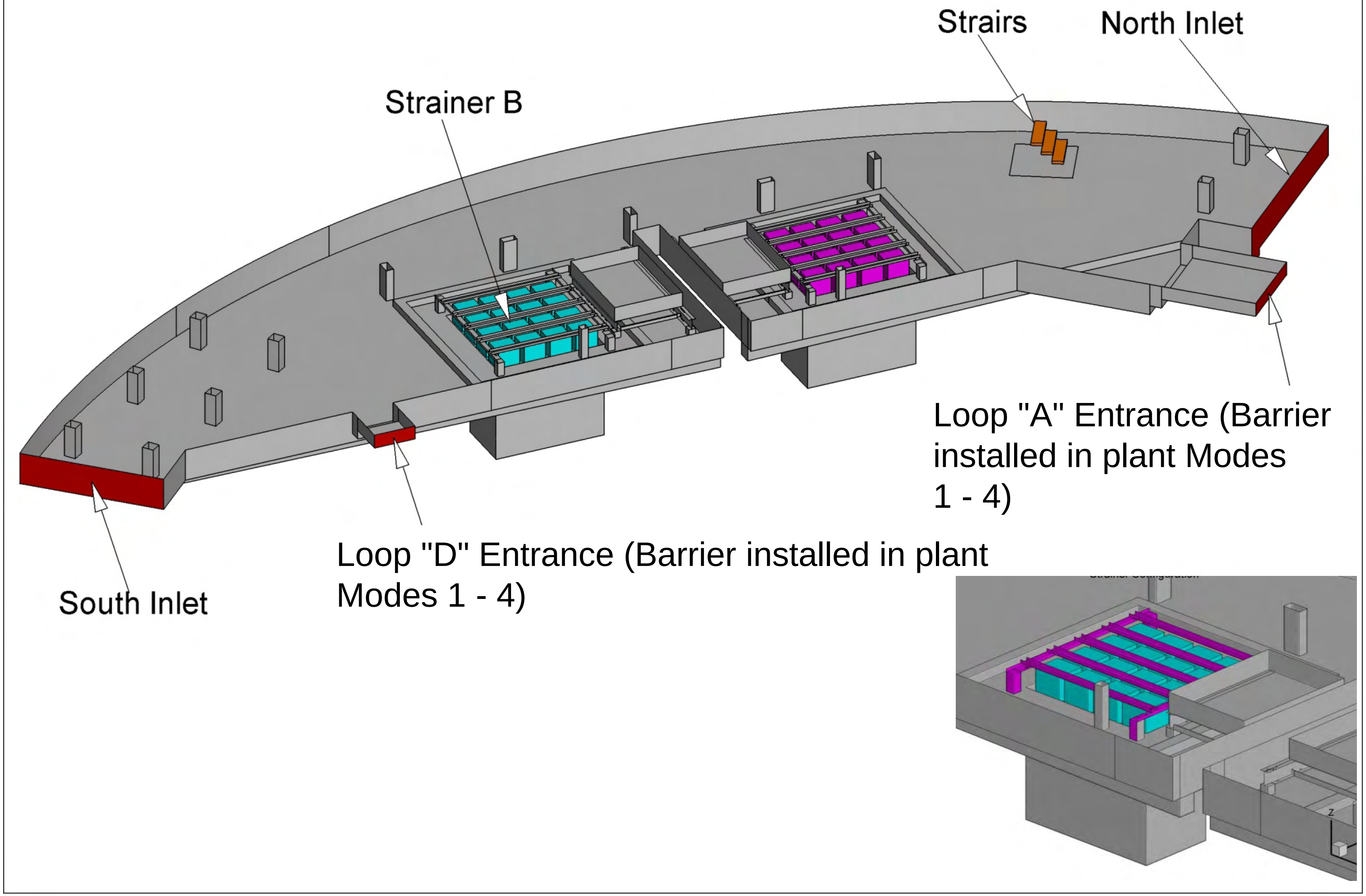
- Subsequent CFD simulation results showed sensitivity of flow patterns to obstacles near sump pit and complex flow patterns within the sump strainer array.
  - Velocities within 8 ft of Callaway sump and 13 ft of Wolf Creek sump higher than test flume CFD due to angular velocity component in flow.
  - Design basis test photos and observations for both Wolf Creek and Callaway noted no settling of debris within 23 ft of the test strainer modules.
    - Fiber-only test photos (with clear visibility in the test flume) also noted no appreciable settling within 23 ft of test strainer modules.
    - Note that test flume velocities within 23 ft were three times higher than the incipient tumbling velocity for small fiberglass (0.06 ft/s) and twice that for large fiberglass (0.12 ft/s).

RAI #27 (cont'd)

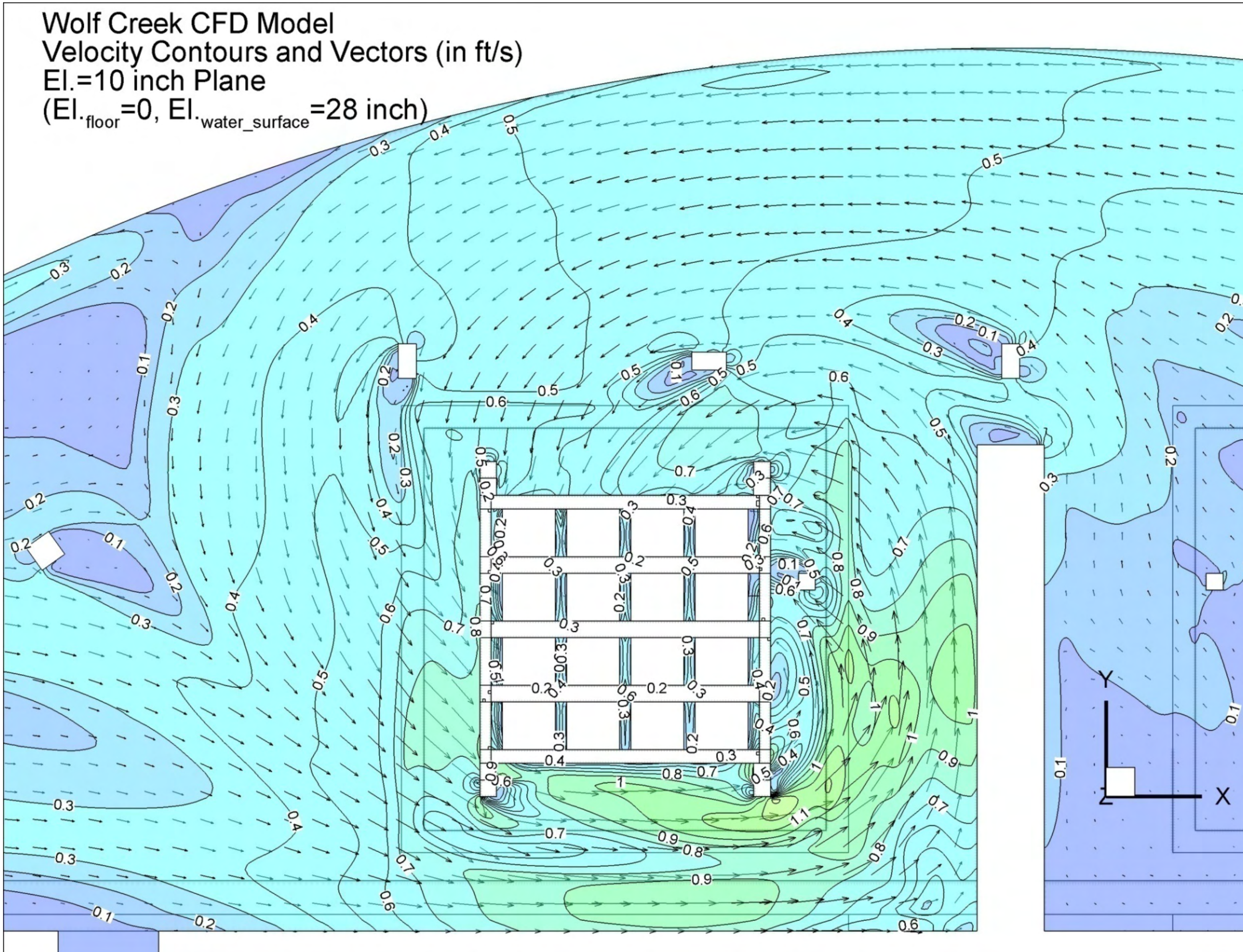

Wolf Creek Refined CFD Model Configuration
Strairs
North Inlet
Strainer B
Loop "A" Entrance (Barrier installed in plant Modes 1 - 4)
Loop "D" Entrance (Barrier installed in plant Modes 1 - 4)
South Inlet

RAI #27 (cont'd)

Callaway Refined CFD Model Configuration

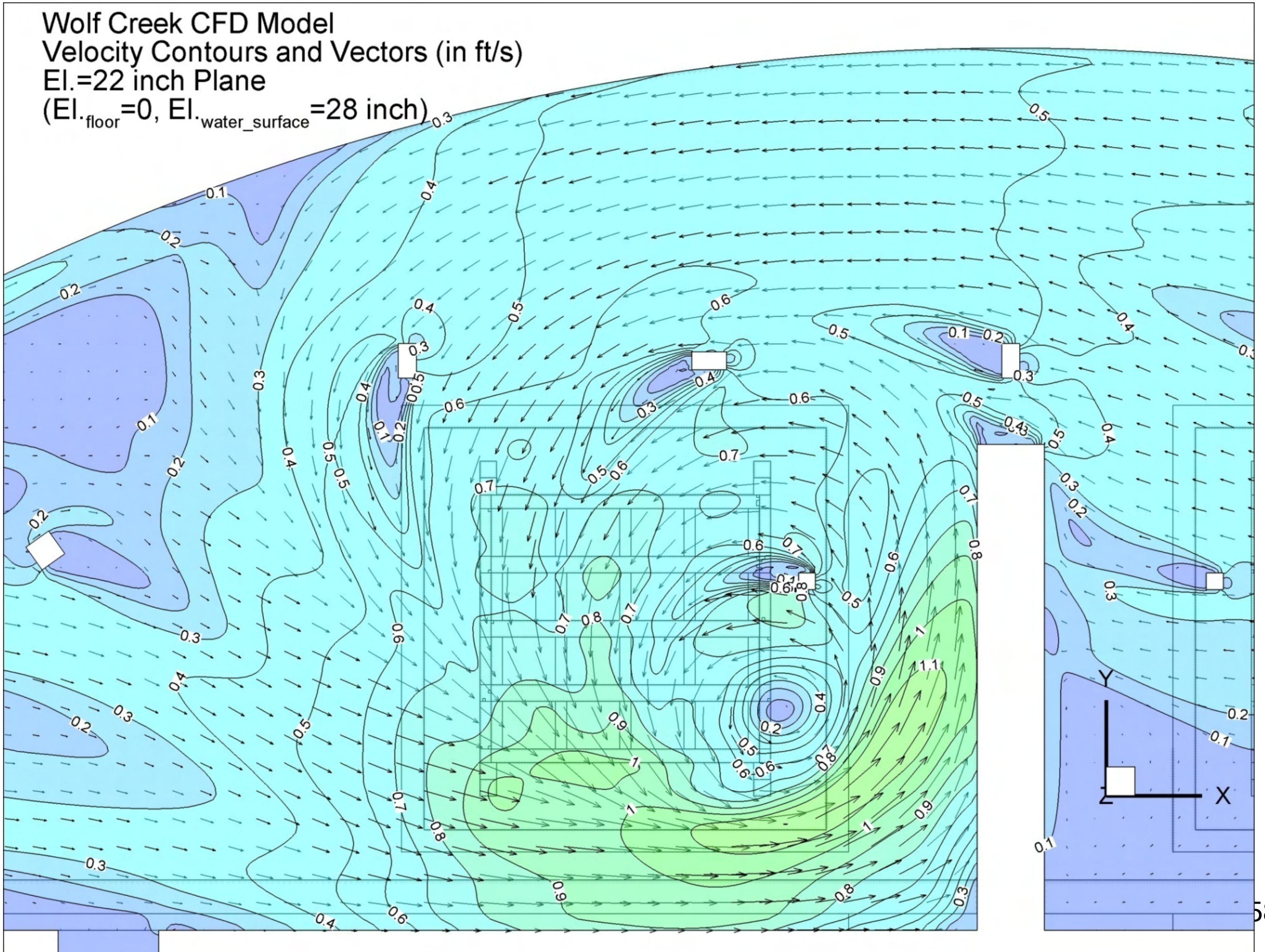


RAI #27 (cont'd)



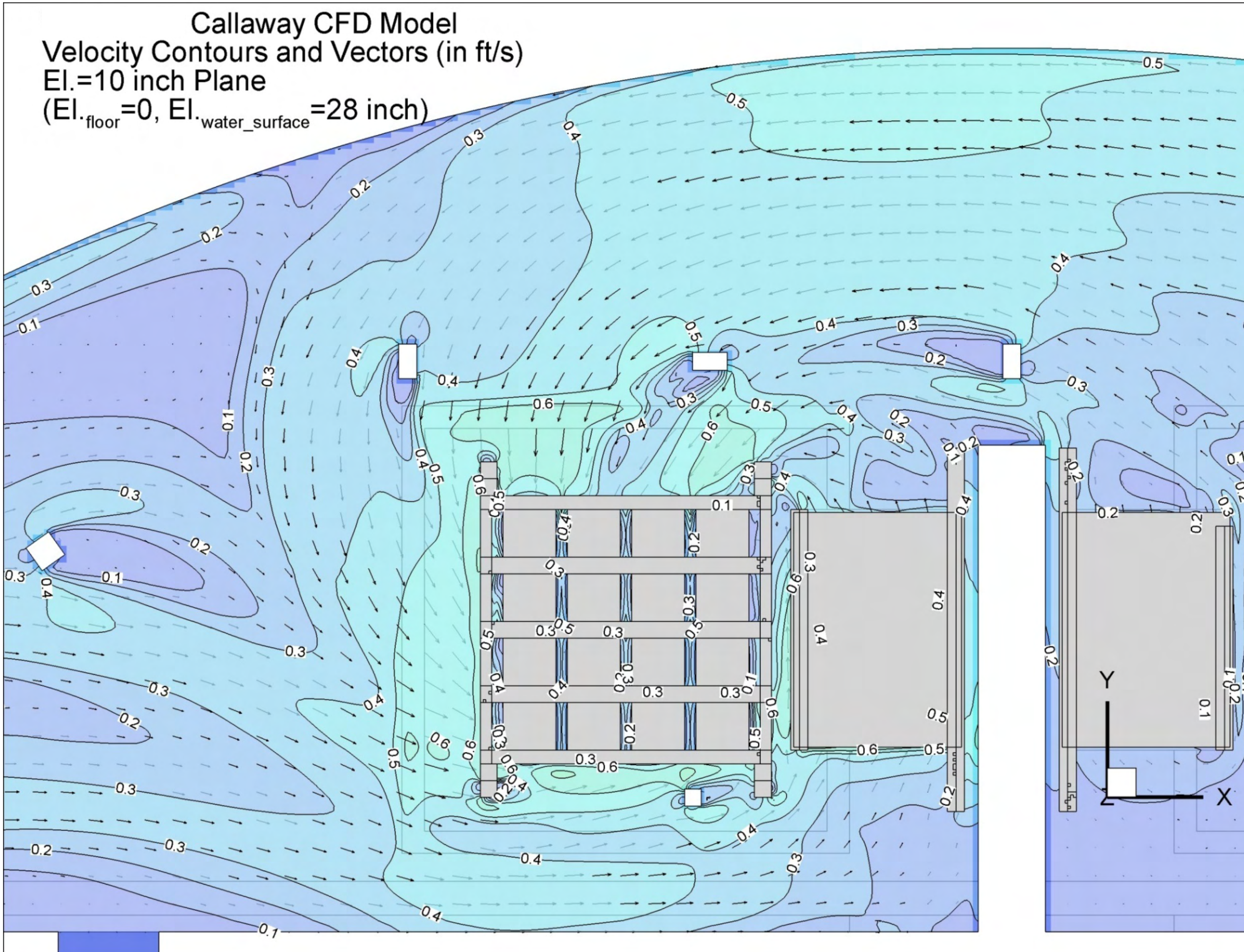
Wolf Creek CFD Model
Velocity Contours and Vectors (in ft/s)
El.=10 inch Plane
(El.floor=0, El.water_surface=28 inch)
Y
X
Z

RAI #27 (cont'd)

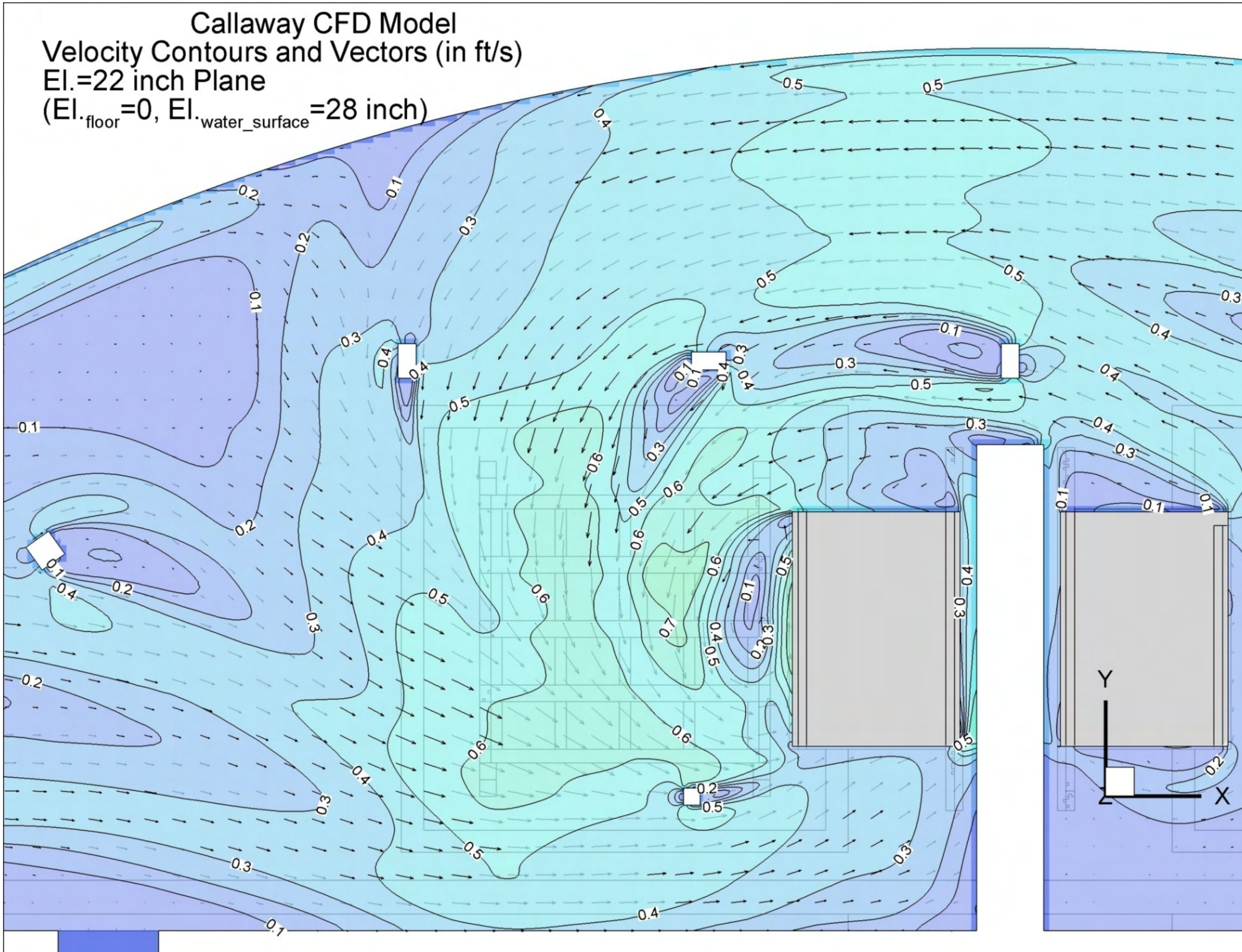


Wolf Creek CFD Model
Velocity Contours and Vectors (in ft/s)
El.=22 inch Plane
(El.floor=0, El.water_surface=28 inch)
Y
X

RAI #27 (cont'd)


Callaway CFD Model
Velocity Contours and Vectors (in ft/s)
El.=10 inch Plane
(El.$_{floor}$=0, El.$_{water\_surface}$=28 inch)
Y
X

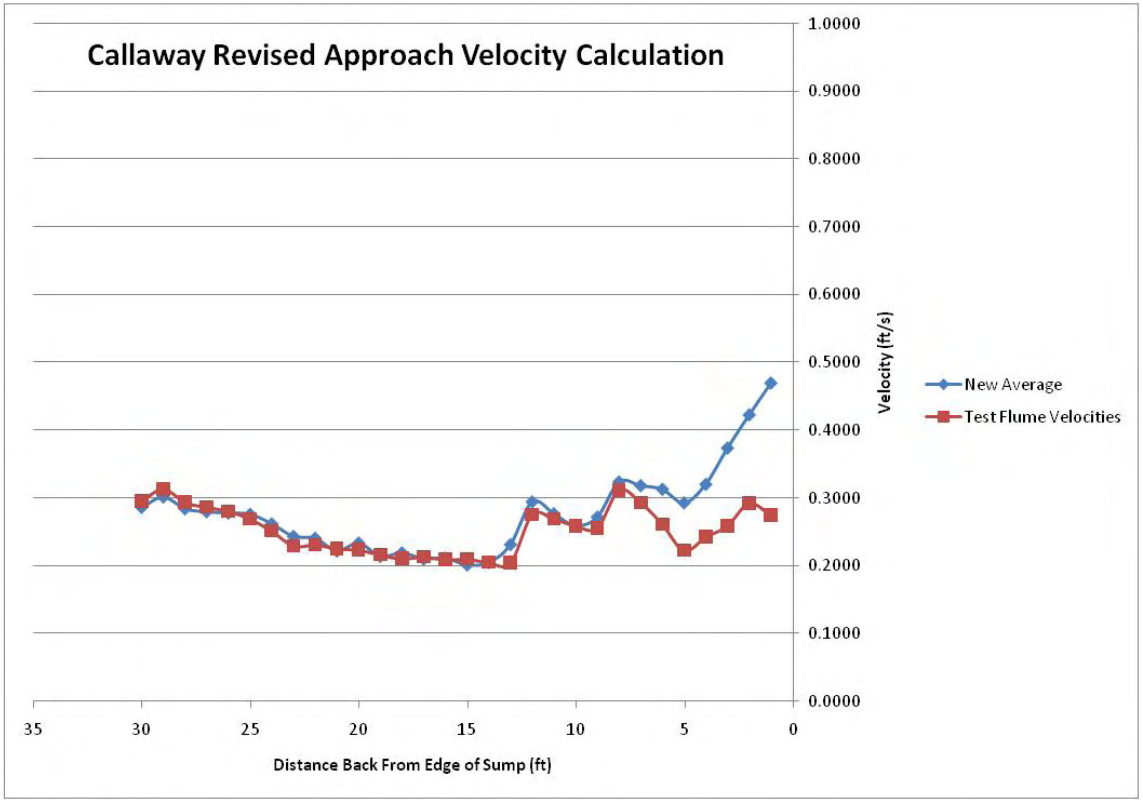
RAI #27 (cont'd)



Callaway CFD Model
Velocity Contours and Vectors (in ft/s)
El.=22 inch Plane
(El.floor=0, El.water_surface=28 inch)
Y
X
Z

RAI #27 (cont'd)

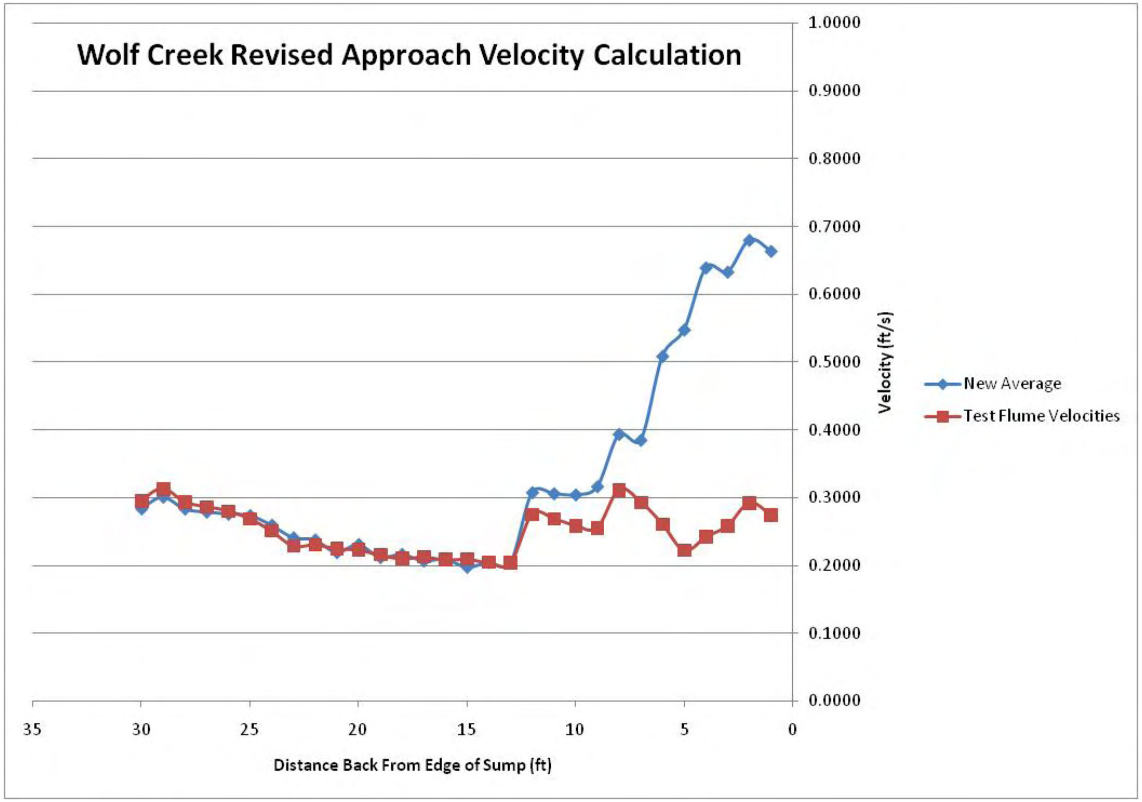
Approach Velocity Calculation with TSP Basket and Instrument Support



- Velocities in Drop Zone and up to 14 ft back from sump equivalent
- Velocities from 8 ft to 14 ft very similar
- Velocities from 1 ft to 8 ft higher based on refined CFD

RAI #27 (cont'd)

Approach Velocity Calculation with Instrument Support

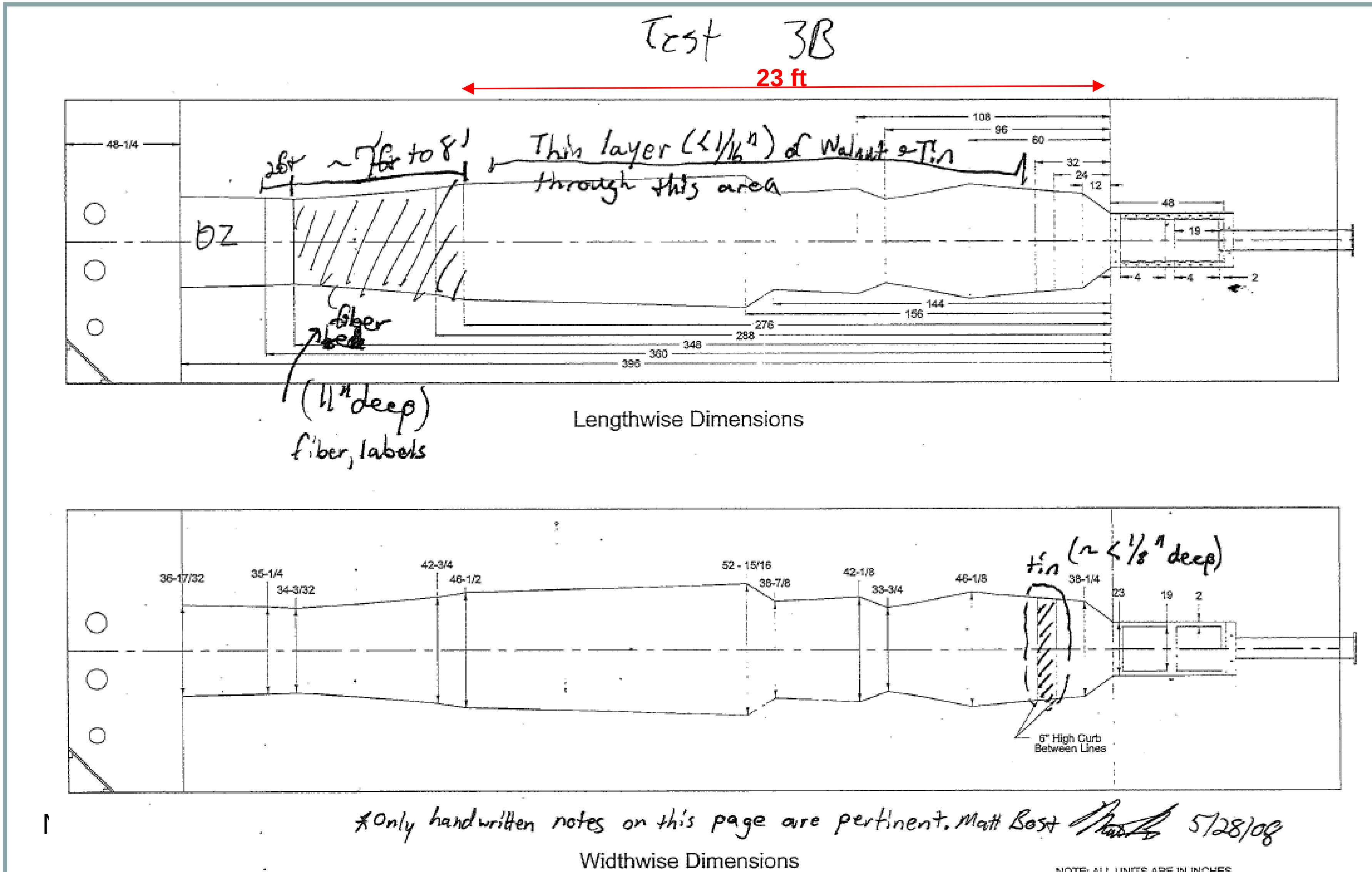


- Velocities in Drop Zone and up to 13 ft back from sump equivalent
- Velocities from 1 ft to 13 ft higher based on recent CFD

RAI #27 (cont'd)

Material Deposition Observations Test 3B – Wolf Creek Design Basis Test

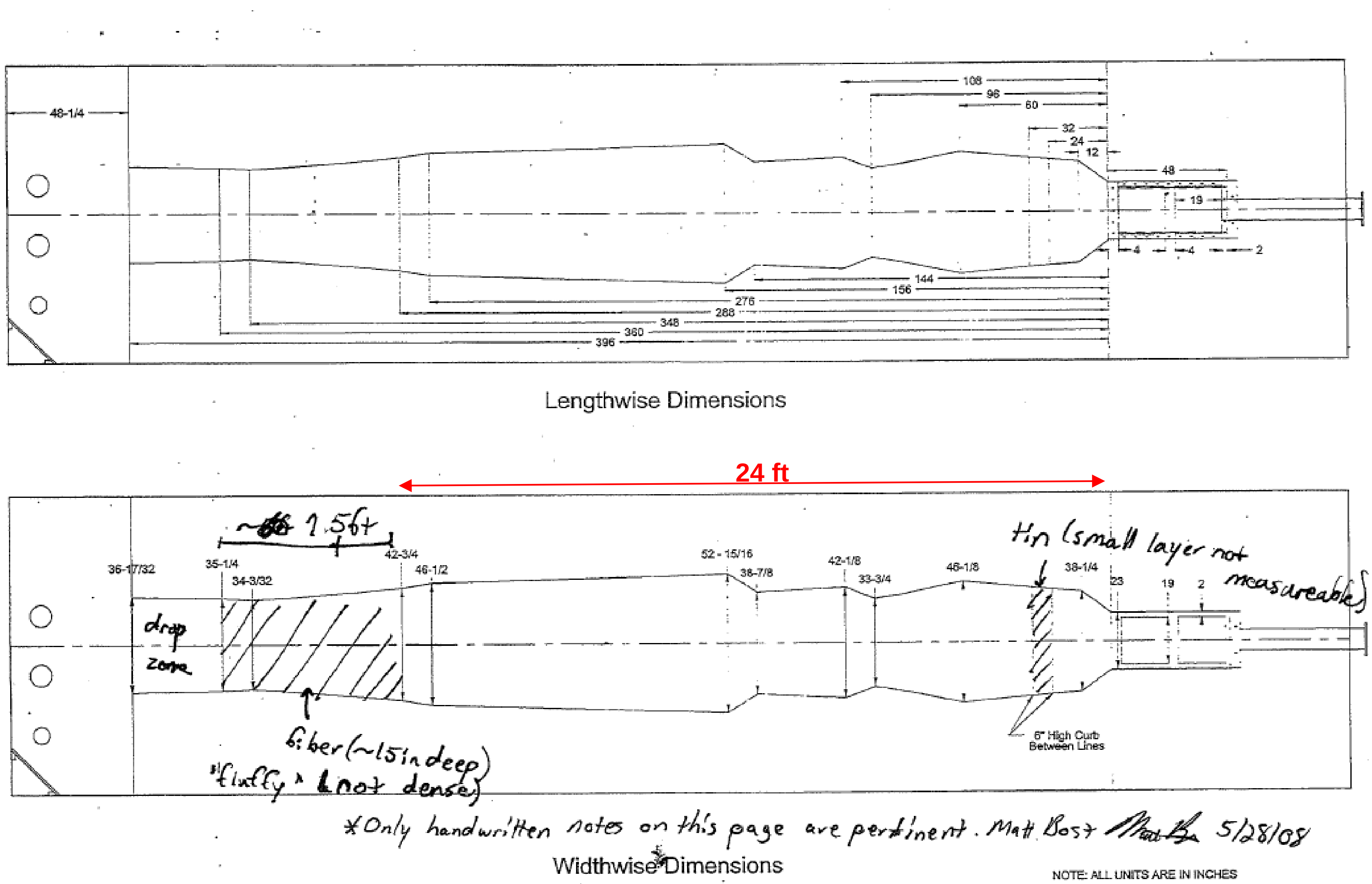
Reference : Areva Document #63 - 9069460 – 001 : **Wolf Creek / Callaway Test Plan for ECCS Strainer Performance Testing**



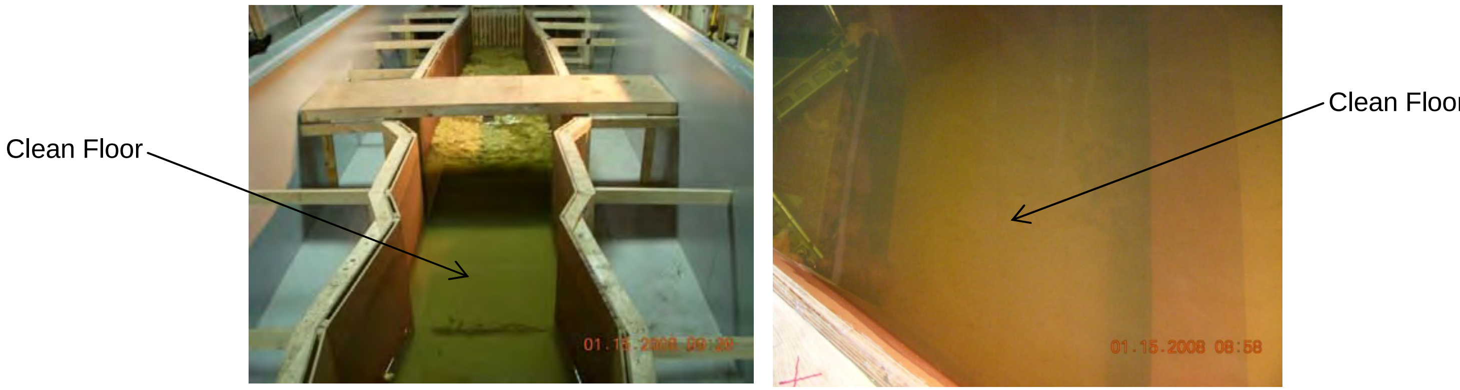
RAI #27 (cont'd)

Material Deposition Observations Test 3C – Callaway Design Basis Test

Reference : Areva Document #63 - 9069460 – 001 : **Wolf Creek / Callaway Test Plan for ECCS Strainer Performance Testing**



RAI #27 (cont'd)



Photos from Fiber Only Test – Test 2A

Photos from Wolf Creek Design Basis Test – Test 3B

RAI #27 (cont'd)

- Differences in flow patterns near sump pit between Debris Transport CFD and Large Flume CFD were attributable to resolution of flow near the sump and the detailed modeling of the strainer array.
- Higher velocities predicted near sump pit demonstrated in subsequent CFD modeling conducted in response to RAI #27 did not affect the validity of the Wolf Creek and Callaway Design Basis Testing since debris settling was not observed in the test flume within 13 ft of the test strainer where the velocities were predicted to be higher.
- Conclusion: Even though the test flume velocities near the strainer were less than predicted by the refined CFD, the testing was bounding.

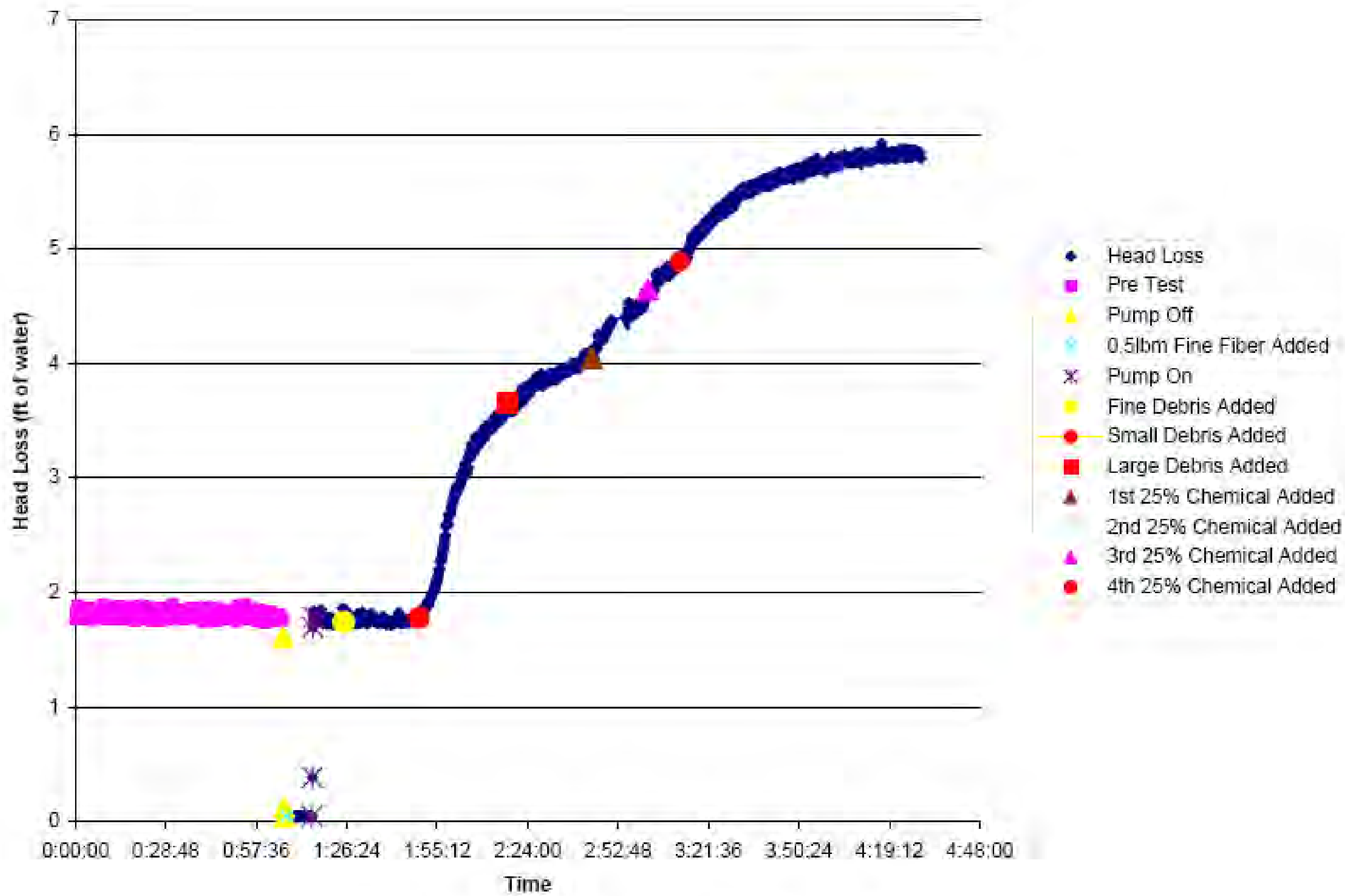
RAI #22

- The small fines mixture used contained more than 30% fine fibrous debris - see RAI # 17
- PCI's debris preparation white paper supplement supports the 30% amount of fine fibrous debris in the small fines mixture - see RAI # 17
- The small flume test video shows the fine fibrous debris separate from the small fines mixture upon introduction into the flume.

RAI #22 (cont'd)

- The head loss testing for WC/CNP did account for erosion of this debris due to
  - Increased velocities from the decreased flow area over the settled debris
  - Fibers separated upon introduction into the flume, as shown in the video
  - The head loss curves shows large increase in head loss which we believe is related to fine fibrous debris being transported to the screen, which would include any erosion – see figure below
- No fiber was observed to settle within 23 ft. downstream of the debris accumulation

RAI #22 (cont'd)



Wolf Creek Design Basis Head Loss Test

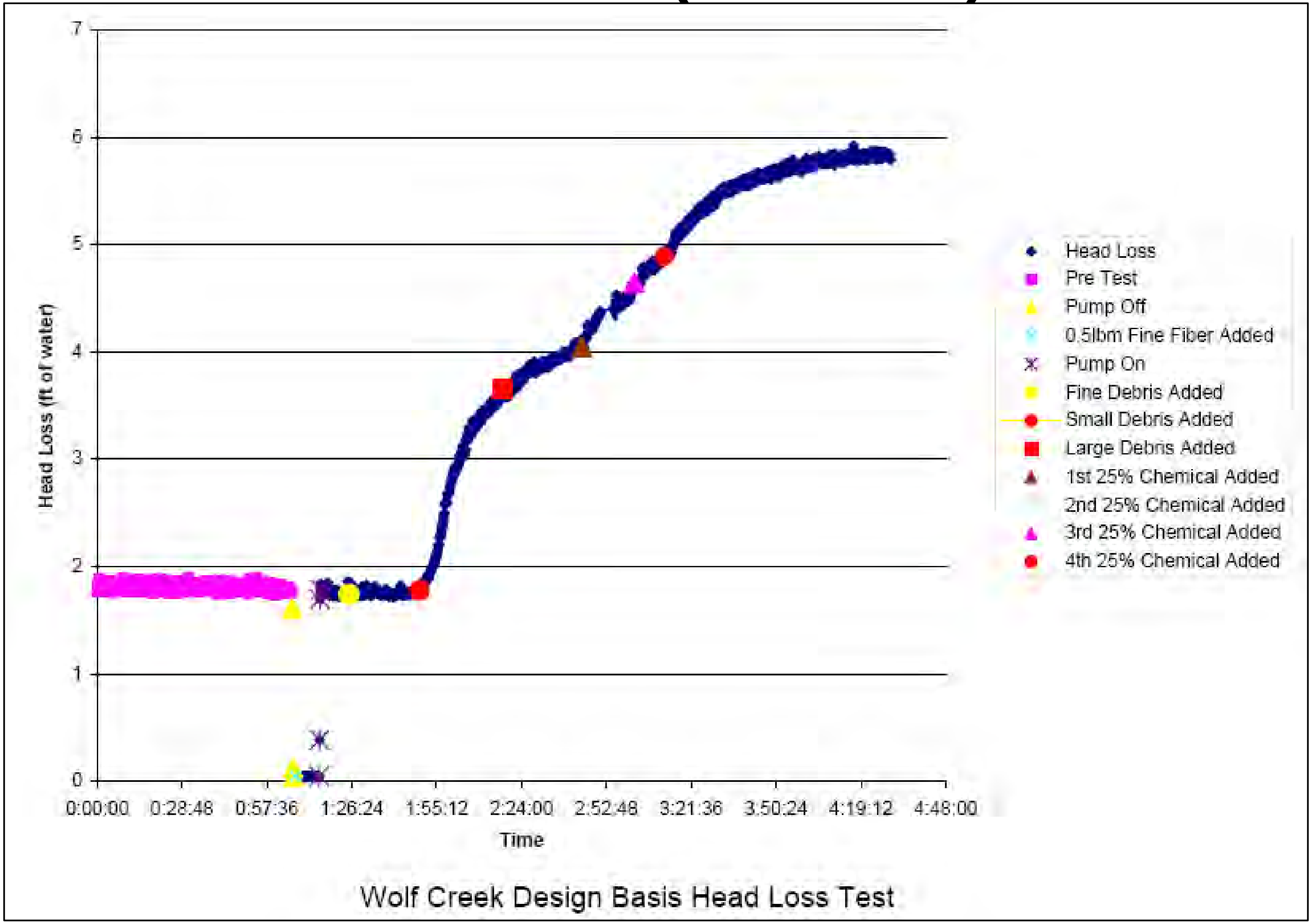
RAI #37

- Small coating chips did not inhibit transport of Nukon fines.
- Small coating chips (1/64” and 1/8” – 1/4”) were added after some Nukon fine fibrous debris to the test flume

RAI #37

- Two pool turnovers between addition of next debris types – so adequate time (7 min) available to transport material.
- The introduction sequence did not affect the test results, since subsequent head loss testing shows a significant jump in head loss when the small fines mixture was added. See figure below from RAI #22.

RAI #37 (cont'd)



Head Loss (ft of water)
7
6
5
4
3
2
1
0
0:00:00
0:28:48
0:57:36
1:26:24
1:55:12
2:24:00
2:52:48
3:21:36
3:50:24
4:19:12
4:48:00
Time
Head Loss
Pre Test
Pump Off
0.5lbm Fine Fiber Added
Pump On
Fine Debris Added
Small Debris Added
Large Debris Added
1st 25% Chemical Added
2nd 25% Chemical Added
3rd 25% Chemical Added
4th 25% Chemical Added
Wolf Creek Design Basis Head Loss Test

RAI #39a

- The head loss extrapolation makes no assumptions about the particular thickness of the debris bed

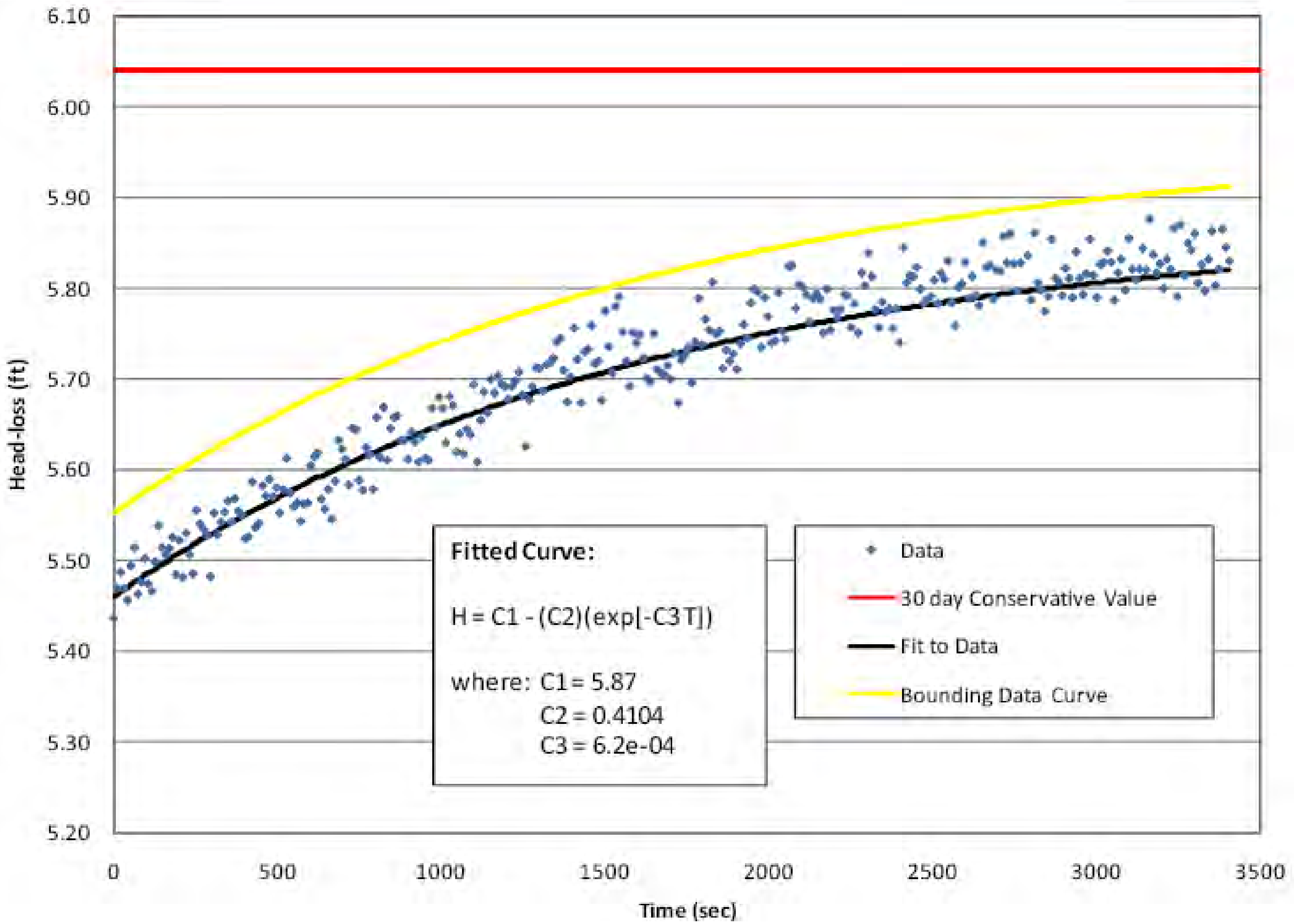
RAI #39b

- The interpretation of C_1 as clean strainer head loss should be limited to Eq. 2 in the 12/22/2008 supplemental response
- The clean strainer head loss is not calculated as part of the data fitting effort

RAI #39c

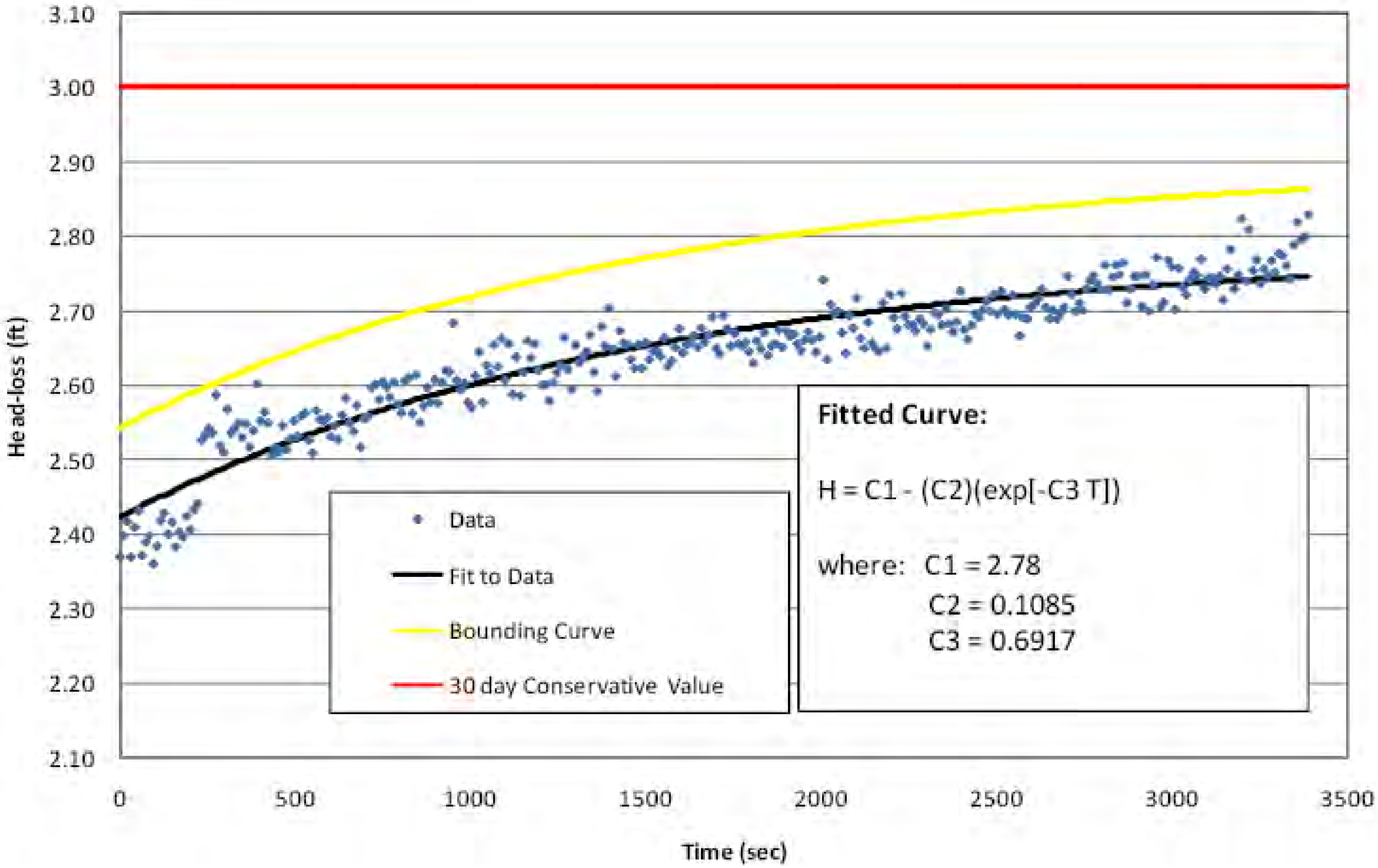
- A more detailed look at the data fit is given in the following graphs
  - The data is shown along with the mean fit and a statistically meaningful bounding curve to all collected data points
  - The 30 day head loss value used in further analysis is based on the extrapolated head loss determined from the data-bounding curve
- For conservatism, additional margin was added
  - The maximum difference between the mean curve fit and any data point is added to the bounding curve value (yellow line)
- The resultant 30 day head loss value is shown as a red horizontal line at 6.04 ft for Wolf Creek and 3.00 ft for Callaway

RAI #39c (cont'd)



Wolf Creek 30-day head loss curve

RAI #39c (cont'd)



Callaway 30-day head loss curve

RAI #2 – Callaway Only

- For main steam line break and main feedwater line break, no ECCS recirculation is required

End of Presentation