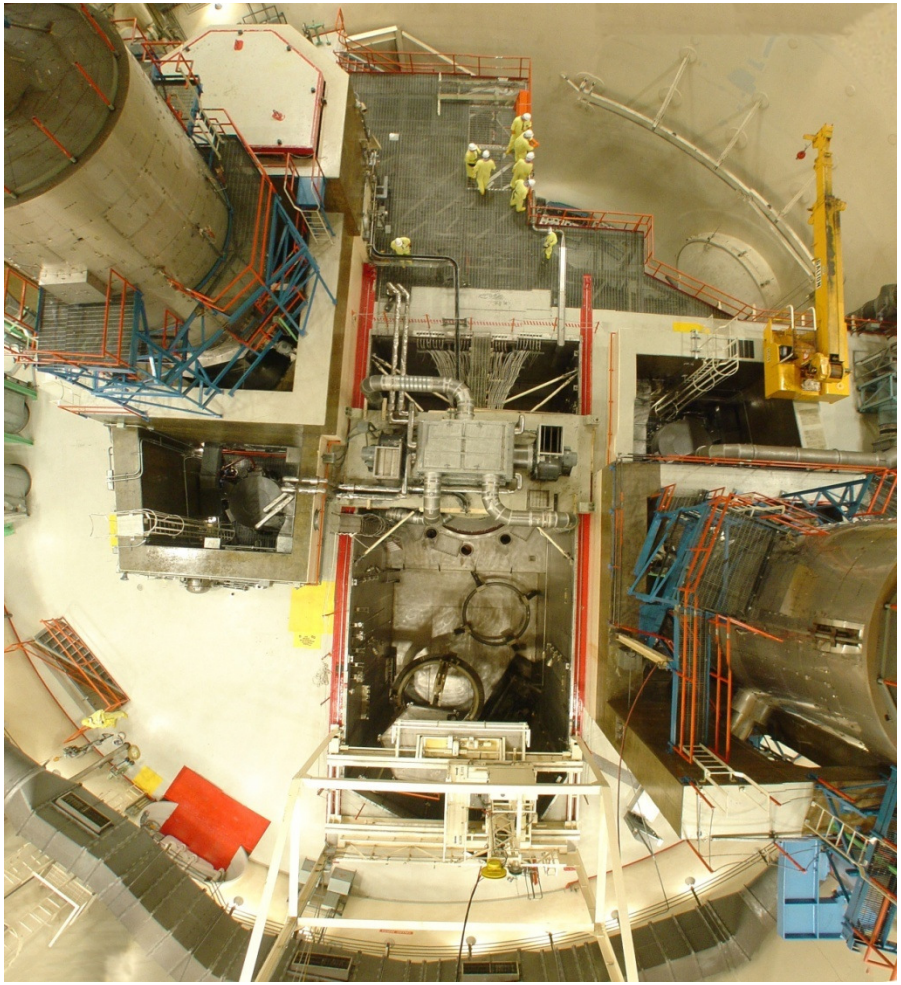
GSI-191 RESOLUTION FOR KEWAUNEE POWER STATION



KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- KEWAUNEE TELECONFERENCE PARTICIPANTS:
- DOMINION:
  - JACK DILLICH, DIRECTOR NUCLEAR ENGINEERING
  - MICHAEL L. MILLER, MANAGER NUCLEAR DESIGN ENGINEERING
  - SCOTT PUTMAN, PROJECT MANAGER
  - LORI CHRISTENSEN, MECHANICAL DESIGN ENGINEERING
  - TOM BREENE, LICENSING
  - JACK GADZALA, LICENSING
- PERFORMANCE CONTRACTING, INC. (PCI)
  - JIM BLEIGH, ENGINEERED SYSTEMS MANAGER
  - CHRIS KUDLA, CONSULTANT
- ALDEN RESEARCH LABORATORIES, INC. (ARL)
  - STU CAIN, PRESIDENT
- ATOMIC ENERGY OF CANADA LIMITED (AECL)
  - DAVID GUZONAS, PRINCIPAL SCIENTIST
  - DAVID RHODES, PRINCIPAL ENGINEER

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

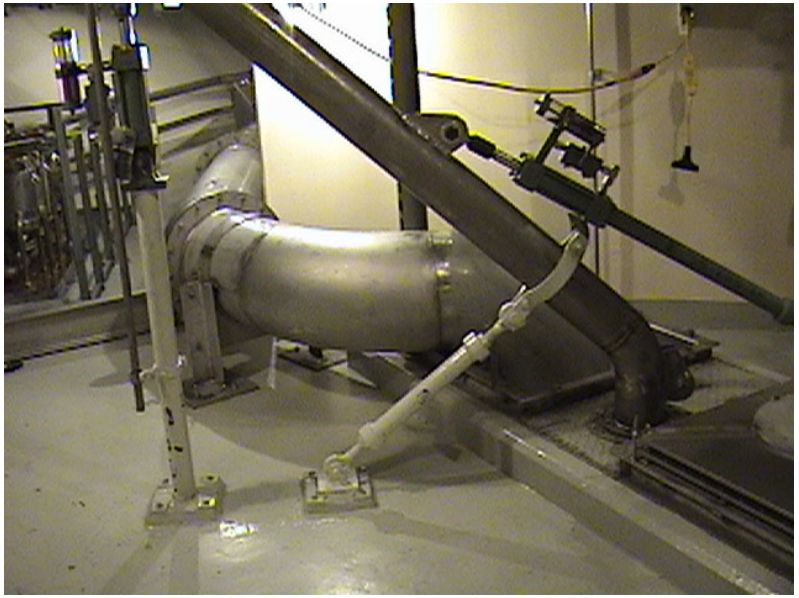
- TODAY'S PRESENTATIONS WILL COVER MATERIAL WE INTEND TO PROVIDE IN OUR RAI RESPONSE
- THE FINAL RAI RESPONSE WILL BE PREPARED, REVIEWED AND APPROVED IN ACCORDANCE WITH OUR CORRESPONDENCE PROCESS

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- REPLACEMENT STRAINER
  - DESIGNED BY PCI
  - TESTED BY PCI/AREVA/ARL

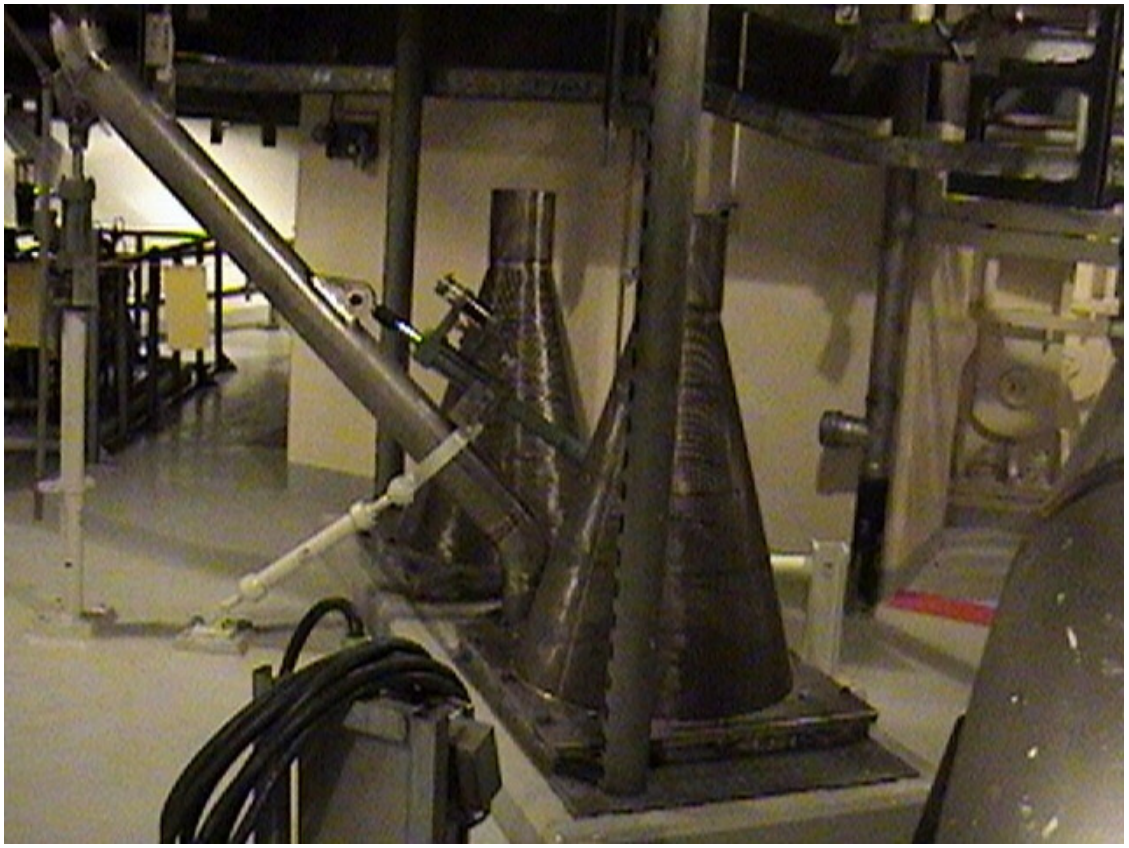
KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- INSTALLED 2006 REFUELING OUTAGE
  - STRAINER SURFACE AREA 768.7 FT2



KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- ORIGINAL CONTAINMENT SUMP STRAINER MODULES
  - 39 FT2 TOTAL SURFACE AREA (TWO MODULES COMBINED)



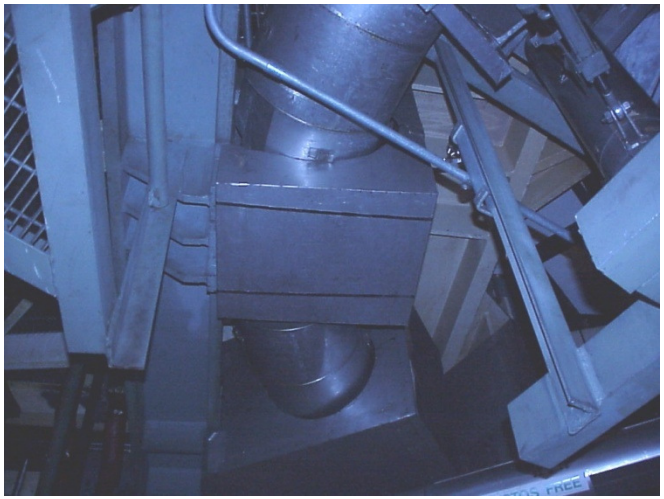
KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- KEWAUNEE IS A SINGLE UNIT, 2-LOOP PWR
  - 597 MWe
  - NSSS BY WESTINGHOUSE
- KEWAUNEE DESIGN BASIS DEBRIS
  - REFLECTIVE METAL INSULATION (RMI) ON RCS
  - 40.3 FT3 TEMPMAT ON PRESSURIZER SURGE LINE PIPE SUPPORTS
    - ENCASED IN STAINLESS STEEL RIVETED PANELS
    - THIS DEBRIS SOURCE REPRESENTS 85% OF KEWAUNEE'S FIBROUS DEBRIS
    - OTHER FIBER IS PIPE COVER (2.44 FT3), CABLE INSULATION, THERMOBESTOS FIBER AND LATENT FIBER
  - PARTICULATE DEBRIS CONSISTS OF COATINGS, LATENT AND SMALL QUANTITY OF THERMOBESTOS

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

PRESSURIZER SURGE LINE (TEMPMAT)

TEMPMAT



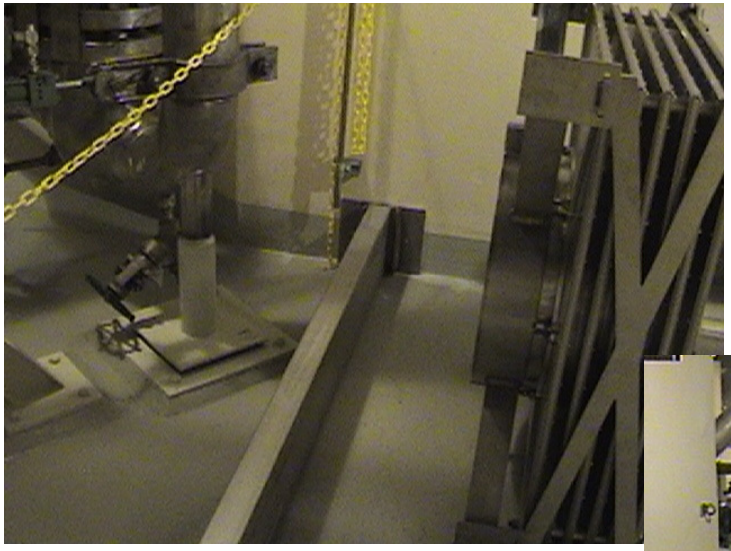
NUKON

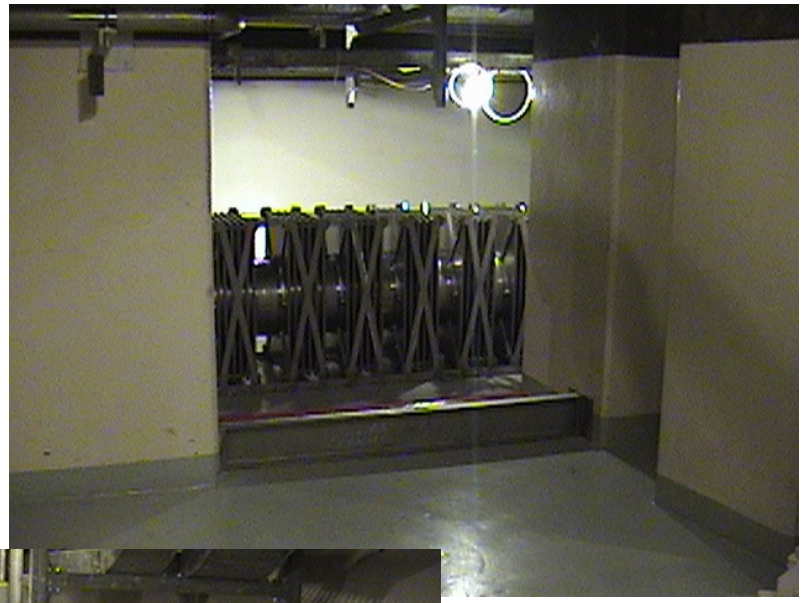
KEWAUNEE POWER STATION – GSI-191 RESOLUTION

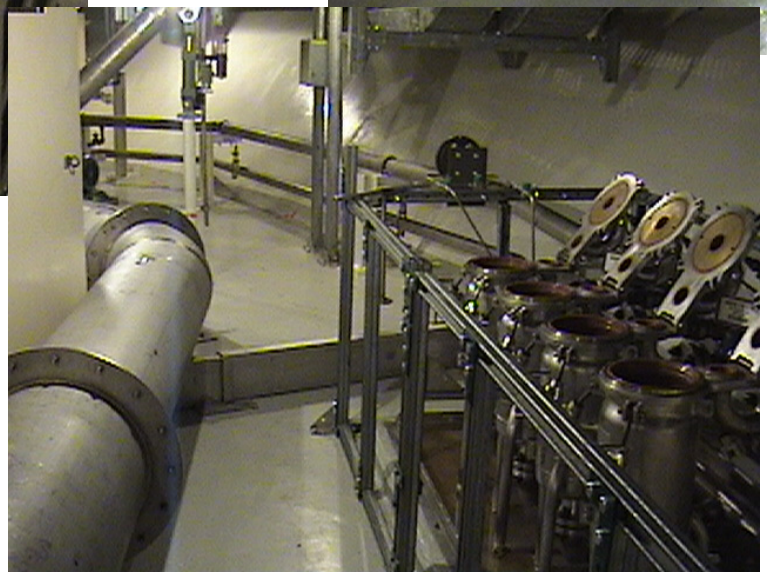
- KEWAUNEE DESIGN BASIS
  - DESIGN BASIS RECIRCULATION FLOW
    - SINGLE TRAIN OPERATION
    - 1990 GPM RHR PUMP FLOW (INCLUDES PUMP RECIRC FLOW)
    - 1870 GPM THROUGH RECIRCULATION STRAINER
  - RECIRCULATION STRAINER
    - 768.7 FT2 SURFACE AREA, 0.066 IN. PERFORATIONS
    - LOW APPROACH VELOCITY 0.0056 FT/SEC @ 1920 GPM FLOW THROUGH STRAINER (1870 GPM + 50 GPM MARGIN ADDED)
    - LOW APPROACH VELOCITY RESULTS IN MINIMAL TURBULENCE
  - DEBRIS INTERCEPTORS INSTALLED TO PREVENT MATERIAL MOVING ALONG THE SUMP FLOOR FROM REACHING THE STRAINER

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- DEBRIS INTERCEPTORS







KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- LARGE BREAK LOCA SCENARIO
  - USING MAXIMUM RWST INJECTION FLOWS:

    <u>T (TIME) + 0 MIN.</u>

    START OF LOCA - START RCS INJECTION AND CONTAINMENT SPRAY

    <u>T + 21 MIN.</u>

    RWST REACHES 37% SWITCHOVER LEVEL (MANUAL SWITCHOVER)

    <u>T+ 29 MIN.</u>

    RECIRCULATION BEGINS

    SUMP LEVEL 43.44 INCHES (MINIMUM) (40.5 IN. CONSERVATIVELY USED IN ANALYSES)

    STRAINER SUBMERGED 6.19 INCHES (43.44 – 37.25 INCH STRAINER HEIGHT)

    RCS INJECTION AND CONTAINMENT SPRAY CONTINUES

    <u>T + 43 MIN.</u>

    RCS INJECTION FLOW ENDS, CONTAINMENT SPRAY ENDS

    SUMP LEVEL > 5.75 FT OF WATER

    LONG TERM RECIRCULATION CONTINUES (NO RECIRC SPRAY)

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- NET POSITIVE SUCTION HEAD (NPSH) MARGIN

PARAMETER	HEAD (FT)	COMMENT
NPSH AVAILABLE	24.108	TOTAL WATER HEIGHT AT THE ONSET OF RECIRCULATION, MINUS PIPING FRICTION LOSSES [26.224 – 2.116]; USES 43.44 IN. SUMP LEVEL
NPSH REQUIRED	8	AT MANUFACTURER-SPECIFIED DESIGN FLOW RATE 2000 GPM (BOUNDS DESIGN BASIS FLOW DURING RECIRCULATION)
NPSH MARGIN	**16.108**	

- OVERVIEW OF FLUME TESTING
  - 2006 - STRAINER HEAD LOSS FLUME TESTS
  - 2007 – FIBER TRANSPORT TESTS
  - 2008 – STRAINER HEAD LOSS FLUME TESTS (LARGE SCALE FLUME)

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- 2006 TESTS
  - ARL SMALL FLUME
  - DESIGN BASIS DEBRIS LOAD
  - POWDERED SODIUM ALUM SILICATE CHEM SURROGATE
  - TESTED AT 2X DESIGN BASIS FLOW
  - DEBRIS STIRRED IN FLUME AND OVERHEAD SPRAYS USED TO MINIMIZE SETTLING
  - MAX HEAD LOSS WAS THIN BED TEST 3.79 FT OF WATER (CSHL + DEBRIS BED LOSSES) AT 2 X DESIGN BASIS FLOW
  - SIGNIFICANTLY BELOW 10 FT OF WATER ACCEPTANCE CRITERIA

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

2006 TEST FLUME – MANUAL STIRRING

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- 2007 TESTS
- FIBER TRANSPORT TESTS
- ARL SMALL FLUME
- DEBRIS INTERCEPTOR (C8X18.75 CHANNEL) IN FLUME; 3/8 IN. GAP MODELED
- DEBRIS SCALED TO DEBRIS INTERCEPTOR LENGTH (9.6% OF TOTAL DEBRIS)
- TESTED AT FLOW RATE EQUIV. TO CROSS SECTIONAL FLUID VELOCITY OVER SOUTH DEBRIS INTERCEPTOR, 0.113 FT/SEC
- TESTS RESULTED IN $\leq$ 5% TRANSPORT OF FIBER DOWNSTREAM OF DEBRIS INTERCEPTOR
- NO THIN BED OCCURRED USING 12.2 FT2 STRAINER
- DEBRIS INTERCEPTORS IN COMBINATION WITH LOW SUMP POOL VELOCITIES AND LOW STRAINER APPROACH VELOCITY PROTECTS STRAINER FROM THIN BED

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

2007 TEST FLUME – FIBER TRANSPORT TESTS

DEBRIS INTERCEPTOR

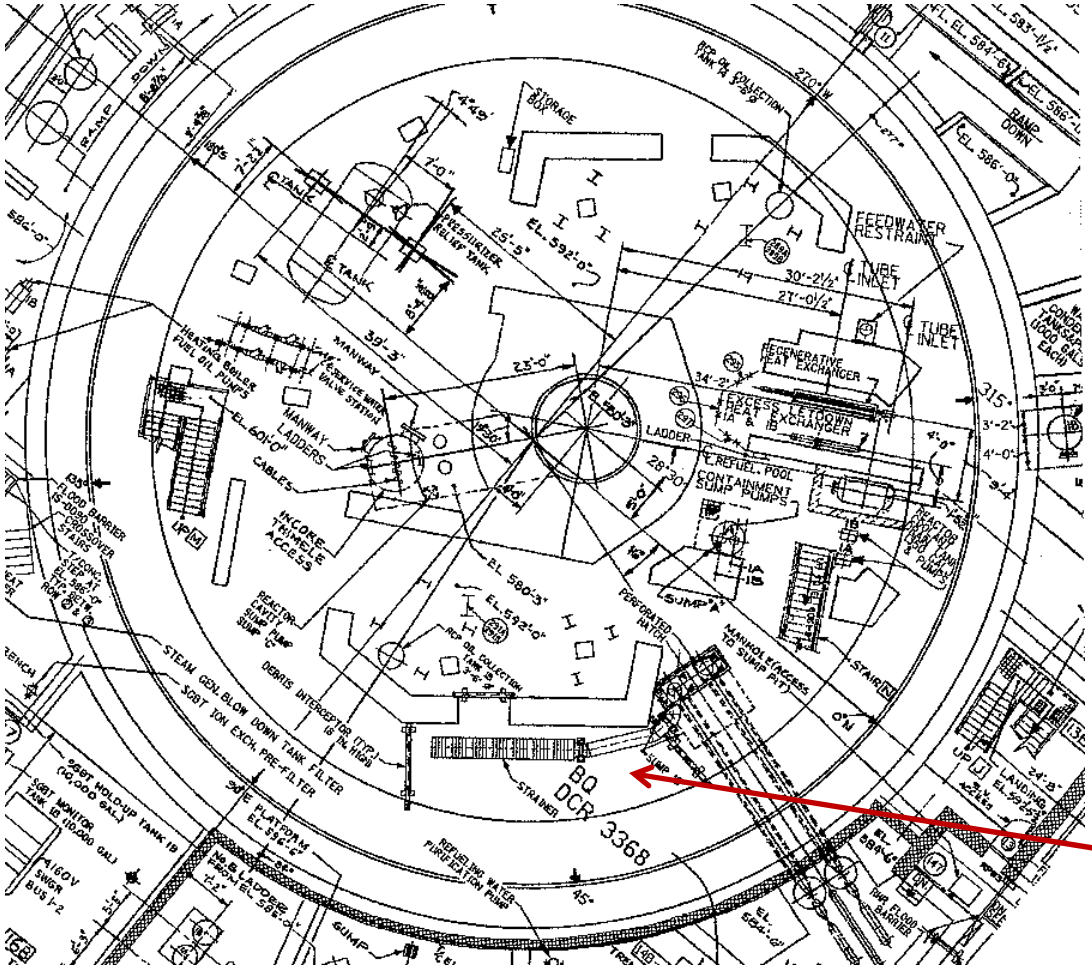
FLUME INLET (UPSTREAM SIDE)

FLOW

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- COMPUTATIONAL FLUID DYNAMICS (CFD) ANALYSIS
  - TWO FLOW SIMULATIONS MODELED
    - INITIAL START OF RECIRC WITH INJECTION AND RECIRC FLOW OUT THE RCS BREAK, INJECTION SPRAY, AND RECIRC SUMP FLOW
    - LONG TERM RECIRCULATION – RCS BREAK FLOW EQUAL TO RECIRCULATION FLOW, NO SPRAY
  - MOST CONSERVATIVE SIMULATION (START OF RECIRC) USED WHEN DETERMINING DEBRIS SUBJECT TO TRANSPORT TOWARD THE STRAINER/DEBRIS INTERCEPTOR AREA
    - PLANT CONDITION LASTS APPROX. 14 MINUTES
  - FOR SIMPLICITY, BOTH MODELS USE 40.5 INCH SUMP WATER LEVEL
    - MORE CONSERVATIVE THAN 43.44 IN. MIN. LEVEL AND LONG TERM SUMP LEVEL (> 5.75 FT)

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

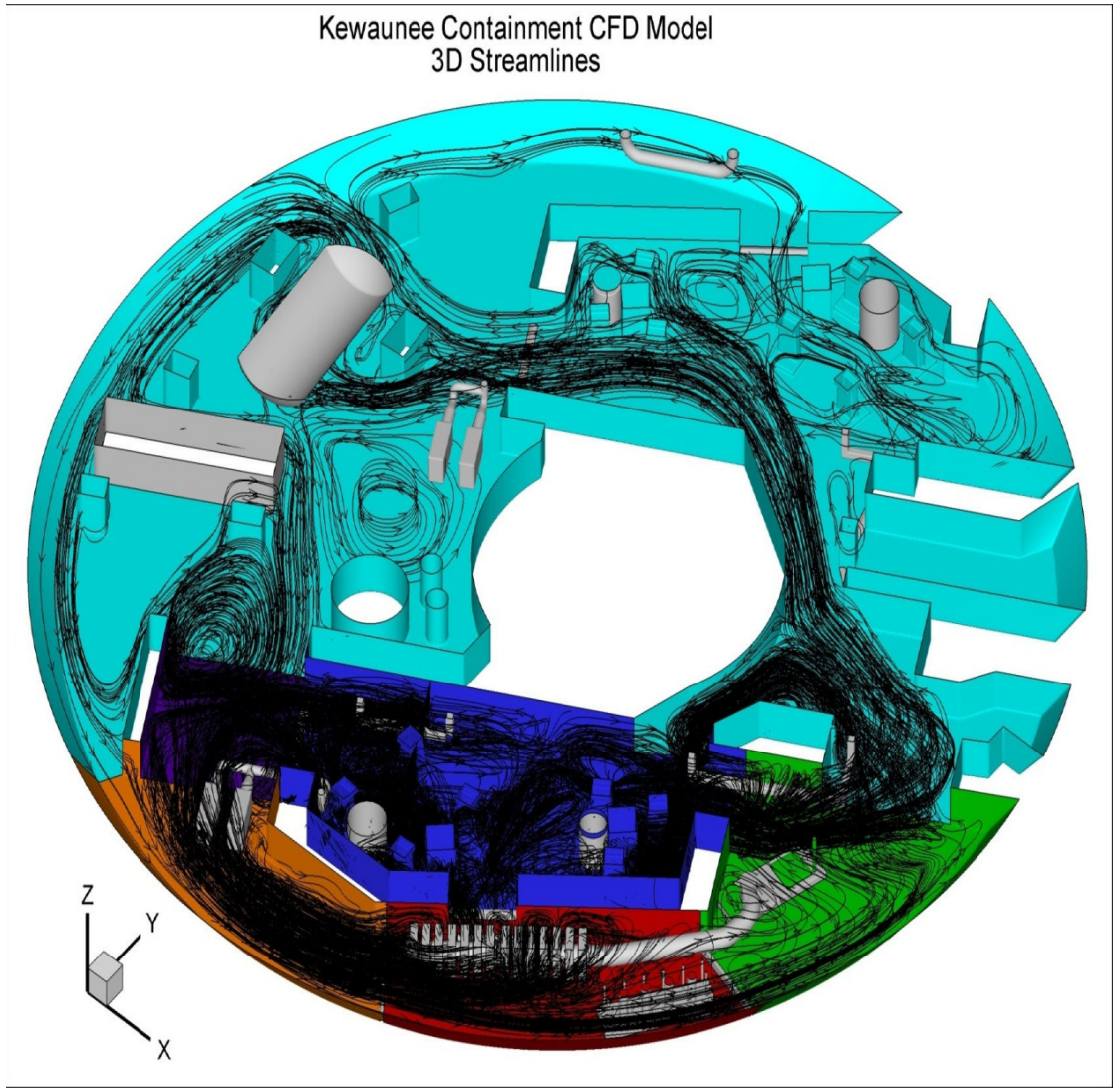


N

STRAINER

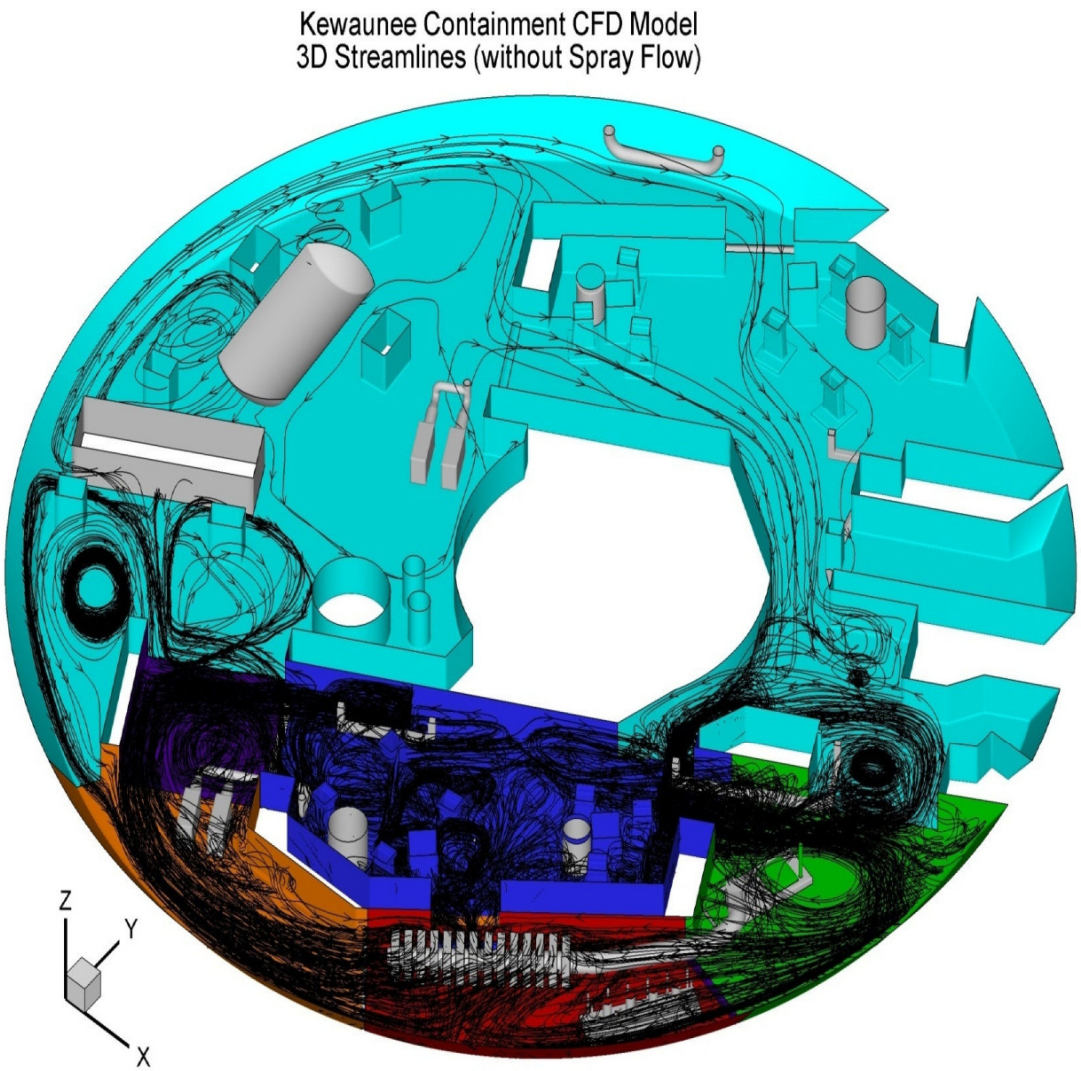
KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- SIMULATION AT START OF RECIRC (INJECTION & RECIRC IN PROGRESS)



KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- SIMULATION DURING LONG TERM RECIRCULATION



KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- 2008 STRAINER TESTS
- ARL LARGE SCALE FLUME
- ALL FINE AND SMALL DEBRIS SUBJECT TO TRANSPORT PLACED IN FLUME
- WCAP-16530-NP USED TO CREATE CHEMICAL SURROGATE (ALOOH)
- DEBRIS INTERCEPTOR & 3/8 IN. GAP MODELED IN FLUME
- DEBRIS INTRODUCED FROM UPSTREAM DROP ZONE
- TOTAL HEAD LOSS (DEBRIS BED + CSHL) FOR DESIGN BASIS DEBRIS LOAD AT DESIGN BASIS FLOW RATE = 1.1 FT OF WATER
- TOTAL HEAD LOSS (DEBRIS BED + CSHL) FOR DESIGN BASIS DEBRIS LOAD PLUS ADDITIONAL FIBROUS, LATENT DEBRIS AND <u>DOUBLE CHEMICAL DEBRIS CONCENTRATION</u> FOR ADDED DEBRIS LOAD MARGIN = 3.28 FT OF WATER
- ALL TESTS SIGNIFICANTLY BELOW 10 FT OF WATER DESIGNATED BY KPS AS ACCEPTANCE CRITERIA

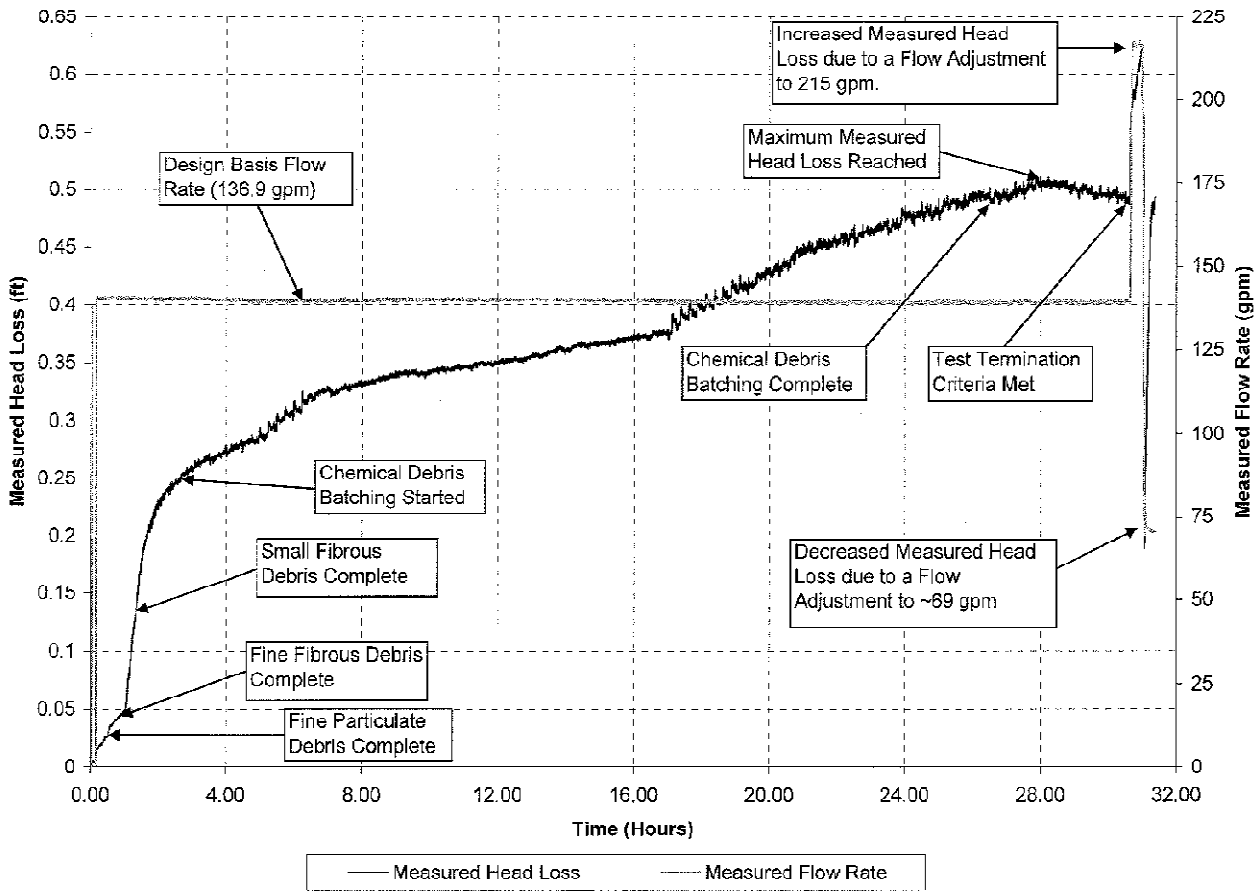
KEWAUNEE POWER STATION – GSI-191 RESOLUTION

2008 TESTS – LARGE SCALE FLUME TESTS

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- DESIGN BASIS CASE; WATER TEMP 105.8 F
  - MAX HL 0.51036 + CSHL = 1.1034 FT WHEN TEMP-CORRECTED

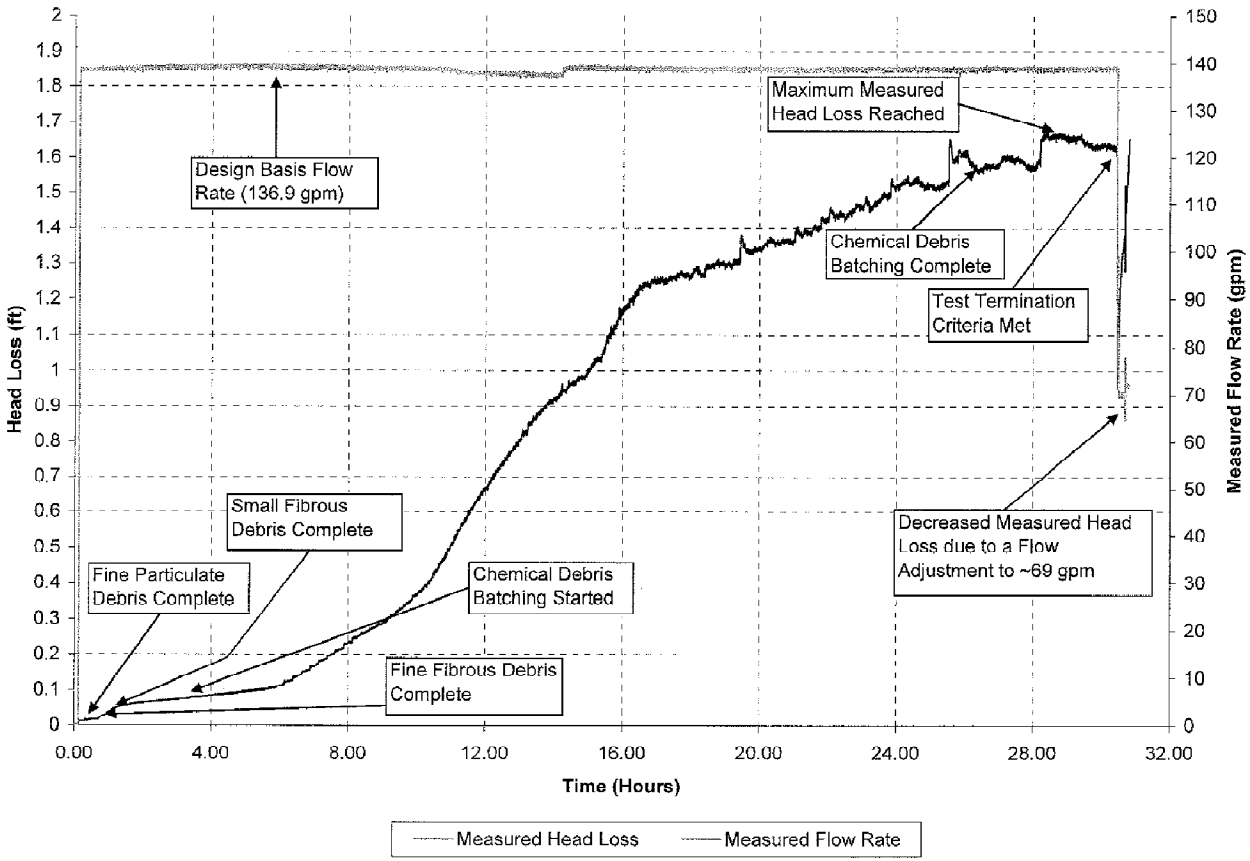
Figure 8-3: Test 3 Raw Data (Flow and Head Loss)



KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- DB CASE W/ADD'L FIBER, LATENT AND 200% CHEMICALS
  - WATER TEMP 116.1 F; MAX HL 1.6697 + CSHL = 3.286 FT WHEN TEMP. CORRECTED

Figure 8-4: Test 9 Raw Data (Flow and Head Loss)



KEWAUNEE POWER STATION – GSI-191 RESOLUTION

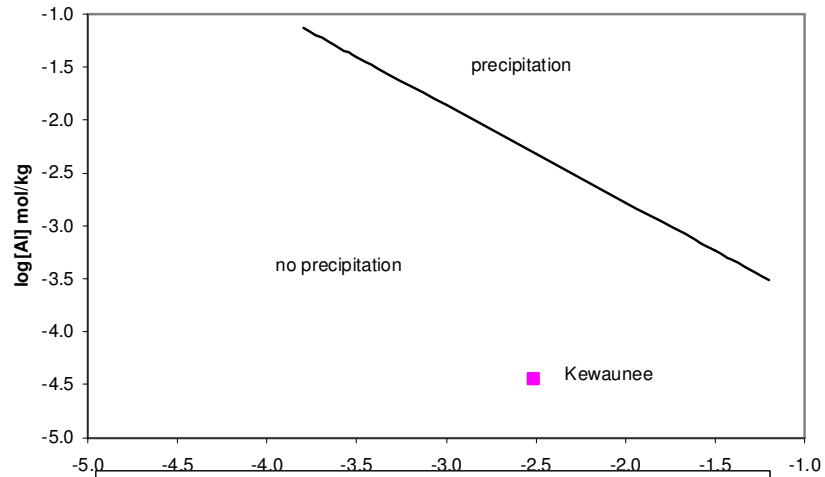
- CHEMICAL EFFECTS USING WCAP
  - AREVA PREPARED A CHEMICAL PRECIPITATION ANALYSIS FOR KEWAUNEE USING WCAP-16530-NP
  - PRECIPITATE IS SODIUM ALUMINUM SILICATE (NaAlSi308)
  - DESIGN BASIS CASE CALCULATED 8.286 mg/L CONCENTRATION

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- CHEMICAL EFFECTS EVALUATION BY AECL
  - Al RELEASE FROM SPRAYED ALUMINUM
  - SHORT INJECTION SPRAY TIME (< ONE HOUR LBLOCA), NO RECIRCULATION SPRAY
  - ICET TESTS SHOW VERY LITTLE Al RELEASE FOR SPRAY < 4 HOURS
    - SPRAYED COUPONS IN TEST 1 (PH 10, NO TSP) GAINED A SMALL AMOUNT OF WEIGHT, SUBMERGED COUPONS LOST OVER 25%
    - SEM IMAGES OF SPRAYED AL COUPONS SHOWED LITTLE CORROSION, WHILE SEM IMAGES OF SUBMERGED COUPONS SHOWED A THICK CRUST OF CORROSION PRODUCTS
    - OVER 90% OF AL RELEASED INTO SOLUTION FROM 3 SUBMERGED COUPONS
      - LESS THAN 10% FROM FIBERGLASS AND THE 56 SPRAYED ALUMINUM COUPONS
      - TOTAL WEIGHT LOSS = 0.15%, TWO ORDERS OF MAGNITUDE LESS THAN SUBMERGED COUPONS
    - LACK OF MECHANISM FOR CORROSION PRODUCT TRANSPORT AFTER SPRAY CEASES
    - EXPECT VERY LOW Al CONCENTRATION IN THE SUMP WATER FROM ALUMINUM COMPONENTS

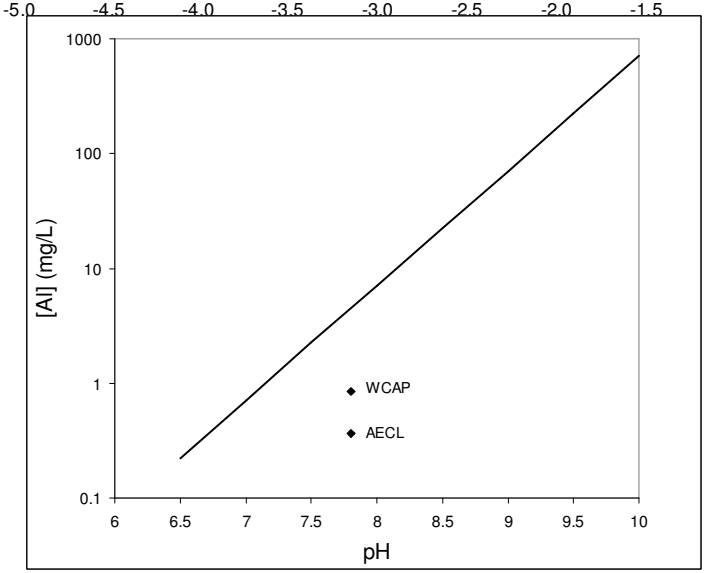
KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- Precipitation zones for sodium aluminosilicates at 25°C and 0.89 M hydroxide
  - No aluminosilicate species expected



- Maximum sump Al concentration:
  - AECL calculation = 0.37 mg/L
  - WCAP prediction = 0.82 mg/L

- Worst case Al concentration below experimentally measured Al solubility (Bahn et al. [2008])
  - No Precipitation Expected



KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- NET POSITIVE SUCTION HEAD (NPSH) MARGIN

PARAMETER	HEAD (FT)	COMMENT
NPSH AVAILABLE	24.108	TOTAL WATER HEIGHT AT THE ONSET OF RECIRCULATION, MINUS PIPING FRICTION LOSSES [26.224 – 2.116]
MAXIMUM MEASURED DEBRIS LADEN STRAINER HEAD LOSS *	3.286	CLEAN STRAINER HEAD LOSS AND DEBRIS LADEN STRAINER HEAD LOSS COMBINED, TEMPERATURE-CORRECTED TO 65 DEG F
NPSH REQUIRED	8	AT MANUFACTURER-SPECIFIED DESIGN FLOW RATE 2000 GPM (BOUNDS DESIGN BASIS FLOW DURING RECIRCULATION)
NPSH MARGIN	**12.822**	

* MAXIMUM STRAINER HEAD LOSS (CSHL+DEBRIS BED HL) IS LIMITED TO 10 FT UNLESS STRUCTURAL REANALYSIS IS PERFORMED

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

- ITEMS REMAINING FOR GSI-191 RESOLUTION
  - REACTOR VESSEL CORE COOLING DOWNSTREAM EFFECTS
    - REACTOR VESSEL DOWNSTREAM EFFECTS EVALUATIONS HAVE BEEN COMPLETED FOR KEWAUNEE USING WCAP-16406-P AND WCAP-16793-NP
    - KEWAUNEE WILL REASSESS ITS EVALUATIONS UPON NRC ISSUANCE OF THE FINAL SAFETY EVALUATION FOR WCAP-16793-NP

KEWAUNEE POWER STATION – GSI-191 RESOLUTION RAI QUESTIONS

A. BREAK SELECTION

1.A THREE ANALYZED BREAKS RESULTING IN WORST DEBRIS QUANTITY/COMBINATION

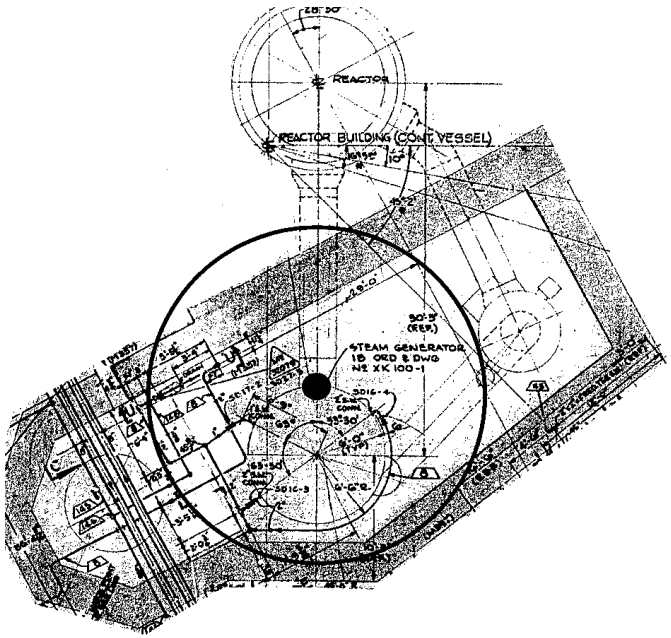
1.B ADDITIONAL BREAKS NOT ANALYZED AS WOULD NOT CHANGE DEBRIS SOURCE TERM DUE TO LARGE ZONES OF INFLUENCE

1.C RCS LOOP B CONTAINS PRESSURIZER

1.D RX VESSEL NOZZLE BREAK NOT A LIMITING BREAK

KEWAUNEE POWER STATION – GSI-191 RESOLUTION RAI QUESTIONS

- BREAK SELECTION
  - REFER TO SECOND KPS HANDOUT, PAGES 1 - 4



BREAK S3 RCS HOT LEG
ZOI = 5.45 D R = 13'-2"

B. DEBRIS GENERATION / ZONE OF INFLUENCE

2. USE OF 5.45D FOR THERMOBESTOS
3. REPAIRS TO THERMOBESTOS & FIBERGLASS INSULATIONS
4. VERIFY LATENT DEBRIS IS FINES
5. TEMPMAT FINES
6. FIBER EROSION OVER MISSION TIME

C. DEBRIS CHARACTERISTICS

7.A THERMOBESTOS AS 100% FINES

7.B FIBERGLASS PIPE COVER SIZE DISTRIBUTION

D. LATENT DEBRIS

8. LATENT DEBRIS SAMPLING METHODOLOGY

KEWAUNEE POWER STATION – GSI-191 RESOLUTION RAI QUESTIONS

E. DEBRIS TRANSPORT

9. DEBRIS INTERCEPTOR TESTS

10.A FIBERGLASS EROSION TESTS

10.B MINIMUM TUMBLING VELOCITY & DEBRIS SETTLING

10.C DURATION OF EROSION TESTS

11. EROSION OF THERMOBESTOS – SEE QUESTION B.6

12. EROSION OF DEBRIS IN TEST FLUME

13. CFD IDENTIFICATION

13.A HOW DEBRIS INTERCEPTORS MODELED IN INPUT DECK

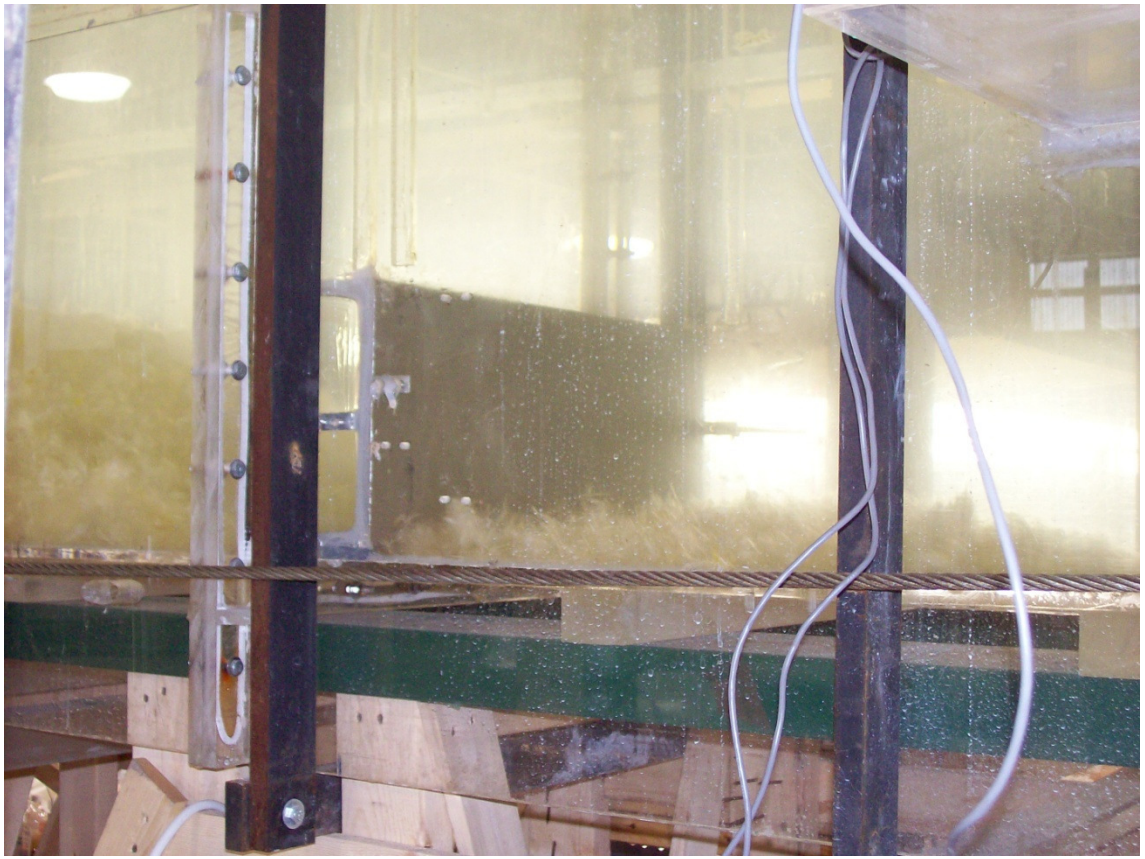
13.B LOCATIONS OF DRAINAGE

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

2007 FIBER TRANSPORT TESTS

- 33% FIBROUS DEBRIS, 0.113 FT/SEC OVER DI (TEST 3B)

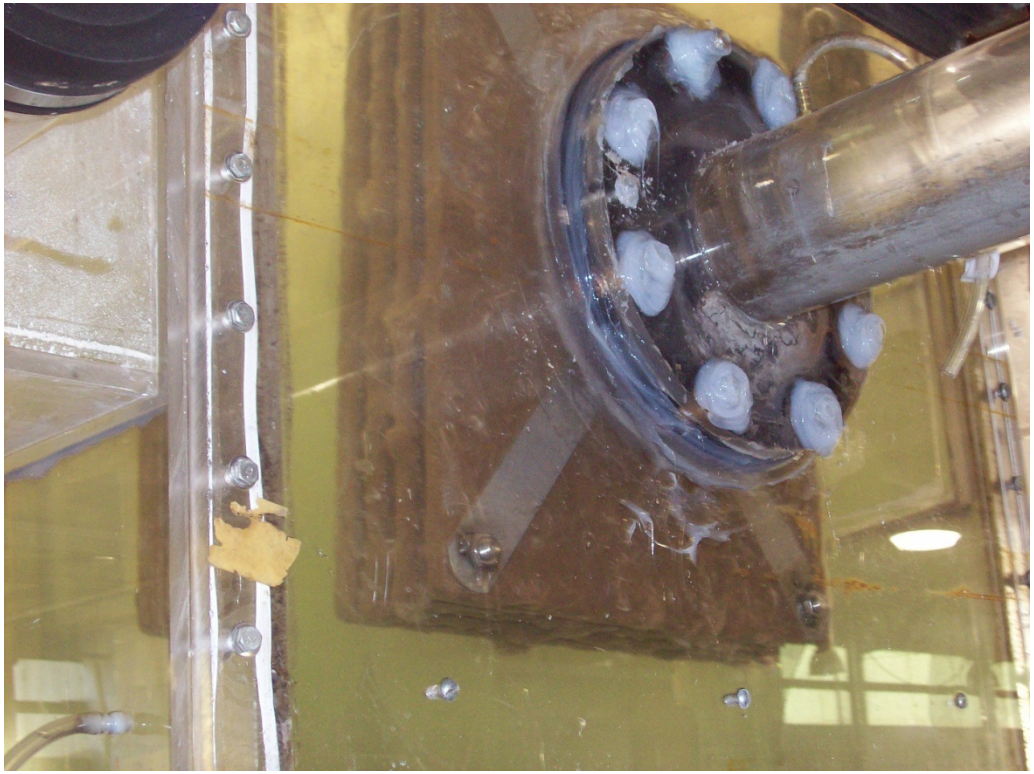
FLOW



KEWAUNEE POWER STATION – GSI-191 RESOLUTION

2007 FIBER TRANSPORT TESTS

- 33% FIBROUS DEBRIS, 0.113 FT/SEC OVER DI (TEST 3B)



KEWAUNEE POWER STATION – GSI-191 RESOLUTION

2007 FIBER TRANSPORT TESTS

- 100% FIBROUS DEBRIS; 0.113 FT/SEC OVER DI (TEST 1B)

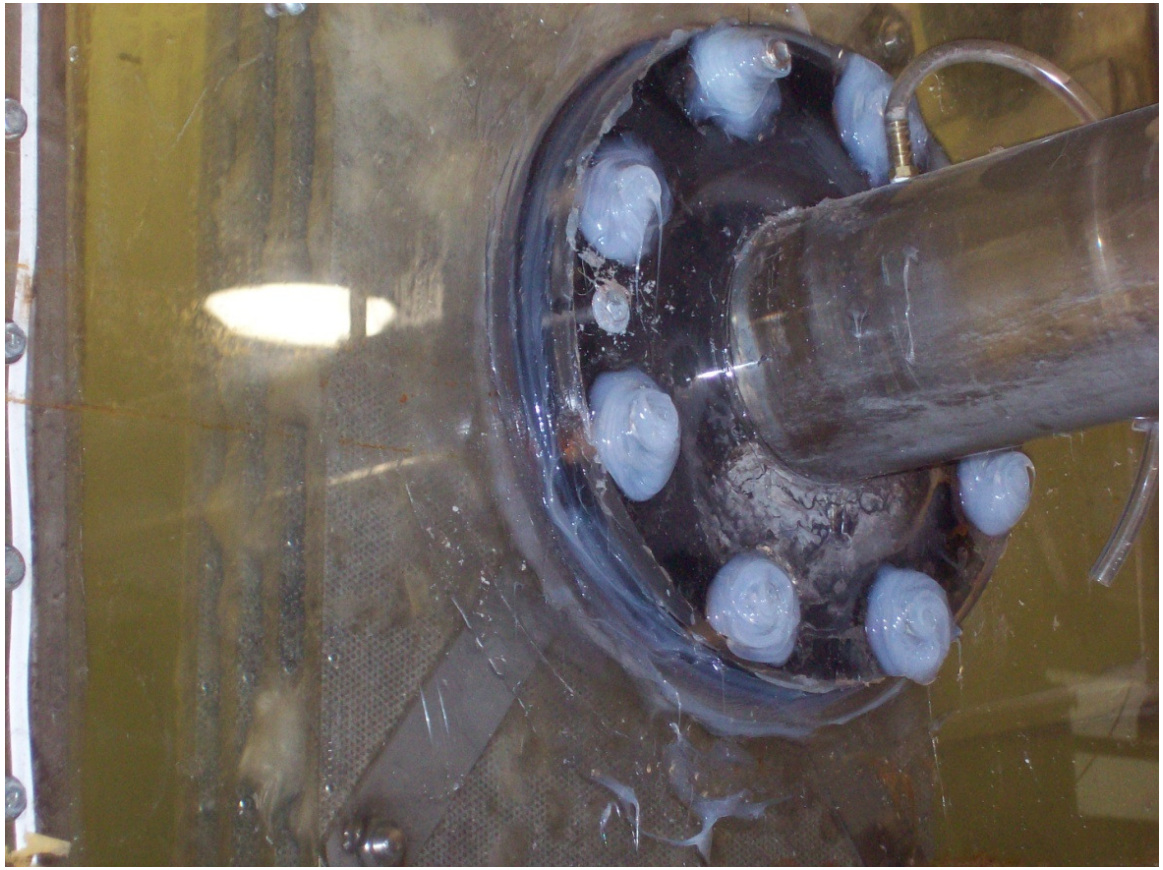
DEBRIS INTERCEPTOR

FLOW

KEWAUNEE POWER STATION – GSI-191 RESOLUTION

2007 FIBER TRANSPORT TESTS

•100% FIBROUS DEBRIS; 0.113 FT/SEC OVER DI (TEST 1B)



KEWAUNEE POWER STATION – GSI-191 RESOLUTION RAI QUESTIONS

- RAI E.9.j, E.13.a – e, E.15 AND E.16
  - REFER TO SEPARATE HANDOUT BY ARL

E. DEBRIS TRANSPORT

13.C SIZE OF COMPUTATIONAL DOMAIN

13.D MAIN PHYSICAL MODELS

13.E BOUNDING SIMULATIONS

14. SETTLING ON UPPER ELEVATIONS

15. CONTOUR PLOTS OF VELOCITY AND TURBULENCE

16. DISTANCE OF DEBRIS ADDED IN TEST FLUME

17. DEBRIS FLOATATION

F. HEAD LOSS AND VORTEXING

18. CLEAN STRAINER HEAD LOSS METHODOLOGY

19.A MEASURED HEAD LOSS AND CSHL

19.B HEAD LOSS TEMPERATURE CORRECTION

19.C HED LOSS TEST METHODOLOGY

19.C.I DEBRIS INTRODUCTION

19.C.II DEBRIS ADDITIONS AT < 100% FLOW RATE

19.C.III DEBRIS PREPARATION AND SURROGATE SIZE

19.C.IV DEBRIS CHARACTERISTICS FOR SURROGATES

19.C.V PROCEDURE STEPS

19.C.VI DESCRIPTION OF TEST FACILITY

19.C.VII DEBRIS INTRODUCTION TECHNIQUES

KEWAUNEE POWER STATION – GSI-191 RESOLUTION RAI QUESTIONS

F. HEAD LOSS AND VORTEXING

19.C.VIII THIN BED INCREMENTAL FIBER

19.C.IX DEBRIS BY EACH DEBRIS ADDITION

19.C.X SCALING FACTORS

19.C.XI FLOW RATES

19.C.XII DENSITY-CORRECTED SURROGATES

19.C.XIII STIRRING

19.C.XIV DEBRIS THAT SETTLED

19.C.XV AGGLOMERATION OF DEBRIS

20. VORTEX EVALUATION CONDITIONS, ASSUMPTIONS
21. VOIDING EVALUATION
22. FLASHING
23. HEAD LOSS PLOTS

KEWAUNEE POWER STATION – GSI-191 RESOLUTION RAI QUESTIONS

F. HEAD LOSS AND VORTEXING

24. VENTED STRAINER
25. TEST TERMINATION
26. HEAD LOSS EXTRAPOLATION TO MISSION TIME
27. SCHEMATIC OF TEST FLUME
28. DEBRIS INTERCEPTOR DESIGN IN PLANT AND FLUME

G. NET POSITIVE SUCTION HEAD (NPSH)

29. BASIS FOR DESIGN FLOW RATES
30. BASIS FOR NPSH REQUIRED FOR RHR PUMPS
31. SUCTION LINE FRICTION LOSSES
32. SBLOCA VS. LBLOCA
33. HOT LEG INJECTION (NOT USED), UPI AND COLD LEG INJECTION BOUNDED BY NPSH CALC
34. HOLD UP VOLUMES IN CONTAINMENT
35. MANUAL OPERATION OF TWO TRAINS RHR IN RECIRC MODE

H. STRUCTURAL ANALYSES

36. DESIGN CODE
37. DESIGN MARGINS
38. NO IMPINGEMENT ON STRAINER MODULES
39. DEBRIS INTERCEPTOR STRUCTURAL ADEQUACY

I. UPSTREAM EFFECTS

40. REFUELING CAVITY DRAIN LINE

J. DOWNSTREAM EFFECTS / IN-VESSEL

41. FINAL RESPONSE WITHIN 90 DAYS OF SER ISSUANCE

K. CHEMICAL EFFECTS

42. NO PLANT-SPECIFIC REFINEMENTS TO WCAP-16530-NP BASE MODEL
43. MIN/MAX PH

L. LICENSING BASIS

44. STRAINER SURVEILLANCE REQUIREMENTS

- NO CURRENT TECHNICAL SPECIFICATIONS
- TRANSITION TO IMPROVED TS WILL REQUIRE INSPECTION FOR DEBRIS, STRUCTURAL DISTRESS, ABNORMAL CORROSION
- CONTAINMENT INSPECTION PROCEDURES ALREADY IMPLEMENT THE NEW INSPECTION REQUIREMENTS